Department of Agriculture, Food and Rural Development

Investigations of Animal Health Problems at Askeaton, County Limerick

MAIN REPORT

BÓRD SLÁINTE
AN MHEÁN-IARTHAIR

Agriculture and Food Development Authority

Environmental Protection Agency

Establishment
The Environmental Protection Agency Act, 1992, was enacted on 23 April, 1992, and under this legislation the Agency was formally established on 26 July, 1993.

Responsibilities
The Agency has a wide range of statutory duties and powers under the Act. The main responsibilities of the Agency include the following:

- the licensing and regulation of large/complex industrial and other processes with significant polluting potential, on the basis of integrated pollution control (IPC) and the application of best available technologies for this purpose;

- the monitoring of environmental quality, including the establishment of databases to which the public will have access, and the publication of periodic reports on the state of the environment;

- advising public authorities in respect of environmental functions and assisting local authorities in the performance of their environmental protection functions;

- the promotion of environmentally sound practices through, for example, the encouragement of the use of environmental audits, the setting of environmental quality objectives and the issuing of codes of practice on matters affecting the environment;

- the promotion and co-ordination of environmental research;

- the licensing and regulation of all significant waste disposal and recovery activities, including landfills and the preparation and periodic updating of a national hazardous waste management plan for implementation by other bodies;

- implementing a system of permitting for the control of VOC emissions resulting from the storage of significant quantities of petrol at terminals,

- implementing and enforcing the GMO Regulations for the contained use and deliberate release of GMOs into the environment;

- preparation and implementation of a national hydrometric programme for the collection, analysis and publication of information on the levels, volumes and flows of water in rivers, lakes and groundwaters, and

- generally overseeing the performance by local authorities of their statutory environmental protection functions

Status
The Agency is an independent public body. Its sponsor in Government is the Department of the Environment and Local Government Independence is assured through the selection procedures for the Director General and Directors and the freedom, as provided in the legislation, to act on its own initiative. The assignment, under the legislation, of direct responsibility for a wide range of functions underpins this independence. Under the legislation, it is a specific offence to attempt to influence the Agency, or anyone acting on its behalf, in an improper manner.

Organisation
The Agency's headquarters is located in Wexford and it operates five regional inspectorates, located in Dublin, Cork, Kilkenny, Castlebar and Monaghan

Management
The Agency is managed by a full-time Executive Board consisting of a Director General and four Directors The Executive Board is appointed by the Government following detailed procedures laid down in the Act.

Advisory Committee
The Agency is assisted by an Advisory Committee of twelve members The members are appointed by the Minister for the Environment and Local Government and are selected mainly from those nominated by organisations with an interest in environmental and developmental matters The Committee has been given a wide range of advisory functions under the Act, both in relation to the Agency and to the Minister.

Investigations of Animal Health Problems at Askeaton, Co. Limerick

MAIN REPORT

Department of Agriculture, Food and Rural Development, Veterinary Laboratory Service
Teagasc, Johnstown Castle Research and Development Centre
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Environmental Protection Agency

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Investigations of Animal Health Problems at Askeaton, Co. Limerick.

Main Report

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NOTE

This document is one of a five-volume report on the investigations of animal health problems in the Askeaton area of Co. Limerick, carried out in the period 1995 – 1998. The five volumes are as follows:

- Main Report
- Animal Health
- Soil, Herbage, Feed and Water
- Human Health
- Environmental Quality

The investigations were prompted by reports of severe animal health problems on two farms in the Askeaton area, which first came to notice in the early 1990s. In February 1995, following preliminary investigations by Limerick County Council, the Environmental Protection Agency was requested by the Minister of State at the Department of Agriculture, Food and Rural Development to co-ordinate a wider study of the situation. This was considered necessary, as there were local concerns that human health was also being affected in the area and that environmental pollution was involved.

Arrangements for the undertaking of the investigative work were put in place in late February 1995, this being assigned to the Veterinary Research Laboratory of the Department of Agriculture, Food and Rural Development (animal health), Teagasc (soils, herbage and related aspects), the Mid Western Health Board (human health) and the Environmental Protection Agency (environmental quality aspects). Subsidiary studies were carried out by Coillte and the Mid Western Health Board, respectively, on tree health and the levels of metals and other substances in vegetable produce.

Field measurements and observations took place between March 1995 and December 1998. Interim reports were published in December 1995, June 1997 and August 1998.

Acknowledgements

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Dr William L. Magette, now at UCD, who consulted a number of veterinary Professors in US universities on behalf of the EPA.

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EXECUTIVE SUMMARY

INTRODUCTION

1. This document gives an abridged account of the investigations into the animal health problems in the Askeaton area of Co. Limerick and also provides an overall discussion and conclusions. Detailed accounts of the individual aspects of the investigations are given in the four accompanying volumes.

2. In early 1995, the Minister of State at the Department of Agriculture, Food and Rural Development (DAFRD) requested the EPA to co-ordinate an investigation into the causes of the severe animal health problems which had come to public attention in the early to mid 1990s on two farms (Somers and Ryan) near Askeaton, Co. Limerick. These problems had caused much local concern and there were additional fears that human health might be at risk if, as was suspected by persons in the area , environmental pollution was involved.

3. Following preliminary meetings in February 1995, it was agreed that the investigations would involve four main areas, viz animal health, soil and herbage, human health and environmental quality and that these would be assigned, respectively, to the Veterinary Laboratory Service (VLS) of DAFRD, Teagasc (Johnstown Castle Research and Development Centre), the Mid Western Health Board (MWHB) and the EPA.

4. A Technical Group consisting of representatives of the agencies involved and of Limerick and Clare County Councils was convened by the EPA to oversee and help co-ordinate the investigations. In addition, an Interdepartmental Committee (Agriculture, Food and Rural Development, Health and Environment and Local Government) was organised to monitor the progress of the investigations on behalf of the Government. The agencies also met periodically with the local representative group (Askeaton/Ballysteen Animal Health Committee) over the course of the investigations.

5. The EPA invited consultants from the US EPA and from the UK Central Veterinary Laboratory to the Askeaton area in 1995 to examine the situation on the farms and to advise on the nature of the investigations. Mr Chris Livesey of the UK CVL was retained as consultant to the EPA for the duration of the investigations. In addition, the EPA commissioned studies on the environmental effects of sulphur dioxide and the potential impact of sulphur deposition in the Askeaton area.

6. Interim reports on the investigations were published in December 1995, June,1997 and August, 1998. In addition, seven Progress Reports were prepared for the Interdepartmental Committee over the course of the investigations. These reports were made available to the Askeaton/Ballysteen Animal Health Committee and to other interested parties in the area.

ANIMAL HEALTH

7. During 1995, existing information on the nature of the animal health problems on the two farms was collated and assessed. Following on from this, a range of studies was planned to address the situation. In response to local comment, other farmers in the area who considered that they were experiencing unusually severe problems were requested to identify themselves to the VLS. This led to a total of 25 other farms being taken into consideration in the investigations.

8. The main question to be addressed by the animal health studies was whether or not there was an unusually high level of animal disease in the Askeaton area and, if so, what were the underlying causes and was there evidence for the involvement of environmental pollution.

9. The following studies were planned to address the specific area of animal health:
   - Monitoring of health and production of cattle on the two severely affected farms over two years. In the case of the Somers farm, the monitoring there was duplicated on the State farm at Abbotstown, Co. Dublin to which some of the Somers cattle were transferred and from which cattle were brought to the Somers farm.
   - A retrospective epidemiological survey of the Somers and Ryan farms and of the 25 other farms identified by their owners as affected by a high level of animal ill health.

- A longitudinal study of animal health and production on four of the other 25 self-identified problem farms.
- A contemporary investigation of animal health on the remaining self-identified problem farms.
- Studies of the immune function of animals on and from the Somers and Ryan farms in Askeaton and the Control farm at Abbotstown.
- A questionnaire survey of animal health and production in the Askeaton area and in other areas in Co. Limerick and adjacent counties.
- A study of the effect of feeding soil from the Somers farm to laboratory rats.
- An investigation of a postulated association between enzymatic anomalies in voles and environmental pollution in the Askeaton area.
- Toxicological assessments of blood and tissue of animals from Askeaton farms.

10. During the **monitoring study** on the Somers and Ryan farms and on the Abbotstown farm, carried out between 1996 and 1998, the overall level of mortality and disease was low; in particular, there was no recurrence of the severe animal health problems of previous years on the Somers and Ryan farms. Animal and milk production were generally satisfactory while the occasionally reduced fertility rates on the two Askeaton farms were readily explainable in terms of the normal risk factors and there was no evidence for the involvement of unusual factors.

11. The **retrospective epidemiological study** confirmed the seriousness of the animal health problems on the Somers and Ryan farms but did not show a high incidence of unusual diseases or suggest a common cause for these problems. There were indications that a limited recourse to veterinary advice led to a low rate of diagnosis of the problems on both farms and that, on the Ryan farm, factors such as the out-wintering of pregnant cows on inadequate nutrition may have contributed to the severity of the problems there. The observations recorded in the study were not consistent with the involvement of environmental pollution as a factor in the animal health problems on these two farms.

12. Just over half of the 25 other farms included in the **retrospective epidemiological study** appeared to have had moderately severe or severe animal health problems and, again, there was no indication of a high incidence of unusual disease. The absence of a common disease syndrome and the lack of concurrence in time or location of the animal health problems reported on these farms are inconsistent with a single off-farm causative factor such as pollution.

13. The incidences of diseases were generally within expected ranges on the four **Longitudinal Study** farms throughout the periods of observation. Poor milk production results on one farm could not be investigated due to its later withdrawal from the study. Fertility performance was generally within norms.

14. The **questionnaire survey of animal health** identified clear differences between the putative exposed (Askeaton and surrounds) and non-exposed regions in terms of farm size and enterprise type. The main findings of significance in relation to animal health were the higher reported rates of suckler cow mortality, as well as ill-thrift in cows and dry stock, in the putative exposed than non-exposed area. The reasons for these differences could not be determined on the basis of the survey results.

15. The immunological study did not show any deficiency of immune function in cattle located at or originating in Askeaton. While animals at the Askeaton locations showed significantly lower activity of one of the immune functions measured, there was no evidence that the finding was of clinical significance. Animals at both sites were in good health throughout the study. Factors which may have contributed to the differences observed in the cow study include age and pregnancy. The results of a supplementary experiment to investigate the effects of transport on blood samples from the steer study were inconclusive.

16. The **rat feeding trial** showed no adverse effects in animals receiving food adulterated with soil from the Somers farm compared to those receiving soil from a control source in their diet.

17. The **vole studies** showed that the lower activity of the hepatic enzyme, glutathione peroxidase, in animals from an Askeaton site compared to animals from control sites was associated with a lower concentration of selenium in herbage at the former location and more likely to be due to natural variations of the element there than the effects of pollution.

18. The **toxicological assessment** based on analyses of tissue and blood samples from cattle or cattle carcases from the Askeaton area showed that the concentrations of fluorine and of a range of metals, including aluminium, were well below those likely to be harmful.

SOIL, HERBAGE FEED AND WATER

19. A substantial portion of the Teagasc field investigations was initiated early in 1995 and completed in that year. Further analyses of soils and monitoring of herbage composition were undertaken in subsequent years to provide clarification of certain aspects and to complement the Longitudinal and Retrospective Epidemiological studies (see Animal Health above).

20. Overall, the main purposes of the Teagasc investigations were, firstly, to obtain evidence of previous inputs to soil, herbage and water that may have contributed to the animal health problems on the Askeaton farms and, secondly, to provide management and some analytical support to the VLS in relation to the conduct of the Monitor, Longitudinal and Retrospective studies.

21. The investigations were comprised of the following studies:
    - Survey and classification of soils and an assessment of their production potential
    - Sampling and analyses of soils for a range of inorganic components
    - Sampling and analyses of herbage for a range of inorganic components
    - Analysis of supplied and natural waters on the farms
    - Analysis of feed concentrates and mineral mixes in use on the farms
    - Analysis of fodder (silage and hay)
    - Botanical evaluation of herbage and vegetation on the farms

22. In addition to the Somers and Ryan farms, these observations and measurements were made on a Control Farm situated in the same area and on which there were no reports of animal health problems.

23. The **soil types (classes)** were similar on the three farms and characteristic of the north Co. Limerick area. There were no anomalies which might have had significance in relation to the animal health problems.

24. Concentrations of **minerals and trace elements in soil** were within the ranges observed at national level in the case of the Somers, Ryan and Control farms and of the 23 farms partaking in the Retrospective Epidemiological Study on which such analyses were undertaken. Elevated levels of certain elements, such as selenium, molybdenum and heavy metals, were detected in a few small areas on some farms. While some of these levels were high enough to be harmful, they were clearly attributable to natural geochemical features. There was no evidence that soils were contaminated by atmospheric deposition of substances, such as sulphur, fluorine or heavy metals.

25. Concentrations of **minerals and trace elements in herbage** were also within expected ranges. Again there was no evidence of contamination with potential pollutants arising from local emissions. However, molybdenum concentrations in herbage on half of the farms in the Retrospective Epidemiological Study were relatively high and could have affected copper absorption by the grazing animal. The relatively high concentrations of sulphur measured in herbage samples from the Somers farm in 1994 were not borne out by the more detailed measurements made in 1995 and by the subsequent monitoring of herbage sulphur on the farm.

26. Sources of **water for livestock** on the farms, while showing bacterial contamination in some cases, did not contain significant levels of potentially harmful substances.

27. Analyses of **feeds, concentrates and mineral mixes** used on the Somers, Ryan and Control farms showed these to be within manufacturers' specifications and there was no evidence of contamination with potentially harmful substances at the time of sampling.

28. While the nutritive value of the **silage** on many of the farms was relatively low in national terms, the results were not untypical of farms in the Co. Limerick area. Silage of this quality would require supplementation with concentrates to ensure adequate nutrition of livestock

29. PCBs concentrations in soil samples from the three farms were at background levels.

30. Examinations of **damage to hedgerows and other vegetation** on the Askeaton farms observed during the investigations indicated that this was due to natural factors such as unfavourable weather conditions rather than to atmospheric pollution. **Discoloration of grass** on some of the Askeaton farms, which was brought to the attention of the investigating team on a number of occasions, is not unusual in pastures and is caused by less than optimum uptake of nitrogen and phosphorus.

HUMAN HEALTH

31. The MWHB was first appraised of human health concerns in the Askeaton area when invited to attend a meeting of the local representative group in January 1995. Following the commissioning of the animal health investigations, the MWHB initially surveyed the general practitioners in the general area to assess their level of concern on the health status of the local community. While this did not indicate that any widespread human ailments had come to the notice of the practitioners, it confirmed that there was considerable public concern that the animal health problems might have implications for human health, especially if environmental pollution was involved. Following this initial assessment, therefore, a series of more formal studies was defined and organised during the latter half of 1995 and these were put into effect in 1996.

32. The purpose of the human health studies was to determine if the health experience of people living in the putative exposed area (i.e. the area encompassed by the farms reporting animal health problems) was different to that of residents in a number of control areas in Co. Limerick and surrounding counties and, if so, could the difference be attributed to environmental pollution.

33. The following studies were undertaken by the MWHB:
    - Literature review of the effects of common atmospheric pollutants on human health
    - Births and congenital abnormalities
    - Sex ratio
    - Twin rates
    - Survey of general practitioners' perceptions of health problems in their practices
    - Health status
    - Acute health effects (diary study)
    - Cancer incidence
    - Mortality
    - Adolescent health
    - Child absenteeism
    - Horticultural produce
    - Chloracne
    - General medical script (abnormal prescribing patterns)
    - HIPE (hospital in-patient enquiry)

34. The **literature review** suggested that adverse reactions to atmospheric pollutants may be observed at levels significantly below existing standards.

35. The rates of **births** and **congenital abnormalities**, of **twinning** and the **sex ratios** were similar in the exposed and control areas and were in line with national rates.

36. The **survey of general practitioners** found those in the exposed area had more concerns regarding rates of miscarriage, serious illness and patient health than those in the control areas. These concerns were not borne out by the results of the investigations undertaken.

37. The **health status survey**, which was based on a self-administered questionnaire, indicated a mild excess of self-reported ill health in the exposed area for many of the measures used in the assessment, compared to some of the control areas. However, the significance of these results is uncertain given the high level of environmental awareness in the Askeaton area and the bias that this could introduce in self-reporting. In addition, a similar level of self reported ill-health was shown by the responses in two of the control areas; this pattern is not consistent with the locations of the potential pollution sources in the area.

38. The **acute health effects/diary study**, which was also based on self-reporting and involved persons living on the farms with animal health problems, showed an excess of mild ill health on two farms and poor health

among individuals on a further three farms. However, in most cases the ill health experienced did not lead to medical intervention. Again, the possible bias involved in a self reporting exercise in an area of heightened environmental awareness must be considered when assessing these results.

39. There was no evidence that **cancer risk** was greater in the exposed area compared to the control areas or the national position. On the contrary, the data suggested that the risk in the area was lower than expected on the basis of national rates.

40. Overall, the **mortality** rates in the exposed area were lower than expected but all-cause mortality in the age group 0-14 of both sexes and respiratory mortality for males of all ages were higher than the average for the Limerick region. There was no indication of an increased mortality nearer to the main source of pollutants in the area.

41. The **adolescent health** study was based on a US-devised child health questionnaire administered to 750 secondary school pupils, of whom one third resided in the exposed areas and the remainder in control areas. In general, the responses to the questionnaire indicated that the physical health of teenagers in the exposed area was no different to that of their counterparts in the control areas.

42. The study of **absenteeism** in primary school records was undertaken as a measure of illness levels among young children in the exposed and control areas. Over the ten year period (1986-1995) for which records were examined, the exposed area had a statistically lower rate of attendance in nine of these years. However, the difference (0.5 to 1.5 days on average) was small and may not be clinically significant. In addition, the assumption that absences are due to ill health may not be correct in all cases.

43. The sampling of **horticultural produce** in the area was undertaken in response to the concerns of growers there that their vegetables might be perceived by potential buyers as having originated in an area affected by environmental pollution. However, measurement of fluoride and a range of metals, including aluminium, in these vegetables showed that levels were not appreciably different to those in vegetables from control areas and were well within safe limits for human consumption..

44. Reports in the press at the beginning of the investigations suggested that there were cases of **chloracne** in the area. This is a skin condition caused by the presence of chlorinated organic compounds in air and is most notably associated with the incident at Seveso in Italy. However, checks made with specialist medical personnel indicated that a case of chloracne had never come to their notice in the State. It was concluded that the reports had no foundation.

45. The proposed studies based on **General Medical Script** and **HIPE** were not proceeded with as initial assessment showed the presence of deficiencies in the data bases pertaining to these areas. It was not practicable to overcome these deficiencies within the confines of the investigations.

ENVIRONMENTAL QUALITY

46. In view of the widespread concern in the Askeaton area in early 1995 that the animal health problems were the result of environmental pollution, it was necessary to examine this aspect in detail as part of the investigations. While there was no clear evidence for the involvement of pollutants, the presence of a number of large industrial undertakings in the area, in particular the nearby Aughinish Alumina (AAL) plant and the ESB generating plants at Moneypoint and Tarbert west of Askeaton, constituted a potential for such a situation. If these activities were involved in bringing about the animal health problems in the area, it was most likely that this would be through emissions to the atmosphere leading to reduction in air quality or deposition of pollutants on to grassland.

47. In order to assess the position, the EPA undertook the following studies between March 1995 and December 1998:
    - Determination of the potential for atmospheric emissions from the local industries and ESB plants and the risks associated with these.
    - Estimation of the amounts of pollutants emitted from these sources.
    - Assessment of the areas where these might have the greatest impact.
    - Determination of the short term variations of the concentrations of gaseous pollutants in the Somers and Ryan farms and at control locations.
    - Determination of the deposition rates of potential pollutants on the Somers and Ryan farms.

- Determination of the levels of a number of other potential pollutants in the local environment regarding which concerns had been expressed.

48. The main potential pollutants in the **atmospheric emissions** in the area are the gases sulphur dioxide (SO_2) and nitrogen oxides (NO_x), fine particulate matter and metals and their compounds. The gases and particulate matter are potential irritants of the respiratory system and may aggravate diseases such as bronchitis and asthma. In high concentrations the gases may have acute effects on skin and eyes. In addition, the deposition of sulphur and nitrogen oxides and their derivatives can lead to acidification of poorly buffered soils and waters while increase of soil sulphur may adversely impact the uptake of other elements into herbage. In addition, high sulphur levels in herbage are known to reduce the availability of copper and selenium to animals. Many metal compounds are potentially toxic, but those emitted in the Askeaton area or which may originate in dust blown from the waste lagoons at the AAL plant would not be regarded as particularly harmful and occur naturally in soils at relatively high concentrations.

49. Estimation of the **amounts of pollutants emitted** in the general area was made in respect of SO_2 and NO_x and showed that these were relatively large, accounting, respectively, for over 50 per cent and nearly 25 per cent of the estimated national emissions of the gases. However, the bulk of the local emissions is accounted for by the two ESB plants at Tarbert and Moneypoint. In the case of the AAL plant, annual SO_2 emissions showed only moderate variation over the period 1990-1999, with the exception of 1994 when they exceeded the limit set in the local authority planning permission.

50. Mathematical modelling of the dispersal of the emissions from the ESB and AAL plants indicates that **areas of greatest impact** were likely to be in hilly terrain in the vicinity of Foynes, some distance from the locations of the problem farms. However, the predictions indicated that the emissions would not give rise to concentrations in excess of current standards. This was borne out by the results of the measurements made as part of the existing air quality monitoring networks operated by the ESB and AAL since the mid 1980s.

51. Operation of automated monitors on the Somers and Ryan farms showed that **hourly concentrations of SO_2** there were well within the revised EU standards for the protection of human health to be achieved by 2005. However, substantially elevated concentrations were recorded over short periods on both farms and were mostly associated with winds from the direction of the AAL and ESB plants. These raised concentrations were not high enough to cause acute effects. Hourly concentrations of SO_2 recorded on the Abbotstown farm did not show concentrations of the same order. Annual mean concentrations of SO_2 on the Askeaton farms, based on the hourly measurements, were within the limit set by the new EU directive for the protection of ecosystems. This was also the case for the stations in the ESB and AAL monitoring networks, both for the periods before and after 1995.

52. The **deposition rates of potential pollutants** on the Somers and Ryan farms and at a third site, based on the analysis of daily samples, were similar to those for areas in Ireland and other European countries shown to be unimpacted by artificially acidified precipitation. The composition of precipitation on two additional farms was shown to be similar to that on the former indicating that deposition was also similar. The pH of the daily samples did not reflect the occurrence of markedly alkaline or acidic conditions.

53. **Other potential pollutants** measured included particulate matter, fluorine, organic compounds such as dioxins and PAH , and aluminium. While the possibility of significant contamination with some of these substances was considered very low, they were included in the measurements because of specific concerns expressed. Results confirmed that the levels present in the media examined (soil, milk and water) were near background or well below those likely to be harmful.

DISCUSSION AND CONCLUSIONS

54. While the original question to be addressed by the investigations was the cause of the severe animal health problems on the Somers farm, it soon became clear that a wider perspective needed to be taken. This was required by the identification of a second farm (Ryan) with serious problems and the possibility that a further 25 were similarly affected. In addition, there were concerns that environmental pollution was involved and that, as a consequence, human health might be at risk. Thus, the investigations had to address the following issues:

- Was there any evidence of an unusually high incidence of animal health disease in the Askeaton area?
- If so, what were the causes?
- Was there any evidence that environmental pollution contributed to increased incidence of animal health disease?
- Was there also a threat to human health?

55. In respect of the animal health problems *per se*, it was considered that the following were possible causes:
    - Infectious agents
    - Nutritional deficiencies or imbalances
    - Toxic substances in the diet
    - Environmental pollution
    - Farm environment

56. The animal health studies showed that there was no widespread or unusual **infectious agent** present on the farms.

57. The examination of soils and herbages on the farms did not suggest the presence of any widespread **nutritional deficiencies** which might have accounted for the animal health problems. However, it was noted that silage quality was relatively poor and would have required adequate supplementation to provide a adequate level of nutrition.

58. There was no indication of the presence of **toxic substances** in the diet of the livestock, this being borne out by the soil feeding experiment on rats and the analyses of tissues from cattle.

59. Measurements of the ambient levels of potentially harmful substances emitted in the Askeaton area and of others in respect of which concerns had been expressed did not suggest the Askeaton area was subject to significant **environmental pollution,** based on a comparison of the resulting data with standards and background levels. In addition, the timing of the problems on the Somers and Ryan farms and on the other 25 showed little correspondence and were thus inconsistent with the impact of an off-farm factor such as environmental pollution.

60. Observations suggested that certain aspects of the farm environment (viz poor cubicle design and out-wintering of pregnant cows fed on poor quality silage) on the Ryan farm may have contributed to the serious animal health problems in that case. As the most serious problems on the Somers farm occurred some time prior to the commencement of the present investigation in 1995, it is not possible to assess the role of farm environment factors there. However, in both cases, there appears to have been a relatively limited recourse to specialist veterinary advice on the animal health problems.

61. In general, the results of the investigations are consistent in indicating that the involvement of an off-farm factor, such as pollution, in the animal health problems in the Askeaton area is very unlikely. They also show that there could have been no basic problems arising from soil or herbage composition on the farms. These outcomes are supported by the satisfactory performance on the Somers and Ryan farms during the Monitor study.

62. The results also indicate that it is very unlikely that the animal health problems implied a risk to human health. While this does not necessarily rule out the presence of a separate human health problem, the various studies carried out to compare health in the Askeaton area with that in control areas did not support such a possibility.

63. In conclusion, the following answer to the questions posed above are considered to be supported by the results of the investigations:
    - While there was undoubtedly an unusually high incidence of animal disease on a small number of farms in the Askeaton area, neither the number of farms involved, nor their distribution, suggests that this was evidence of a phenomenon affecting the wider Askeaton area as a whole (i.e. the area encompassed by this investigation).

    - In view of the foregoing conclusion, the question of the cause of the animal health problems, in its wider sense, is redundant. The likely causes of disease on the Ryan farm in 1994 and 1995 were multi-factorial in origin and, while it was not possible to identify all the contributory factors, the

combined effect of out-wintering pregnant cows during the poor weather of 1994 and 1995 together with inadequate pre-calving nutrition would have increased the number of animals with heightened susceptibility to disease. The lack of contemporaneous information precludes a similar assessment of the situation on the Somers farm.

- There was no convincing evidence that environmental pollution contributed to the animal health problems on either of the two index farms or the 25 other self-identified problems farms.

- In view of these conclusions, there is little basis for concern that reported animal health problems represented a threat to human health. An independent human health problem arising from atmospheric emissions in the area is unlikely in view of the ambient levels of pollutants measured during and before the investigations. The specific studies comparing human health experience in the Askeaton area with that in control areas showed none or only minor differences between the populations compared.

64. While the conclusions are not definitive in respect of the causes of the animal health problems, it is hoped that the investigations will have given assurances that these problems were not the result of some area-wide factor or factors which might also have had implications for human health.

65. A number of recommendations is made to improve the future response to situations like that at Askeaton. These are in addition to the protocol for the investigative approach already drawn up in 1997. *Inter alia,* they include the maintenance of databases on the incidences of human and animal diseases and the establishment of a national toxicology centre.

Chapter One

INTRODUCTION

BACKGROUND

In the early to mid 1990s, serious animal health problems on two farms near Askeaton, Co. Limerick came to public attention. The problems on the farm of Mr Liam Somers at Issane, Ballysteen, appeared to have arisen somewhat earlier than those on the farm of Mr Justin Ryan located at Toomdeely but both cases were characterised, *inter alia,* by ill-thrift, reduced milk production and excess mortality of cows and loss of calves at birth. Initial investigations by the private veterinary practitioners and the Regional Veterinary Laboratory did not indicate the involvement of a common factor and a range of ailments were described. However, there were suggestions that nutritional factors leading to loss of immune function could be at the base of the problems.

At this stage the possibility of the direct or indirect involvement of an environmental pollutant was raised. In particular, suspicions centred on the emissions from the nearby bauxite processing plant operated by Aughinish Alumina Ltd but those from the ESB plants further west at Tarbert and Moneypoint were also highlighted. Limerick County Council, at that time the sole statutory pollution control authority in the Askeaton area, commenced monitoring of sulphur dioxide levels and precipitation quality on the Somers farm in 1993. The County Council also engaged consultants to assess for them the situation on the Somers farm. In addition, an assessment of the situation on his farm, in regard particularly to possible pollution, was made by an environmental consultant, on behalf of Mr Somers.

A number of possible causes of the animal health problems were put forward on the basis of these assessments but were not capable of being substantiated by existing information. In addition, local concerns were widening to include considerations of possible impacts on human health; these concerns were conveyed to the Mid Western Health Board at a meeting called by local representatives in January, 1995. At the same time, the problems on the two farms were attracting considerable media attention. In these circumstances, the Government took the view that a more comprehensive investigation of the situation was warranted. Thus, in early February 1995, the EPA was invited to a meeting with the Minister of State at the then Department of Agriculture, Food and Forestry at which the Agency was asked to co-ordinate a detailed investigation of the circumstances surrounding the animal health problems and to determine, if possible, the cause or causes of the problems.

ORGANISATION OF THE INVESTIGATIONS

As a first step, following the Minister's request, the EPA convened a meeting of the interested parties in Limerick on 23rd February 1995 to discuss the situation. At the meeting, a number of possible causes of the animal health problems, including environmental pollution, was postulated and it was made clear that each of these would have to be assessed. A proposal was made by the EPA to divide the investigation into four areas, viz animal health, plant and soil quality, air quality and emissions and human health. This was accepted and the main responsibility for each of these areas was assigned as follows:

Veterinary Laboratory Services (VLS) of the Department of Agriculture, Food and Rural Development (DAFRD), Abbotstown, Co. Dublin
- All aspects of the animal health investigations.

Teagasc, Johnstown Castle Research and Development Centre, Co. Wexford
- Investigation of the composition of the soils, herbage, drinking waters and animal feeds on the problem farms as well as a general survey of vegetation.

Mid-Western Health Board (MWHB), Limerick
- Human health aspects.

Environmental Protection Agency (EPA) (Overall Co-ordinator)
- Information on industrial processes in the area, including emissions, measurements on these emissions, and monitoring of air and precipitation quality.

In order to co-ordinate the work, a working group comprised of the scientific personnel involved in each area, together with representatives of Limerick and Clare County Councils, was established by the EPA. The investigative programmes proposed by each of the agencies were discussed at a meeting of this group (Technical Group) in Dublin on 30th March 1995. Subsequently, these programmes were outlined at a public meeting in Askeaton on 11th April, which was convened by the a local representative group, the Askeaton/Ballysteen Animal Health Committee (ABAHC). Further meetings of the Technical Group were held through the period of the investigations in order to monitor progress and to enhance co-ordination of the various activities.

Also in 1995, an Interdepartmental Committee was formed, consisting of the secretaries of the Departments of Agriculture, Food and Rural Development, Environment and Local Government and Health, to oversee the progress of the investigations and to report to the Government on this. A total of seven progress reports were prepared for the Interdepartmental Committee throughout the period of the investigations.

Detailed protocols for the parts of the investigation dealing with the soils and herbage and other agronomic aspects of the farms and with emissions and air and precipitation quality were finalised in March 1995 and sampling and measurements in both of these areas commenced in that month. The former, carried out by Teagasc, were largely completed in autumn 1995 and subsequent measurements on soils and herbage were in the nature of continued monitoring of aspects which needed further clarification and of back-up to the animal health investigations. A detailed assessment of the local industry was completed by the EPA in 1995. The initial environmental measurements by the Agency were of an exploratory nature and were completed in October 1995. Subsequently, the Agency instituted detailed monitoring programmes for air quality and atmospheric deposition.

While existing information was collated and assessed in 1995, the main animal health investigations did not commence until 1996 due to the negotiations required between the two farmers involved and DAFRD on the arrangements for the use of their farms for the monitoring studies proposed. Such studies comprised the major aspect of the animal health programme. The negotiations with Mr Somers were completed in October 1995 when the terms for the lease of his farm by DAFRD were agreed, while the State purchased Mr Ryan's farm in November 1995. The take-over of and various arrangements for the proposed studies on the two farms were carried out in the early months of 1996 and detailed observations commenced in April of that year. An investigation of immune function in cattle also commenced in mid 1996 following the recruitment of specialist staff. A retrospective survey of 25 other farms, whose owners had voluntarily identified animal health problems, was started in late 1995. This study led to a detailed monitoring study of selected farms which commenced in 1996.

As in the case of the animal health aspects, initial work on the human health aspects in 1995 was generally concerned with the collation of readily available information. However, the MWHB considered that the reports of various ailments in the local population warranted systematic investigation, and a series of studies on a number of public health issues in the area was planned over the latter part of 1995. These included, *inter alia*, a general baseline study of public health in the area as well as assessments of rates of congenital abnormalities, cancers and mortality. All of these studies commenced in 1996. The Epidemiology Department of UCD was engaged by the MWHB to advise on the planning of the studies and to assist in the assessment of the results.

In addition to the foregoing, two additional studies were organised. An examination of the levels of metals and other potentially toxic substances in horticultural produce from the Askeaton area was carried out in 1996 by the MWHB. This study was a response to representations received by the EPA from the County Horticultural Adviser on behalf of vegetable growers in the Ballysteen area. The growers feared that their business would be adversely affected by the public perception of a health problem in the area (Ballysteen) in which the vegetables were sourced.

Concerns had also been expressed that trees on the problem and other farms in the area were exhibiting damage which might be due to air pollution. In order to check on this possibility, Coillte, on behalf of the Forest Service, instituted, in 1996, monitoring of a number of tree plots in plantations in the vicinity of Askeaton. The procedures used followed the protocol established for national monitoring of forest health. The results of the monitoring of trees in 1996 and 1997 have been given in the second and third interim reports on the investigations (EPA, 1997, 1998). Those for 1998 are set out in Appendix A with an overall assessment for the three year period of observation.

Originally it had been envisaged that the investigations would be completed within a year. However, it soon became clear that in the case of the animal health studies, especially the monitoring of cattle on the two problem farms, and also for some of the human health studies, a considerably longer period would be needed to obtain

representative and sufficiently detailed information. Thus, the period of observation extended up to the end of 1998 for some, at least, of the aspects covered by both of these areas of the investigation. It was also decided to continue the environmental measurements as long as the animal health studies were in operation, in case there was a need for contemporaneous data in the event of a deterioration of animal health on the farms. Thus, the EPA's investigative programme also continued to the end of 1998.

COMMUNICATIONS

The investigations extended over three years and arrangements were made, therefore, to keep the local community and the wider public informed of progress and of significant findings. As an initial step, an information booklet prepared by the EPA and outlining the intended measurements and observations was circulated in the Askeaton and adjacent areas in June 1995. Subsequently, the most important mode of communication was effected through periodic meetings of the agencies involved in the investigations with the officers of the ABAHC. In addition to these meetings, the MWHB met regularly with a human health sub-committee of the ABAHC. More informal contact was maintained with Mr Somers, who remained on his farm as manager for the duration of the investigation, during visits of Teagasc and VRL personnel.

Over the course of the investigations, three interim reports were published (EPA, 1995, 1997, 1998). These covered, respectively, the initial investigations up to September, 1995, and the continuing work to December, 1996 and December, 1997. The 1995 report presented the full details of the measurements made by Teagasc on soils and herbage. These reports and the progress reports prepared for the Interdepartmental Committee were disseminated directly to the farming community in the Askeaton area through the ABAHC and were also made available to the local industries.

During the course of the investigations, a number of possible pollution incidents were reported to the agencies. These were responded to where practicable and the causes or likely causes of the phenomena observed were determined. A call-out service in respect of reported air pollution events was organised by the EPA through its locally based staff.

ENGAGEMENT OF CONSULTANTS

Since experience in assessing the possible role of environmental pollution in the promotion of livestock ill health was relatively limited in Ireland, the EPA decided to obtain the opinions of experts from outside the State who had dealt with such matters in their own countries. Mr Chris Livesey, Head of Toxicology at the UK Ministry of Agriculture, Fisheries and Food (MAFF) Central Veterinary Laboratory, Weybridge, was retained as adviser by the Agency throughout the investigations. In August, 1995, Drs Gerry Henningsen and Mark Wickstrom, veterinary toxicologists attached to the Denver Office of the US Environmental Protection Agency, came to Ireland at the invitation of the EPA to examine the situation on the farms in Askeaton and were further consulted on occasion in the following years.

In addition, the Agency commissioned two specific studies in relation to sulphur dioxide which was judged to be the main pollutant emitted in the Askeaton area (see Chapter Five). The first involved a review of the scientific literature on the ecotoxicology of sulphur dioxide and was undertaken by Drs Mary Brennan and Paul Dowding of TCD; the second, carried out by Dr N. F. Suttle, Honorary Research Fellow at the Moredun Foundation for Animal Health and Welfare in Edinburgh, was an assessment of the likely impact of the emissions of the gas in the Askeaton area on livestock. The assessments of these experts on the situation in the Askeaton area are referred to at appropriate points in this and other reports.

FORMAT OF REPORT

The full report on the investigations at Askeaton consists of five volumes, viz sectoral reports on each of the four main areas and this volume. In the following chapters, condensed accounts of the animal health, soils and herbage, human health and environmental investigations are given in turn, based on the relevant sectoral reports. These are followed by a general discussion and overall conclusions. In addition to these volumes, a short, less technical account of the investigations has been prepared as a general source of information.

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Chapter Two

ANIMAL HEALTH

P. COLLERY, J. MCLAUGHLIN, P.J. O'CONNOR, J. BRADLEY and A. JOHNSON.

INTRODUCTION

This chapter comprises a condensed version of the Animal Health Volume dealing with veterinary investigations into the animal health and production problems on farms in the Askeaton and surrounding area. These investigations, which were the responsibility of the Veterinary Laboratory Service (VLS) of the Department of Agriculture and Food and Rural Development (DAFRD), in conjunction with Teagasc, comprised the following epidemiological and monitoring studies:

- A detailed monitoring, over a two-year period, of the health and production of indigenous and brought-in cows on one of the most severely affected farms (Somers farm - Index Farm A). This study was duplicated on a farm remote from Askeaton (Control Farm) with Askeaton and non-Askeaton origin cows.
- A detailed monitoring over a two-year period of the health and production performance of indigenous and brought-in cows on a second severely affected farm (Ryan farm - Index Farm B) in Askeaton.
- A Retrospective Epidemiological Survey of 25 self-identified 'problem' herds in the affected area, as well as the two Index Farms.
- A two-year Longitudinal Study of animal health and production on five of the self-identified problem farms.
- A contemporary investigation of animal health on the remaining self-identified problem farms.
- A series of studies to measure the immune function of animals on and from the two Index Farms.
- A questionnaire survey of animal health and production in the Askeaton area and in other areas remote from Askeaton.
- A laboratory trial to investigate the effects of feeding soil from one of the Index Farms on laboratory rats.
- A field study to investigate a suggested association between concentrations of certain liver enzymes of voles from the Askeaton area and environmental pollution.
- Pathological and analytical investigations on carcasses of animals from farms in the Askeaton area.

Background

Reports of severe animal disease and production problems on farms in the Askeaton area originated from Index Farm A. This was a medium-sized dairy farm situated about two km from the town of Askeaton (Fig. 2.5). The main problems reported, which were said to have commenced around 1988, were infertility, pining and mortality in cows and growing stock, perinatal calf mortality, diarrhoea in calves and skin lesions in cows and growing cattle. The herdowner considered that the problems were linked to environmental pollution.

A second farm in the area (Index Farm B) was reported to have suffered severe animal health problems in 1994 and extending into 1995. These were characterised by a high incidence of illthrift, illness and mortality in cows and growing cattle, abortion, calving difficulty and infertility in cows, and illness and deaths in calves. Index Farm B was a medium-sized dairy farm situated about 0.5 km from the town of Askeaton and about 1.2 km

from Index Farm A (Fig. 2.5). The owner of this farm also considered that the problems were associated with environmental pollution.

At an early stage of the EPA-led investigations in the area in 1995 it became clear that concerns regarding an association between animal health problems and environmental pollution in the Askeaton area were not confined to the two Index Farms. There were reports that other farms had experienced an excess of animal disease in recent years. Following consultations with herdowners and residents in the Askeaton area and surrounds, a further 25 farms were identified whose owners considered they had experienced an excess of animal disease or production problems. In November 1995, a detailed **Retrospective Questionnaire Survey** of animal health and production was initiated on these farms in order to assess the nature and extent of the reported disease problems.

As detailed environmental investigations and monitoring up to and including 1995 had shown no evidence that the area was subject to significant environmental pollution (EPA, 1995), it was decided to initiate a number of prospective animal health studies to monitor the incidence of disease on the most severely affected farms in the area over an extended period. These comprised firstly, a two-year **Monitor Study** of animal health and production on the two Index Farms combined with a comparative study on a Control Farm (Abbotstown) remote from Askeaton and secondly, a **Longitudinal Study** of animal health and production on five of the 25 self-identified problem farms.

Owing to the apparently infectious nature of many of the conditions reported from the two Index Farms, a number of studies were also undertaken to investigate the possibility that animals on these farms had a reduced immune response. These comprised a series of **Immunology Studies** to measure the immune responses of animals located on and originating from both of the Index Farms, together with parallel studies on a remote Control Farm (Abbotstown).

A **Questionnaire Survey** on animal health and production was administered to approximately 600 herdowners in the Askeaton area and in areas of the mid-west remote from Askeaton as part of a larger Mid-Western Health Board questionnaire survey of human health.

A laboratory rat **Feeding Trial** was undertaken to investigate the possibility that soils from one of the index farms (A) contained an unidentified toxic substance.

A **Field Study** was carried out to investigate claims that lower concentrations of certain enzymes in the livers of voles from the Askeaton area might have been associated with environmental pollution.

Detailed **pathological** and **analytical** examinations were carried out on carcasses (or tissues therefrom) of animals from the area.

Approach to Investigations

The central questions to be answered by the Askeaton animal health investigations were:

Was there any evidence of an unusually high incidence of animal disease in the Askeaton area?
and if so,

a. What were the underlying reasons?

b. Was there any evidence that environmental pollution contributed to an increased incidence of animal disease?

Disease Incidence

In order to investigate claims of an abnormal incidence of animal disease, it is necessary in the first case to define the norm. As many animal diseases occur to varying degrees on all farms, e.g. mastitis, infertility, and lameness in cows, the usual approach is to define normal or acceptable ranges of disease incidence based on the results of population surveys.

Unfortunately, other than scheduled or notifiable diseases, there are few up-to-date statistics available in this country on the incidences of the common endemic animal diseases in farm populations. Although a postal survey of certain animal health and production indices was carried out in the Aughinish area between 1979 and 1981 (Rogers *et al.*, 1984), most of the information collected on disease occurrence related to the presence or absence of specific diseases on a farm rather than to disease incidence at farm level. Farm practices have also

altered to such an extent as to render the animal production data of limited comparative value in the present analysis. While the questionnaire survey of animal health and production carried out as part of the present investigation addresses this deficit to an extent, completion of the section relating to disease incidence (treatment rates) was generally poor which make its interpretation difficult (*see below*).

Two sources of comparative data that are drawn upon in the following analysis are the Teagasc DairyMIS survey and the UK DAISY survey. The former covers about 340 dairy farms in a moderately intensive dairying region in the south of Ireland and provides information on cow-culling and calf mortality (Crosse, 1991). It has a three-tiered system of data collection. At the most intensive level are about 60 high-producing farms that provide regular records on feeding, fertilizer usage, milk production, cow fertility, and culling.

The DAISY survey, which is more comprehensive, is based on data collected from dairy herds situated mostly in Southern England (Esslemont and Spincer, 1993). This survey has been in operation for 20 years. The herds are intensively managed and a high degree of data recording is implemented.

While frequent reference will be made to both of these sources - as they are the most comprehensive collections of information on disease incidence available in dairy herds in these islands - they do have limitations with regard to the comparisons that can be made with farms in the Askeaton area. Farms participating in recording schemes of this type tend to be larger and more intensively managed than the average. The average DairyMIS herd, for example, comprises 80 cows with an annual average yield of 5,228 kg[1] per cow (1,150 gallons). DAISY herds average 150 cows with average annual yield of 7,274 kg (1,600 gallons). In contrast, the estimated average number of milking cows in dairy herds reporting an excess of animal health and production problems in the Askeaton area was 44 with an average yield per cow of about 3,637 kg (800 gallons) in 1994.

As a consequence of these differences, disease incidence rates and targets may not always be comparable with those for farms in the Askeaton area. Infertility, for instance, is likely to be more of a problem on a large intensive dairy farm than on a small or medium-sized, less intensive farm (Barr *et al.*, 1993). Cow mortality, on the other hand, is generally higher on small farms (Menzies *et al.*, 1996).

In addition to these sources, reference will be made throughout the following assessment of disease incidence in the Askeaton area to rates reported from a variety of published sources - both Irish and international. Lists of reference ranges compiled from surveys of commercial farm animal populations are given in Appendix A to this chapter.

Causes of Disease

The general approach to identification of the causes of disease has altered radically in recent years. While in the past, the emphasis was on the attribution of causation to specific aetiological agents, the multifactorial nature of disease is now more widely accepted (Thrushfield, 1995; Waltner-Toews *et al.*, 1995). The basis of this is to identify, as far as possible, the primary and secondary factors responsible for the initiation of disease. Together, these are referred to as risk factors for the diseases concerned.

Even in relation to conditions where primary aetiological agents have been clearly identified – e.g. infectious agents such as rotavirus, cryptosporidia, *Haemophilus*, and *Pasteurella* - the additional involvement of one or more secondary risk factors is usually instrumental in tipping the balance from health to disease. Secondary risk factors for the development of disease of animals under farm conditions include origin and size of susceptible population, nutrition, housing, and weather (Bruning-Fann and Kaneene, 1992). As these factors are, to a greater or lesser extent, functions of the environment provided by the management system under which the animals are maintained, the pivotal role played by management in determining the health status of farm animals must be recognised.

A number of studies have confirmed that management is by far the most important determinant of variability in disease incidence rates between farms (Hancock and Wickse, 1988; Klerx and Smolders, 1997). This is not to say that one system of management is necessarily better than another – it is only to affirm that management is a critical determinant of herd health. In addition to examining the immediate causes of disease, therefore, any objective investigation of herds with a reportedly high incidence of animal disease must include assessment of the secondary management factors which are likely to have been influential in relation to health status.

[1] Conversion: 1 gallon = 4.54 kg.

Evidence of Environmental Pollution in the Askeaton Area

Outbreaks of animal or human disease due to environmental pollution can generally be expected to share a number of essential geographical, temporal, and clinical features arising from their common causation. Typically, environmental pollution by a single or group of related compounds could be expected to result in the appearance of a common clinical syndrome, e.g. bone and teeth changes in fluorosis (Shupe, 1980), hyperexcitability and sudden deaths in lead poisoning (Hammond and Aronson, 1964). Conversely, knowledge of the identity of a pollutant, and its associated clinical syndrome, can be used to identify the extent of its effects on an affected region.

While the geographical and temporal associations of a perceived increase in animal health and productions were instrumental in the initiation of the overall Askeaton investigations, there was neither evidence of a common disease syndrome nor of the identity of a specific pollutant. Rather, there were reports of an increased incidence of a variety of conditions that are commonly seen under normal farming practice. The conditions most often recorded as occurring with increased frequency or severity were infertility, illthrift, lameness, and mastitis in cows, and illness and deaths of calves.

With the exception of calf mortality, these conditions are generally referred to as production diseases – so-called because their incidences are partly a function of production while at the same time their occurrence imposes limits on production. They are endemic to virtually all farms and, rather than referring to their absence as being the norm, acceptable ranges of occurrence are generally set as operational targets.

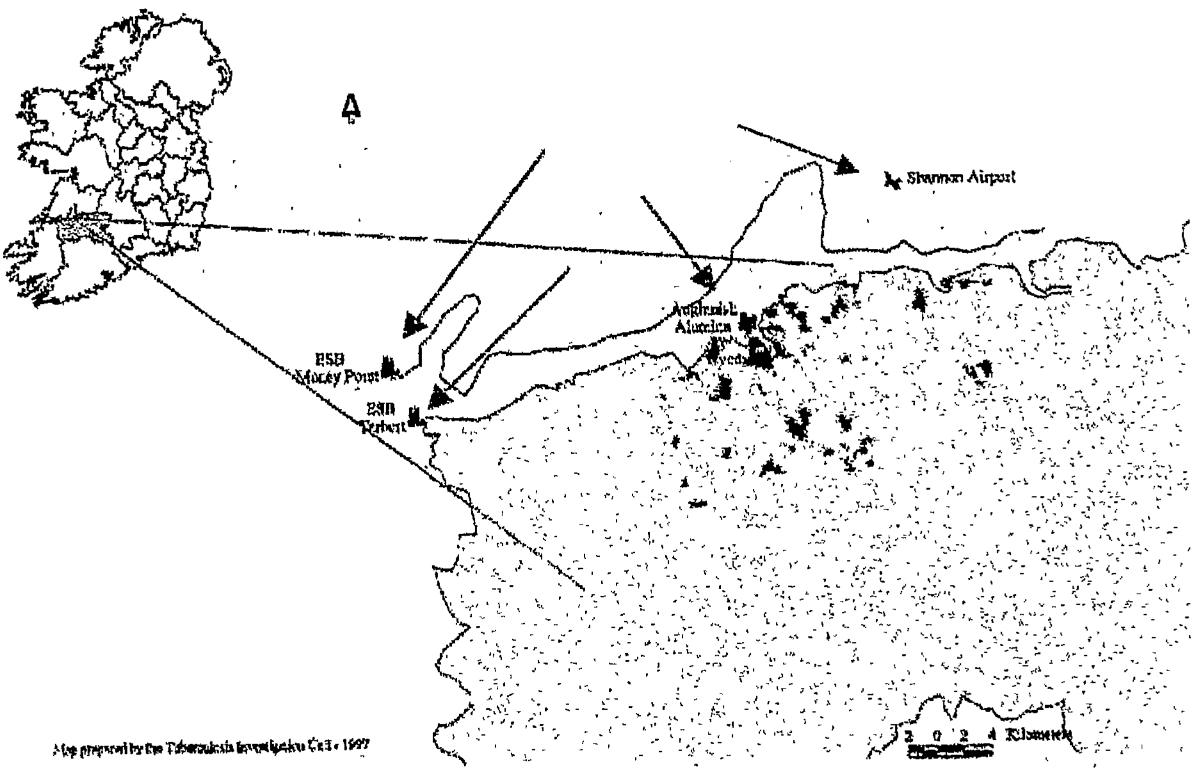

Fig. 2.1 Location of industrial sources of atmospheric emissions (blue arrows) relative to the 27 'problem' farms in the Askeaton area.

The locations of sources of industrial atmospheric emissions in the Askeaton area are shown in Fig. 2.1. Although the nearest and largest is a bauxite refinery (concentrates aluminium oxide from bauxite), aluminium is generally considered to be of very low toxicity for farm animals and any clinical effects would be most likely due to its ability to reduce the availability of the essential elements phosphorus and magnesium. However, there

was no specific evidence to suggest that clinical deficiency of these was unusually common in the Askeaton area. A variety of other chemicals – including fluorine, vanadium and dioxins - were suggested or considered in relation to potential toxicity (EPA, 1995). None, however, were positively associated with identified local industrial sources.

The most visible industrial emissions in the area were those associated with the burning of fossil fuels – both at the nearby alumina plant and also at the more distant electricity generatng stations. While most of the environmental studies were concentrated on monitoring the sulphur dioxide content of these emissions (*see* Chapter Five), it is not clear how this compound might exert a toxic effect at farm level. Although it would have the potential to cause respiratory irritation if inhaled in sufficient concentration, such effects would most likely be transient due to the inevitable dispersion of the pollutant in the atmosphere.

An alternative mechanism of proposed toxicity for sulphur dioxide is that of interference with the availability of the essential metals copper and selenium (Suttle, 1974; Langlands *et al.*, 1981; Rogers, 1990). The biochemical basis for these interactions, and the environmental and nutritional implications of the likely rates of deposition of industrial sulphur on grassland in the Askeaton area, are discussed in depth in the external assessment by N. F. Suttle (*see* Animal Health Volume).

MONITOR STUDY ON TWO INDEX FARMS

A two-part Monitor Study of animal health and production was carried out on the two Index Farms in Askeaton and a Control Farm at the Central Veterinary Laboratory (CVL) in Abbotstown, Dublin. The purpose of the study was to determine if animals (cows and growing stock) on and from the Index Farms continued to exhibit health and production outside accepted normal limits following the implementation of a standardised regime of management and nutrition based on published Teagasc guidelines.

For Part I of the Study, Index Farm A was leased to the Department of Agriculture and Food (DAFRD) in October, 1995, following which essential refurbishments to farm buildings and effluent management facilities were carried out. The herdowner continued to be responsible for the day-to-day running of the trial. An assistant farm manager was also appointed by DAFRD in June 1996. For the purpose of the Monitor Study, the herd comprised about 30 dairy cows, approximately half of which were indigenous to the farm (Askeaton-origin) and half were from the Control Farm at CVL Abbotstown (Abbotstown-origin). The Askeaton-origin cows from Index Farm A were mainly British Friesian type of unknown genetic merit. The Abbotstown-origin cows brought onto Index Farm A were Holstein-type of medium genetic merit. A herd of similar size and composition (i.e. Askeaton- and Abbotstown-origin cows) was maintained at the Control Farm.

The Monitor Study on Index Farm A and the Control Farm commenced on 1 April 1996 and continued until 31 March 1998 (VLS involvement in day-to-day management of Index Farm A ceased at end of 1997). The objective of this part of the study was to monitor animal health and production on both locations following implementation of a set protocol (EPA, 1996, unpublished) and to determine:

a) if serious disease and production problems continued to occur on Index Farm A, and

b) if Askeaton-origin animals on the Control Farm exhibited health or production problems which might be attributable to earlier negative influences (e.g. environmental pollution) experienced on Index Farm A in Askeaton.

Part II of the Monitor Study was undertaken on Index Farm B. Following purchase of the farm in November, 1995, some of the older animals were culled on grounds of advanced age. Essential refurbishment of farm buildings and effluent management facilities was also carried out. In spring 1996, a farm manager was appointed and the herd was augmented by the purchase of pregnant and calved Holstein cows of known pedigree. The indigenous cows on Index Farm B were British Friesian type of unknown genetic merit.

The objective of the study on Index Farm B was to maintain a commercial-type dairy herd of approximately 50 cows according to the same management and nutrition protocol as for Index Farm A and the Control Farm. The study commenced in May 1996. Although the study formally ended in April 1998, monthly animal health and production monitoring continued until October 1998.

Results

Animal Health

Details of the methods used to monitor animal health for the duration of the Monitor Project are described in the Study Protocol (EPA, 1996, unpublished). Briefly, all cattle were subjected to regular veterinary clinical examinations. The results of periodic (monthly in the case of cows) blood sample analyses were also monitored for any evidence of abnormalities. All incidents of animal disease, together with a description of clinical signs and details of treatment, were recorded either by the farm manager/herdowner or by the attending veterinarian. Where necessary, clinical pathology samples were submitted for laboratory examination. Details of all culling events were recorded and tissue samples were collected from animals culled to the abattoir. Where deaths occurred, carcasses were submitted for laboratory post mortem examination.

Part 1 - Index Farm A

Animal health was generally good on Index Farm A throughout the period of the Monitor Project. The main disease problems encountered in 1996 were mastitis and lameness - both of which were largely secondary to the housing problems of the winter of 1995/96 (EPA, 1997). The overall lactational incidence of mastitis in 1996 was 46 *per cent,* which is high. However, the cause in the majority of cases was identified as environmental (i.e. earlier housing problems) and the response to control measures was good. In 1997, the rate had fallen to 14 *per cent* (three cases) which is low. Two cases of acute toxic coliform mastitis occurred in the first three months of 1998. Although clinically severe - and one cow died – the incidence is not unusual. One cow also developed severe udder oedema post-calving in 1998.

The lactational incidence of lameness was 21 *per cent* in 1996 (seven cows). Although relatively high, and could not be classified as a good performance, it was largely secondary to the housing problems over the winter of 1995/96 and was, at any rate, within reported ranges for commercial dairy herds (Appendix A). The incidence of lameness was low in 1997 and 1998 (three months) at two and one cases, respectively.

The incidence of perinatal calf mortality was low in 1996 and 1997. Only one stillbirth was recorded in each of these years. However, five perinatal losses were recorded in the 1998 calving season (extended past end of Monitor Study). While the incidence rate at 18 *per cent* is high, clear-cut diagnoses were made in most cases, i.e. trauma, twin delivery, and haemorrhage.

The incidence of calf diarrhoea was low in 1996 and 1998 at two and one cases, respectively An outbreak of diarrhoea occurred in 1997 when eight cases (five in calves under two weeks of age, three in calves over two weeks) were recorded over a three-week period in May. Most were relatively mild and there were no deaths. While the overall incidence of calf diarrhoea in 1997 was 50 *per cent* as a result of this outbreak, this is within reported ranges and, given the zero mortality rate, cannot be considered as a serious problem.

Incidence rates for the other main disease conditions on Index Farm A were also low and well within acceptable ranges throughout the entire period of the Study. No cases of significant respiratory disease were recorded in calves or weanlings throughout.

Culling on Index Farm A in 1996 was high at 40 *per cent.* Most of the culls were Abbotstown-origin cows with chronic mastitis infections arising from the overwinter housing problems. Culling in 1997 was also high at 26 *per cent.* Over half of this was for infertility. The significance of this is discussed further in the section on fertility performance below.

Part 1 - Control Farm

With the exception of mastitis, the health of Askeaton- and Abbotstown-origin cows and their offspring was good throughout the period of the Monitor Study. Mastitis, however, was a significant problem The incidence in 1996 was 40.5 *per cent.* As with Index Farm B in Askeaton (*see* below), the problem was primarily infectious (*Staphylococci* and *Streptococci*) and had been recognised on the Control Farm prior to the start of the Monitor Study. It is likely that most of the cases in Askeaton-origin cows were new infections acquired following introduction to the herd. The incidence remained high in 1997 (47 *per cent*) largely owing to the restrictions imposed on culling Askeaton-origin cows by the requirements of the Study.

The incidence of other diseases in cows - including lameness - was low throughout the period. No cow deaths occurred in 1996 or 1998. Two cows died in 1997 - both due to acute vulvo-vaginal haemorrhage associated with difficult calvings.

Although the recorded incidence of diarrhoea in calves and weanlings was relatively high in 1996 at 58 *per cent*, most of the cases were mild (nutritional diarrhoea) and of little clinical significance. The incidences of other disease conditions in calves and yearlings were low throughout the period of the Study.

Culling was low on the Control Farm throughout the Study. It was under 10 *per cent* in 1996 and 1997. Culling in 1998 was associated with the termination of the Study at the end of March.

Part 2 - Index Farm B

Animal health was also generally good on Index Farm B throughout the period of observation and no serious disease outbreaks were encountered. The only diseases of any significance were mastitis and lameness.

The lactational incidence of mastitis in 1996 was 21 *per cent*. While relatively high, this is within reported ranges for commercial farms elsewhere (Appendix A). In contrast to Index Farm A, the bulk of cases were infectious rather than environmental in origin and it became clear during the course of investigations that this problem had probably been endemic to the herd for some time prior to the commencement of the Monitor Study. In response to control measures instituted - including culling of persistently infected cows – the incidence of mastitis fell to 18 *per cent* in 1997 and only 4 *per cent* in 1998 (eight months up to de-stocking in October 1998).

Eight cases of lameness were recorded in 1996 – six in indigenous cows and two in bought-in cows. The higher incidence in the indigenous cows largely reflected their age – mean 8.0 years compared to mean 3.5 years for bought-in cows. At 21 *per cent*, it was within reported normal ranges. The incidence of lameness in 1997 rose to 32 *per cent* as a result of two outbreaks of infectious origin (Mortellaro's disease). Although high, the rate was still within reported ranges and was consistent with what could be expected following outbreaks of a moderately infectious condition. A further outbreak of Mortellaro's disease occurred in January 1998 in which 10 animals were affected. All cases responded rapidly to treatment.

The incidence of stillbirths in 1996, at 8.6 *per cent* (three calves), was within published ranges. No stillbirths were recorded in 1997. There were two perinatal calf deaths in 1998 - one was a stillbirth and the other occurred shortly after birth. Both were associated with difficult calvings. Three abortions were recorded in 1996 – though only one was confirmed by the finding of a foetus. No abortions were recorded in 1998. These rates for abortion are within reference ranges.

Incidence rates for metritis (vulval discharge) of from 15 to 17 *per cent* in 1996 and 1997 were comparable to the DAISY average rate of 15 *per cent*. Incidence rates for other diseases in cows and young stock in 1996, 1997, and 1998 were comparable to or lower than published rates. No cases of respiratory disease were recorded in young stock in 1996, 1997, or 1998.

Mortality rates for all categories of cattle were low throughout the period of the Monitor Study on Index Farm B. One cow died in 1996 and one in 1997. The former was following a difficult calving and the latter as a result of hypomagnesaemic tetany. No cows died in 1998. No post-perinatal calf deaths (i.e. excluding stillbirths and calving-associated losses) were recorded in 1996, 1997, or 1998.

Cow culling in 1996 was 23 *per cent* – mainly due to the need to reduce the average age of the herd. Seven of the cows culled were over 11 years old. Culling at 9 *per cent* in 1997 was within target. All were due to infertility (*see below*). Culling in 1998, prior to de-stocking in October, was 10 *per cent* which is within target.

Conclusion

The overall incidence of disease and mortality was low on the three farms during the period of the Monitor Study and was well within reported ranges from Irish and international sources (Appendix A). There was no evidence of a recurrence of the severe animal health problems of previous years on the two Index Farms and no outbreaks of unusual or undiagnosed disease were encountered. While moderately high incidences of mastitis and lameness were recorded, these were associated with risk factors which are common to many commercial farming operations and rates were, in any case, close to or within reported ranges from elsewhere.

Given the severity of the reported problems on the two Index Farms in the years preceding the present study - in particular the exceptionally high reported loss of 32 cows on Index Farm B in 1994-95 - the results represent a dramatic improvement in animal health performance. It must be concluded, therefore, that whatever factors had contributed to the unusually high incidence of disease on the two Askeaton farms in previous years, they were no longer present by early 1996.

Milk Production

While a cow's potential for milk production is genetically determined, its actual expression is a function of health and nutritional status. A significant shortfall in production can be taken to indicate problems in relation to one or both of these areas. Variations in a cow's health and nutritional status can also affect milk quality. The main constituents routinely used to determine milk quality are protein, fat, and somatic cell count. The latter can be used to determine the degree of mastitis infection in a herd. The majority of cows with counts of above 400,000 cells/ml can be regarded as actively or recently infected (Appendix A).

Milk production was reported to have been poor on the two Askeaton Index Farms in the years leading up to the investigation. Concern had been expressed locally that this was due to environmental pollution. One of the objectives of the investigation, therefore, was to monitor milk production of indigenous and brought-in cows on the two Index Farms, and the Control Farm, over an extended period. Milk production – quantity and quality – were measured monthly for all milking cows on all three monitor farms throughout the period of the Study.

Part 1 - Index Farm A

Average lactational yield for the 11 Askeaton-origin cows (average seventh lactation) which were milked in 1996 was 4,355 kg. This was a good result for the type and age of cow. Analysis of results for the Abbotstown-origin cows was complicated by a number of factors related to calving season and the residue of health problems secondary to housing difficulties experienced immediately after their transfer from Abbotstown in the winter of 1995-96. Only two Abbotstown-origin cows calved in Askeaton late enough in 1996 to provide reliable milk recording data. These had 305-day yields of 5,387 and 5,637 kg. These are acceptable performances.

Mean milk protein and fat values were within normal ranges for both Askeaton- and Abbotstown-origin groups throughout 1996. Mean somatic cell counts above 500,000 in the Abbotstown-origin group from March to June, were largely due to the cases of mastitis which had developed as a result of the over-winter housing problems. Counts in the second half of the year were substantially lower – partly due to control measures and selective culling and partly a normal lactational effect.

In 1997, three Askeaton-origin first-calvers had an average total milk yield of 3,237 kg. This is an acceptable performance given that the heifers were under two years of age at calving. The five older Askeaton-origin cows which calved in 1997 had a mean yield of 4,491 kg which is also an acceptable performance.

Four Abbotstown-origin first-calvers had a mean yield of 3,923 kg in 1997 which is an acceptable performance. A fifth first-calver which had a yield of only 2,596 kg may have suffered a sub-clinical uterine infection secondary to the delivery of a dead calf. Mean yield for the remaining 11 Abbotstown-origin cows (average third lactation) was 4,410 kg. While this was only a moderate performance, five cows had lactations of under 240 days due to the combined effect of late calving and a management decision to dry off all cows before the end of the year.

A number of management factors which may have had a negative effect on milk production on Index Farm A in 1997 include inadequate frequency of pasture topping, delayed nitrogen application, and a period of overgrazing in June (*see* Animal Health Volume).

Mean milk protein and fat concentrations were within normal ranges for both groups throughout 1997. However, samples from eight cows in February had protein concentrations below 3.0 g/l which is consistent with post-calving negative energy balance. The significance of this in relation to fertility performance is discussed further below.

Mean somatic cell counts were below 400,000 for the Askeaton-origin cows, and below 250,000 for the Abbotstown-origin cows, throughout the year. These values reflected the low incidence of mastitis on the farm in 1997.

Individual-cow milk production results are not available for the last three months of the Project in 1998 (January to March) as recording concluded with the full transfer of management to the herdowner at the end of 1997.

Part 1 - Control Farm

Ten Askeaton-origin cows with full lactations in 1996 had a mean annual yield of 4,955 kg per cow. Five Abbotstown-origin first calvers had a mean annual yield of 5,428 kg per cow while five cows of average fourth lactation had a mean yield of 6,233 kg per cow. These were good performances.

Mean milk protein and fat values were within normal ranges for both groups throughout the year. No milk protein concentrations below 3.0 g/l were recorded. Mean somatic cell counts above 400,000 were recorded in both Askeaton- and Abbotstown-origin groups on occasions and reflected the high incidence of clinical mastitis cases (*see above*).

In 1997, three Askeaton-origin first-calvers had a mean annual yield of 4,478 kg per cow. Eleven Askeaton-origin cows with full lactations had a mean annual yield of 5,219 kg per cow. Four Abbotstown-origin first-calvers had a mean annual yield of 5,246 kg per cow. Eleven cows with full lactations had a mean yield of 5,382 kg per cow. These are good production results for both groups.

Mean milk protein and fat values were within normal ranges for both groups throughout the year. High somatic cell counts continued to be a problem in 1997. This was mainly due to the retention of animals persistently affected with mastitis.

Thirty five cows – 16 Askeaton-origin and 19 Abbotstown-origin - were milked in the last three months of the project on the Control Farm, i.e. January to March 1998. For cows which calved in 1998, mean daily yield for the Askeaton-origin group was 24 kg in March. The comparable figure for the Abbotstown-origin group was 27 kg.

Part 2 - Index Farm B

Twenty six indigenous (Askeaton-origin) cows calved on the farm in 1996. Excluding cows which had short lactations due to culling, the average annual yield for the remaining 13 (average sixth lactation) was 4,432 kg which is a good performance. Twenty one cows (average second lactation) were bought in to the dairy herd in 1996. Mean yield per cow for the six animals which had full lactations on the farm was 4,951 kg. This is also a good performance.

While mean milk protein and fat concentrations were within normal ranges for both groups throughout the year, samples from six indigenous cows in April had protein concentrations below 3.0 g/l – which is indicative of negative energy balance. Mean monthly somatic cell counts for indigenous cows were above 400,000 on six occasions during the year. Most of the high counts were in the first half of the year and reflected the recognised chronic mastitis problem (*see above*).

Eleven indigenous cows calved into the dairy herd in 1997. Mean yield for the six which had full lactations (five were culled to the suckler herd) was 4,346 kg which is a good performance for age and breed. Mean yield for the 13 bought-in cows which calved on the farm in 1997 was 5,237 kg. Mean yield for a further 13 first-calvers purchased after calving in 1997 was 4,464 kg. These are satisfactory production results.

Mean milk protein and fat concentrations were within normal ranges for bought-in and indigenous cows throughout the year. However, 14 cows had milk protein values below 3.0 g/l at some time in the first three months of 1997. This is indicative of post-calving negative energy balance and is discussed further below in relation to fertility performance.

Mean somatic cell counts for the indigenous and bought-in cows in the dairy herd were around 200,000 throughout the year. The improvement in counts reflected the significantly lower incidence of clinical mastitis and was largely the result of control measures introduced in 1996.

Although the Monitor Study on Index Farm B formally ended in March 1998, monitoring of production of the dairy herd continued up to its disposal in October, 1998. Forty two cows were milked during the year - 33 bought-in and nine Askeaton-origin. Mean yield for the 24 bought-in cows with 200-day plus lactations was 4,469 kg. Mean yield for the six indigenous cows which had lactations of 200 days or more was 4,964 kg. This is a good performance for both groups given that they were dried off early to facilitate depopulation of the herd in October.

Mean somatic cell counts in both indigenous and bought-in groups were below 200,000 throughout most of the year – a fact which reflects the very low incidence of mastitis in 1998 (three cases).

Conclusion

Milk production on the three monitor farms ranged from moderate to good. Mean lactational yields for the Askeaton-origin cows in Askeaton were between 4,000 and 4,600 kg which is an acceptable performance for the type and age of animal. Mean yields for the higher genetic merit brought-in cows on Index Farm B were around 5,000 kg.

While most of the Abbotstown-origin cows on Index Farm A in 1996 were calved too long before milk recording commenced to allow accurate analysis, it is clear that the housing-related health problems which developed over the winter of 1995-96 (EPA, 1997) had long-term effects on milk production. This is not surprising as some animals went dry in individual quarters. Residual udder health problems, as well as short lactations, contributed to an only moderate performance of average 4,410 kg for this (Abbotstown-origin) group in 1997.

Milk quality was satisfactory on the three farms. Group mean protein and fat concentrations were within acceptable limits throughout. Protein concentrations at the lower end of the normal range in individual cows were associated with transient periods of post-calving negative energy balance in 1996 and 1997. The significance of these is discussed further below. Periods of high milk somatic cell counts in the three herds were due to intermittent mastitis outbreaks and the presence of persistently infected carrier animals. These outbreaks, which were not considered unusual for a commercial dairy herd, were controlled by implementation of standard preventative measures.

While the purposes of the study did not include between-farm comparisons of similar-origin groups, it is clear that milk production was higher on the Control Farm in Abbotstown than on Index Farm A for both the Askeaton- and Abbotstown-origin (1997) groups. Milk protein concentration also tended to be higher on the Control Farm than on either of the Askeaton farms in 1997. Only 10 *per cent* of milk samples collected in the first three months post-calving on the Control Farm were below 3.0 g/l. This compares to 40 *per cent* on Index Farm A, and 23 *per cent* on Index Farm B for comparable periods post-calving.

There are a number of factors which are likely to have accounted for these differences in milk yield and quality. In relation to the Abbotstown-origin cows in Askeaton, yields would have been substantially reduced as a result of the housing-related udder and foot health problems experienced over the winter of 1995/96. The significantly shorter lactation lengths on Index Farm A (an on-farm management decision) than on the Control Farm in 1997 would also have reduced yields for both groups of cows in the former location. Differences in nutrition must also have played a role. The generally lower milk protein concentrations on the Askeaton Farms in 1997 than on the Control Farm indicate that energy supply was better matched to production in the latter. It is likely that the better quality silage and grass in Abbotstown was a major influence in this regard.

Nutrition, Body Weight and Condition

Estimation of average daily weight gain is a good indicator of the general health and productivity of growing animals. Any significant check in growth rates will be reflected in failure to reach target weights, and, in more serious cases, chronic ill-thrift. In cows, on the other hand, weight changes largely mirror the reproductive cycle, i.e. a gradual increase during pregnancy followed by a sharp drop at calving and a continued more gradual decline up to about two months post-calving. While the latter is a physiological energy deficit associated with milk production, excessive or prolonged weight loss post-calving is associated with a variety of reproductive and metabolic disorders.

In cows, body condition scoring is a more sensitive indicator of energy balance than weight change. Because of shifts in body water associated with fat mobilization, cows losing condition may actually be gaining weight. According to Ferguson (1991), reductions in body condition score, on the other hand, are highly correlated with adipose tissue mobilization and negative energy balance. On a scale of 1 to 5, cows should have a condition score of between 2.5 and 3.5 at calving and 2.0 to 3.0 at breeding. It is recommended that cows should not lose more than 0.5 of a score between calving and breeding.

Cows and growing stock on the three monitor farms were weighed monthly. Cows and their newborn calves were also weighed immediately after calving. In 1996, body condition scoring was carried out quarterly on the three farms. This was changed to monthly in 1997.

The overall approach to feeding and supplementation is outlined in the Study Protocol (EPA, 1996, unpublished). Concentrate supplementation was carried out according to Teagasc guidelines for efficient commercial dairying. These recommendations take into account both silage quality and milk yield potential of the cows. Pre-calving, it is considered that cows with a condition score of 2.5 at dry-off should reach target condition at calving of 3.0 to 3.5 on good quality silage alone (DMD 70 *per cent* or better). Post-calving, it would be economic to feed 7 to 8 kg concentrates per day to average genetic merit cows on 70 *per cent* DMD silage (Dillon and Crosse, 1997). However, it should be noted that silage quality on the Askeaton farms was generally below 70 *per cent* DMD.

Part 1 - Index Farm A

In 1996, between a half and two-thirds of cows (Askeaton- and Abbotstown-origin groups) had condition scores below the recommended minimum before and/or after calving. Many of these were probably secondary to the 1995-96 overwinter housing problems. By May, which was in the middle of the breeding season, about a third of the cows still had condition scores under the recommended minimum of 2.0. The possible effect of this on fertility performance is discussed below.

In 1997, about a half of the cows had condition scores below the recommended 2.0 to 2.5 at calving. Condition remained below optimum in a number of animals post-calving and in April - the start of the breeding season - five Askeaton-origin and ten Abbotstown-origin cows had condition scores below 2.0. A proportion of these also had low milk protein values (<3.0 g/l) and raised serum βHB values (> 0.9 mmol/l) which are further indications of a negative energy balance at this critical breeding period. Body condition improved throughout the summer.

The condition of cows in both groups was satisfactory in the first three months of 1998. Only three cows in each of the two groups had scores under 2.0 in March. One of these had experienced a difficult calving (twins) and the second was diagnosed with metritis post-calving.

The performance of calves and growing stock was good on Index Farm A throughout the project. Thirteen calves were reared in each of the years 1996 and 1997. Average daily weight gain for calves and yearlings was close to 1 kg and target weights (Teagasc, 1994) were met in all cases on standard rations.

Part 1 - Control Farm

Both groups of cows (Askeaton- and Abbotstown-origin) performed well throughout 1996 and 1997. Condition scores were generally within recommended limits pre- and post-calving. In general, Askeaton-origin cows had higher scores post-calving than Abbotstown-origin cows. The condition of cows in both groups was also satisfactory in the first three months of 1998.

Average daily weight gain for calves and growing stock could not be reliably calculated on the Control Farm as calvings were spread over several months. Calves were turned out onto grass at around 10 weeks of age in 1996 and 1997. Average calf weight in December 1997 was 220 kg which is the target-weight for spring-born calves. Average daily gain for yearlings in 1997 was close to 1 kg which is an acceptable performance.

While not as good as the matching group on Index Farm B in Askeaton, growth rates for the 12 steers in the Immunology Project were satisfactory in 1996 and 1997.

Part 2 - Index Farm B

Special feeding arrangements had to be implemented for the indigenous cows after the takeover of the farm in November 1995 owing to the poor condition of many animals and the risk of hypomagnesaemia (grass tetany; *see* Animal Health Volume).

By spring 1996, all indigenous cows were in good condition pre-calving (score 2.5 to 3.5) and held condition well post-calving. Only one cow had a score of below 2.0 in the two months post-calving and the majority had scores of 3.0 to 3.5. Performance of the bought-in cows was also satisfactory - though condition scores tended to be lower than indigenous cows. Five of the former had scores below 2.0 on at least one occasion in 1996. These reflect breed differences in relation to post-calving energy metabolism and are discussed below.

In 1997, only three cows (all bought-in) had condition scores below the recommended minimum of 2.5 pre-calving. Post-calving, there was a noticeable difference in performance between indigenous and bought-in cows. As a group, the latter suffered a more marked and more prolonged loss in condition than the indigenous cows. While four indigenous cows had condition scores below 2.0 in the first two months post-calving, 17 bought-in cows had scores of below 2.0 during the same period. The significance of these findings in relation to fertility performance is discussed below.

The indigenous cows gained condition throughout the summer - to the extent that they had to be moved to poorer grass for the autumn and early winter to avoid problems associated with excess condition. The bought-in cows performed less well and in September, 13 cows still had scores below 2.0.

Body condition was generally much improved in 1998 when compared to 1996 and 1997. The overall average condition score of 2.2 during the month of May was within Teagasc guidelines for breeding.

Calves were not reared on Index Farm B in 1996. Calf performance was good on the farm in 1997. Average daily gain was around 1 kg from May to October - by which time they had reached target weight of 230 kg for the year.

Eighteen of the 1997 crop of calves were held on the farm in 1998 and used in the Immunology (selenium) Studies. Ten of the 1998 crop of calves were also reared on the farm. Regular weighings were not continued after the formal end of the Monitor Study in March. However, animal performance was good throughout the year.

Twelve steers purchased for the Immunology Studies at about six months of age in October 1996, were maintained outdoors over the winter of 1996-97. They were fed silage *ad-lib* and approximately 1.5 kg beef concentrate per head per day and had reached an average weight of 385 kg by February 1997 which is a good performance. They received no concentrate feeding while at grass during 1997 and had reached slaughter weight by the autumn.

Conclusion

Cow performance overall was satisfactory on the three farms. In general, body condition and weight changes were consistent with normal responses to the varying energy demands of the reproduction and lactation cycles. While post-calving condition losses were, at times, in excess of what is generally recommended, these were clearly physiological or nutritional in origin and were within the normal range for commercial farming (Appendix A).

The study clearly demonstrated a difference between the Askeaton and Abbotstown herds in relation to periparturient energy balance in cows. This difference was particularly apparent in 1997 when cows were monitored throughout an entire production cycle from pre-calving to dry-off. These differences are illustrated in Fig. 2.2 which shows that mean monthly body condition scores on the two farms in Askeaton were near or below the recommended minimum of 2.0 points for up to six months post-calving – while mean scores on the Control Farm (Farm C) remained above 2.5 throughout the equivalent period. Post-calving weight loss was also more marked on the Askeaton farms - in particular on Index Farm A.

That these changes were a reflection of differences in post-calving energy balance is illustrated by the fact that βHB concentrations were significantly higher, and glucose concentrations significantly lower - both indicators of negative energy balance (Lomax, 1992; Whitaker *et al.*, 1993) - in the Askeaton cows than the Abbotstown cows in blood samples collected between 30 and 60 days after calving. Milk protein-to-fat ratios (Fig. 2.3), which are also a measure of energy supply (Duffield *et al.*, 1997), were significantly lower (i.e. more severe negative energy balance; $p < 0.05$) on the two Askeaton farms for the first four months of lactation in 1997.

Although the extent of these differences in performance is somewhat surprising given that the study protocol defined a standard management regime for the three farms, it is clear that the actual implementation of nutritional management in meeting the demands of post-calving production was less successful on the two Askeaton farms in 1996 and 1997 than on the Control farm at Abbotstown throughout or on Index Farm B in 1998. Factors which may have contributed to these differences include pasture management and the implementation of concentrate supplementation recommendations. As reported elsewhere (Soil, Herbage, Feed and Water Volume), grass and silage quality were significantly better in Abbotstown than in Askeaton. This was partly due to the better quality of existing pastures and partly to closer adherence to grass management recommendations in Abbotstown. In June 1997, for example, cows on Index Farm B were only giving 20 kg of milk per day on 4 kg of concentrates due to reduced grass quality as a result of overgrowth. During the same period in 1998, when grass management was as recommended, cows on grass gave 25 kg of milk per day on only 2 kg concentrates.

Differences in performance observed before animals were turned out to grass also indicate that the actual amount of concentrate supplement fed to cows in Askeaton was, at times, inadequate to compensate for the poorer quality silage than in Abbotstown. The under-feeding of concentrate supplementation on Index Farm B in 1996 due to faulty scales has been referred to elsewhere (EPA, 1997). Conversely, periodic over-supplementation of the cows at Abbotstown due to their being milked alongside a winter-milking herd may have contributed to their overall better condition – though the better quality silage at Abbotstown was probably a far more important factor.

Breed differences must also be taken into account when considering the differences in performance between the Askeaton and Abbotstown farms. The indigenous Askeaton cows, which were largely British Friesian type, tended to maintain condition better than the non-indigenous cows. The latter were Holstein-type (Abbotstown-origin) or pure Holstein (bought-in to Index Farm B). Holstein cows have a higher milk production potential and

are known to be more sensitive to post-calving condition loss than the British Friesian. In general, the British Friesian tends to convert energy to fat while the Holstein preferentially converts it to milk - even at the expense of body condition (Webb *et al.*, 1999).

Growing animals, i.e. calves, weanlings, yearlings and two-year-olds, all performed well on the two Index Farms in Askeaton and on the Control Farm in Abbotstown throughout the two-year Project. Target weights were reached or exceeded in acceptable time periods. Ill-thrift was not a problem on any of the three farms and there was no evidence of depressed growth rates or feed conversion efficiency. Age for age, the Askeaton groups of growing animals generally out-performed their Abbotstown counterparts. Given that the animals on the two Askeaton farms spent the greater part of their time outdoors on grass, these results provide convincing

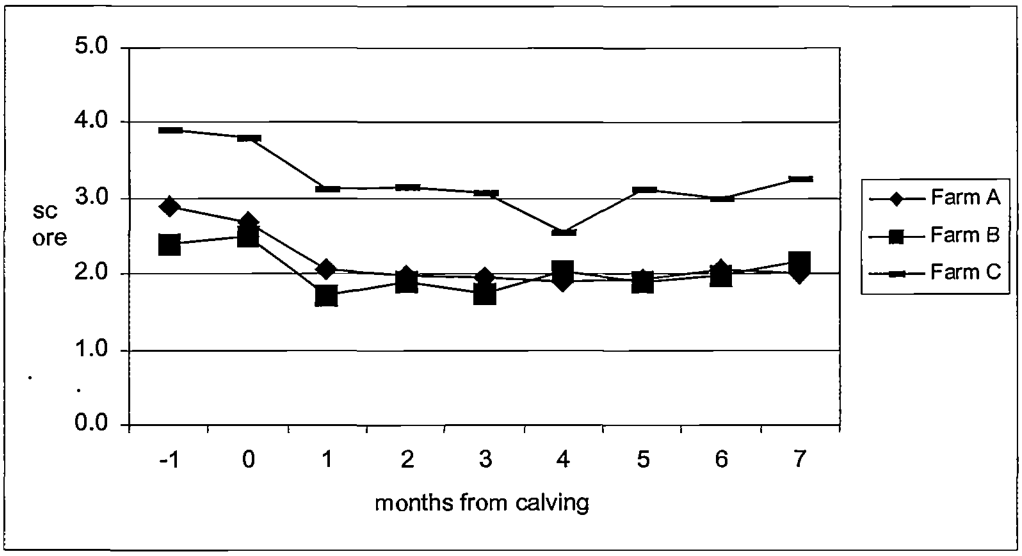

Fig. 2.2 Cow body condition score for periparturient period 1997. (A = Index Farm A, Farm B = Index Farm B, Farm C = Control Farm)

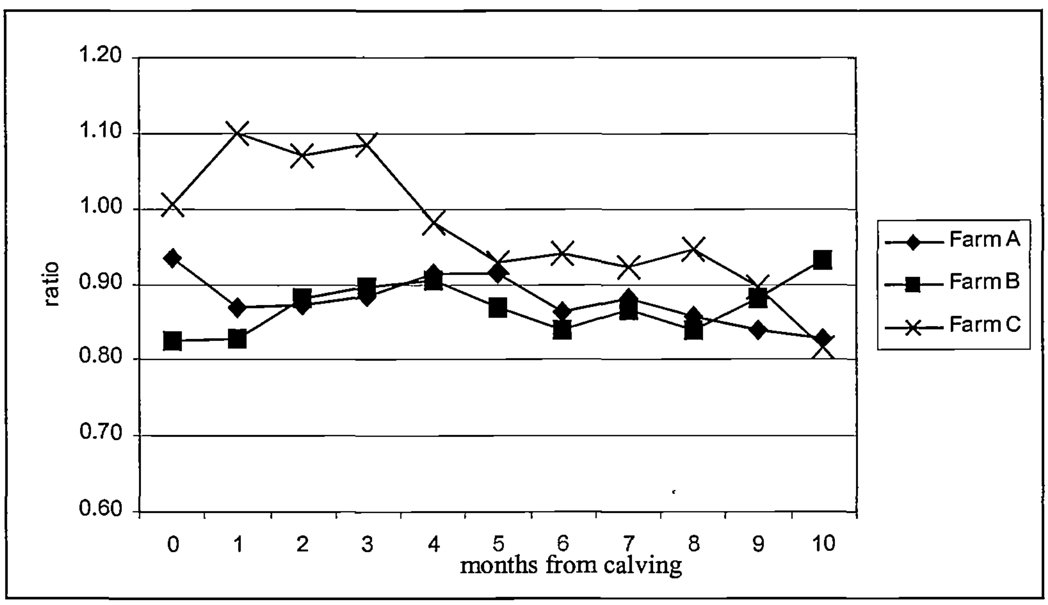

Fig. 2.3 Milk protein to fat ratios for periparturient period 1997. (A = Index Farm A, Farm B = Index Farm B, Farm C = Control Farm)

evidence of the wholesomeness of pastures in the Askeaton area during the two-year period of the trial.

Fertility

Fertility was monitored on the three farms as part of the overall assessment of herd performance. Details of fertility management are described in the Study Protocol (EPA, 1996, unpublished) and were according to standard Teagasc guidelines. Visual heat detection was to be carried out four times daily and tail-painting was used to assist identification of cows in heat. Records were kept of all calvings, heats, services, and pregnancy examinations on the three farms. All dairy cows were served by artificial insemination. Suckler cows on Index Farm B were served by a stock bull in 1997.

Part 1 - Index Farm A

Fertility performance was poor on Index Farm A in 1996. The main problems were a poor submission rate at the start of the season and a poor overall conception rate. The poor submission rate was clearly a problem of heat detection. Although over two-thirds of the herd had calved by March, only one cow had been seen on heat by early May. That the problem was not due to anoestrus (absence of heat due to failure to ovulate) at this time was demonstrated by the results of uterine scanning which indicated that most cows were cycling.

Although it is not possible to determine to what extent the problem was due to inadequate observation on the one hand, and to inadequate expression of heat (suboestrus) on the other hand, it is unlikely that the latter can have accounted for a significant proportion of the missed heats. While excessive negative energy balance is known to delay the onset of heats post-calving – and this may have led to some cases of anoestrus at an earlier stage in the season – there is little evidence to specifically associate energy deficit with suboestrus or silent heats once post-calving cycling has commenced (Allrich, 1993).

Neither was there any evidence that reproductive or other disease could account for the problem. The cows were generally in good health and had normal appetites.

Conception performance was poor in June 1996 - largely due to problems with artificial induction of heats (hormone implants). These had been initiated to deal with the earlier poor submission rate. These results have been discussed in detail elsewhere (*see* Animal Health Volume). Conception rates in May and July were 71 and 50 *per cent*, respectively which represent a good performance.

Fertility performance improved in 1997. Average calving to first service, calving to conception, and submission rates, were all close to target. Though below target at 42 *per cent*, overall conception performance was within the reported range for herds of this size. Milk progesterone analysis at the time indicated that while accuracy of heat detection was good, the efficiency of heat detection was less so – leading to a relatively high incidence of missed heats.

Part 1 - Control Farm

Overall fertility performance on the Control Farm was good in 1996 and 1997. Conception rates were at or above target. Fertility rate was over 90 *per cent* in both years. However, as hormonal induction of heats was used routinely for management reasons, analysis of heat detection performance is of little value.

Part 2 - Index Farm B

Fertility performance was only moderate on Index Farm B in 1996. The submission rate was low due to poor heat detection results at the start of the season. Although calving to first service and calving to conception were within target, overall conception performance was poor.

Part of the reason for the latter was a management decision to serve cows as early as possible after calving in order to tighten up the calving pattern for the following year. This meant that some cows were served at a time when fertility was less than optimal. However, there was also evidence that both the accuracy and efficiency of heat detection were below expectations. Missed heats were a particular problem later in the season.

Overall fertility performance on Index Farm B in 1997 was good. Conception rate to all services was over 50 *per cent* and the fertility rate for the year was 90 *per cent*. However, heat detection rates were again poor at the start of the breeding season and, because of this, a decision was made to increase the use of artificial heat induction with progesterone implants. Subsequent investigation of the problem, based on the result of milk progesterone assays, indicated that while accuracy of heat detection had been good, efficiency was less so - i.e. only about 50 *per cent* of returns to service were being detected.

Fertility performance in 1998 was good. As no new breeding stock were introduced, the herd was essentially the same as that in 1997. Submission rate, heat detection rate, calving to first service, and calving to conception were all close to or better than target. A number of factors can be identified which contributed to this improved performance. Firstly, as part of the management policy for the farm, the calving spread had been reduced from eight to four months over the two previous years. This facilitated the implementation of a more intensive heat detection regime. Secondly, a number of changes in relation to fertility management and heat detection were introduced based on experience in previous years. Thirdly, a tighter control over post-calving nutrition and grass management ensured that cows were in better condition at breeding than in previous years. Mean condition score for the bought-in cows in May 1998, for example, was 2.2 compared to 1.9 in May 1997. Biochemical markers of negative energy balance, i.e. serum βHB and glucose concentrations, were also consistent with a less severe post-calving energy deficit in 1998 than in 1997.

Conclusion

While fertility performance was below target at times on the two Askeaton farms, the results of the present study provided no evidence to suggest that shortfalls in performance could be attributed to unusual factors. The main problems encountered on both farms related to heat detection and, to a lesser extent, conception rates. This is not an unexpected finding as failure to detect heat (non-detected oestrus) is regarded as the commonest cause of infertility in dairy farming (Esslemont and Kossaibati, 1995, 1996). The causes of non-detected oestrus are generally considered to be a function of fertility management (Sreenan and Diskin, 1992; Esslemont and Kossaibati, 1995) rather than reproductive pathology.

There was no evidence, either, that reproductive or systemic disease was a significant contributory factor to the fertility problems at herd level. Animals on the two Askeaton farms were generally in good health throughout. It is likely, however, that the failure to adequately maintain body condition post-calving had a significant negative effect on fertility performance. There is an accepted association between excessive condition loss post-calving and delayed onset of heat (Webb *et al.*, 1999). Condition-scoring, as well as biochemistry results in 1996 and 1997, demonstrated a more severe post-calving negative energy balance on the two Askeaton farms than the Control Farm. The effect of this on fertility may have been mediated through delayed resumption of post-calving oestrus cyclicity, reduced conception rates, or both.

The significantly better body condition of cows on Index Farm B during the 1998 breeding season, on the other hand - as well as the management changes introduced before the start of the breeding season - probably contributed to the greatly improved fertility performance in that year.

The results of fertility performance on the Askeaton farms in 1996 and 1997 must also be viewed in the context of the fertility problems which had built up in preceding years. The calving season on Index Farm B in 1996, for example, which was a legacy of problems encountered by the herdowner in 1995, extended over eight months making heat detection difficult. In addition, the need to retain Askeaton-origin cows in the study on scientific grounds - which on a purely commercial basis would have been culled from the herds - must also have had an overall negative effect on fertility performance.

<u>Blood Analysis Results</u>

Blood samples were collected for analysis from all study cows at approximately monthly intervals throughout the project. Blood samples were also collected from growing stock on the two Index Farms in 1997 and 1998. Other than the Immunology Studies steers, growing stock were not sampled on the Control Farm. A standard test profile was applied involving haematology and biochemistry analyses (*see* Animal Health Volume). Additional diagnostic tests were performed as required, e.g. bacterial and viral culture and serology and non-standard mineral analyses.

Haematology

Group mean values were within accepted reference ranges throughout the two-year period. Occasional individual-animal values outside normal ranges were associated with physiological status (e.g. pregnancy) or intercurrent disease, e.g. lameness or mastitis.

Statistically significant differences for haematology parameters ($p < 0.05$) were noted at times between cow groups on all three farms. However, as group mean values were generally within normal reference ranges, and as the differences were not associated with specific differences in group health status, no particular clinical significance can be attached to these findings.

Biochemistry

The most significant biochemistry changes throughout the Project were at group-level. They were largely seasonal in nature and were associated with variations in nutritional and production status. Raised blood urea concentrations on all three farms during the summer-autumn grazing periods were probably associated with changes in herbage supply and quality (Fig. 2.4). Low urea (and phosphorus) concentrations in the majority of cows in July 1997 on Index Farm A may have been associated with a transient insufficiency of grass supply due to delayed fertilizer application. The more marked fluctuations in mean urea values on this farm than on the other two farms are also suggestive of a less consistent grass management programme.

βHB concentrations above the reference range (0-0.9 mmol/l) were recorded on all three farms on a number of occasions. Samples were generally from recently-calved cows and the findings are consistent with post-calving negative energy balance. They were most notable on the two Askeaton farms in 1997 when about a third of cows had raised values. This finding has already been discussed above in relation to nutritional management and fertility performance. It is worth noting that few raised βHB values were recorded on Index Farm B in the spring of 1998 when fertility performance was good.

Elevated concentrations of the liver enzyme GLDH, noted in a significant proportion of cows on Index Farm A in November 1996 and on the Control Farm in September 1997, were probably production-related. The changes were not associated with any specific signs of ill-health in the animals concerned.

Seasonal changes in copper and magnesium concentrations consistent with changes in herbage composition were also noted. Copper concentrations tended to fall over the summer months. This was most obvious on Index Farm A – although it is unlikely that the reductions were of clinical significance. A similar finding has already been reported by O'Farrell *et al.* (1986) in relation to grazing cattle in Ireland. Low blood magnesium in November 1996 and 1997 on Index Farm A was consistent with reduced dry matter intake on grass. This is a common occurrence in cows on grass at this time of the year and was corrected by housing animals and provision of silage.

Changes in blood selenium concentrations on the three farms reflected their differing selenium status. Index Farm B has a low to marginal soil selenium status. All of the Control Farm, and parts of Index Farm A, would be classified as elevated selenium status.

With the exception of selenium, mean biochemistry values for blood samples collected from growing stock on the two Askeaton farms in 1997 and 1998 were generally within normal ranges.

Conclusions

Haematology and biochemistry findings on cows on the three farms were consistent with animals in overall good health and there was no evidence of changes in blood values which would suggest that toxic or other unidentified factors had a negative effect on herd health. Group fluctuations in a number of parameters were mainly due to seasonal changes in productive or nutritional status. Individual-animal values outside normal ranges were consistent with the type and range of conditions which would be expected in cows and growing stock managed under normal farm conditions.

Conclusions of the Monitor Study

The results of this two-year study, commencing in 1996, have shown no evidence of a continuation of the severe animal health and production problems which had previously been reported on the two Index Farms in Askeaton up to and including 1995. Neither was there any evidence to suggest that health or production were adversely affected by unidentified environmental factors, such as pollution, throughout the duration of the project. Animal health was generally good throughout the period of the study. Diseases encountered generally comprised conditions which are common on farms elsewhere in Ireland and incidence rates were generally within normal limits. The health of calves and growing stock was generally good and no major disease incidents were encountered. There was also no evidence that cows from one of the Index Farms (Farm A), when moved to a distant Control Farm, performed less well than might have been expected given breed and type.

Animal production was generally satisfactory on the three farms. Milk production and body condition performance of both Askeaton- and non-Askeaton-origin cows ranged from moderate on the two Askeaton farms to good on the Control Farm. While fertility performance was below target at times, mainly on the two Askeaton farms in the first year of the project, problems largely related to heat detection and there was no evidence to suggest that other unusual factors were involved.

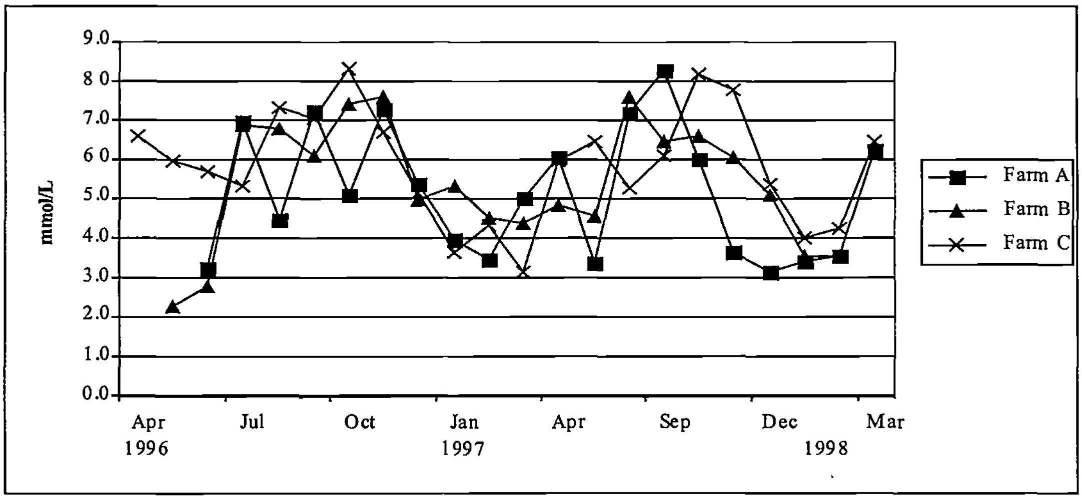

Fig. 2.4 Mean monthly blood urea concentrations for three monitor farms – April 1996 to March 1998 (A = Index Farm A, Farm B = Index Farm B, Farm C = Control Farm)

LONGITUDINAL STUDY ON FOUR FARMS

A Longitudinal Study of animal health and production was undertaken on four (originally five but one herdowner withdrew voluntarily) farms in the Askeaton area. These were selecied from among the 25 self-identified 'problem' farms in the area on the basis of factors relating to the nature, severity, and duration of the disease problems reported.

The objectives of the Longitudinal Study were to monitor animal health and production on the participating farms and to investigate the immediate and underlying causes of disease problems encountered. The farms were visited monthly (or more frequently as required) by the Study Clinician who undertook animal health inspections and collection of records. Analyses of soil, herbage, and fodder were also carried out by Teagasc on the four farms in 1997. A farm management audit was undertaken by Teagasc staff on three of the four participating farms.

Periodic reports on animal health and production were issued to the herdowners and their attending veterinary practitioners throughout the study. Recommendations were also made for control or prevention of specific health problems encountered.

At the start of the study, a group of monitor animals was selected for quarterly blood-sampling and condition-scoring on each farm. Additions and withdrawals were made to and from the groups during the study to allow for sales and culling. Haematology and biochemistry analyses were performed on these blood samples as described for the Monitor Study above.

Farm LS1

This was a medium-sized dairy/store farm. The main animal health problems recorded in the Retrospective Study Report (Farm RS5 – *see below*) were infertility in cows and illthrift in calves and weanlings. The main problems reported at the time of the first visit of the Longitudinal Study in October 1996, were poor condition in cows, extended calving season due to infertility problems in previous years, and illthrift in calves.

Animal Condition and Nutrition

At the initial study visit to the farm, about a third of the cows (dry and milking) had poor body condition scores (<2.0). Recommendations for significantly increased concentrate supplementation were made based on analysis of samples from the 1996 silage crop. These were only partially implemented by the herdowner over the winter/spring of 1996/97.

While the condition of individual cows continued to be a problem, there was an overall improvement throughout the study period. The main factors which were considered by the investigating team to have contributed to poor

condition were inadequate concentrate supplementation to compensate for poor silage quality, and the nutritional stresses associated with out-wintering dairy cows before and after calving.

According to the herdowner, illthrift had been a problem in calves and weanlings for some time. Newborn calves were said to be small and failed to thrive - either indoors or on pasture. Calf and weanling thrive was variable throughout the two-year study. Contributory factors identified included disease and management. A proportion of the calf crop was affected by chronic respiratory disease in both 1997 and 1998. A case of tick-borne fever was identified in the calf group in 1997. There was also evidence that the copper supplementation regime may have been inadequate to compensate for marginal supply at grass. The practice of mixing animal ages at grass is also likely to have had a negative influence on health and thrive. In summer/autumn 1997, for example, animal ages in the calf/weaner group ranged from about four to over 20 months. Besides the fact that older animals can act as reservoirs of infection, it can also be difficult to ensure that younger animals receive their share of supplemental feed. In this context, it is significant that poor thrive was generally more of a problem for calves born later in the year.

Animal Health

The main health problems recorded in calves and young stock were respiratory disease and poor thrive (*see above*). Two outbreaks of respiratory disease were reported. The first was in April 1997. According to the herdowner, all 16 of a group of housed calves began coughing the day after 'caustic smells' were noticed in the air around the farm. There was no veterinary or laboratory investigation of this incident and the animals were treated by the herdowner. Some of these calves, along with others, were the subject of veterinary investigations for illthrift and intermittent coughing while at grass during the subsequent summer and autumn. Although no specific pathogens were identified, haematology results consistent with the presence of inflammatory conditions were noted in blood samples collected on a number of occasions.

The only significant disease outbreak recorded in calves in 1998 was coughing in a group of five calves at grass in June. Clinical examination of the calves confirmed the presence of a moderately severe respiratory tract inflammation. Haematology findings were consistent with a chronic respiratory tract inflammation with infectious involvement. The animals showed a good response to antibiotic therapy - though according to the herdowner subsequent growth rates were lower than expected. According to the herdowner, this outbreak was related to an incident two weeks previously which he considered was atmospheric pollution – but which had not been associated with any clinical signs of illness at the time.

Animal mortality was low throughout the study. Two deaths were recorded in the first year - a stillborn calf and a one-and-a-half year-old heifer which had been severely growth-retarded from an early age. Three calves and a heifer died in 1998. The first two calf deaths occurred within a short time of birth - one following a difficult delivery from a cow with severe mastitis. The third calf death was due to a congenital cardiac anomaly. The death of the heifer was due to injuries she sustained after breaking into a neighbouring field.

Significant disease incidents in the cows in 1997 and 1998 were also largely respiratory in nature. An outbreak of coughing in cows was investigated in June 1997. According to the herdowner, this was a direct result of their exposure to atmospheric pollution which he had noted two days earlier. Although most of the cows exhibited coughing at the time of the veterinary visit to the farm, they appeared otherwise healthy and haematological and biochemical analysis of blood samples showed no evidence of a significant systemic inflammatory response. With the exception of one cow which developed signs of pneumonia two weeks later, all of the cows recovered uneventfully and without treatment. No specific diagnosis was made regarding the cause of the coughing.

Three further outbreaks of respiratory disease in cows were reported in 1998 which, according to the herdowner, were associated with alleged incidents of atmospheric pollution. However, veterinary clinical and laboratory examinations failed to reveal evidence of significant respiratory tract inflammation in the two outbreaks which were reported early enough to allow investigation. According to the herdowner, an incident of irritability in cows at milking in February 1998 may also have been due to atmospheric pollution (*see* Animal Health Volume).

The incidence of other diseases in cows was low. One case each of mastitis and milk fever were recorded in 1997. Two cases of clinical mastitis were recorded in 1998. Occasional other individual-animal incidents were reported. Lameness was not reported to have been a problem in either year. No cows were reported to have died throughout the period of the Study.

Fertility

Infertility was reported to have been a problem on this farm since about 1990. According to the herdowner, the main problem was of cows and heifers failing to show signs of heat. The incidence of repeat-breeders (i.e. multiple returns to service) was also reported to have been a problem in later years.

Fertility performance was good in 1997 – the first year of the Longitudinal Study. About a third of recorded services were natural and two-thirds were by artificial insemination. Only one cow served in 1997 failed to calve in 1998.

A bull was used for all services in 1998. Although detailed fertility records were only maintained for the first month of the breeding season, it was clear that performance was down on 1997. Ultra-sonic scanning carried out in September 1998 indicated that up to 25 *per cent* of the cows were not pregnant.

In the absence of comprehensive records it is not possible to determine the reasons for the lower conception performance in 1998. Possible contributory factors include bull fertility and early embryonic losses. A fertility assessment of the bull was not carried out.

Milk Production

Although individual cow milk recording was not carried out on this farm, available records indicated that production was satisfactory in 1997 and 1998. Total sales were close to quota in both years. Average yield per cow for 1997 was estimated at about 3,596 kg on approximately 391 kg concentrates per head. Estimated average yield per cow up to September, when the study ended, was about 3,300 kg on about 489 kg concentrates.

Blood Analysis Results

Blood samples were collected from young stock and cows on 13 occasions throughout the study period. Mean haematology values were generally within normal ranges throughout. Individual-animal values also generally remained within normal ranges. No evidence of anaemia was detected at any time. White cell counts in blood samples from cows were also generally within normal ranges. However, raised counts – generally due to a neutrophilia – were detected at times in samples from young stock collected during investigations of chronic illthrift and respiratory disease.

Blood biochemical parameters were also mostly within normal ranges throughout the period of observation. Individual-animal results consistent with mild intercurrent sub-clinical inflammatory conditions were observed on occasions (e.g. raised serum globulins or GLDH). Blood βHB concentrations above 0.9 mmol/l detected in cows on a number of occasions were indicative of periodic negative energy balance.

Blood copper concentrations below the normal range of 9.4 – 24.0 μmol/l were detected in about a quarter of all samples collected during the two-year period – mostly from young stock. The significance of this in relation to the copper supplementation programme on the farm has been referred to above.

Conclusion

Animal health was generally good and no serious outbreaks of disease were encountered. While problems with illthrift and respiratory disease in young stock and cows were observed on this farm, performance overall was satisfactory during the almost two-year period of the Longitudinal Study. In relation to poor thrive, there is sufficient information to suggest that nutrition, management, and infectious agents were important contributory factors. Although a number of outbreaks of respiratory disease were investigated in cows and young stock, these were relatively mild in nature and no losses occurred. The fact that no specific determination could be made regarding the possible association between some of these outbreaks and alleged incidents of atmospheric pollution is partly due to the absence of environmental material for analysis (i.e. suspect air samples), and partly to the relatively mild and non-specific nature of the clinical signs observed in reportedly affected animals. The incidents were also apparently restricted in their geographical distribution as no other concurrent reports of atmospheric pollution in the vicinity were brought to the attention of the investigating team.

Fertility performance, overall, was satisfactory and analysis of blood samples collected during the study showed no evidence of unusual health problems.

Farm LS2

This was a medium-to-large mixed dairy/suckler farm. The main animal health problems recorded in the Retrospective Study Report (Farm RS6) were infertility, perinatal calf mortality, and ill-health in calves. The main problems reported to have occurred during 1996 were post-calving vaginal discharge and repeat-breeding in cows, perinatal calf losses, and poor milk production. A case of BVD virus infection was confirmed in a yearling heifer in February 1996. Two incidents of irritability at milking were also reported to have occurred - one shortly after an emission from a local factory was reported to have blown over the farm.

The Longitudinal Study on this farm commenced in December 1996 and concluded in December 1997. The latter was at the request of the herdowner for management reasons. A number of farm visits were also made in 1998 to investigate specific disease problems.

<u>Animal Condition and Nutrition</u>

About a third of the cows (all but one milking) had condition scores under 2.0 at the time of the first farm visit of the Longitudinal Study in November, 1996. Recommendations for concentrate supplementation - based on analysis of samples from the 1996 silage crop - were largely implemented over the winter/spring of 1996/97. Other than expected variations associated with production status, and occasional cases of ill-health, cow condition was not a specific problem at herd-level during the Longitudinal Study.

<u>Animal Health</u>

Six stillbirths were reported in 1997. While the incidence is above target, and indicates a significant problem, straightforward diagnoses were made in most cases. Post-perinatal calf health was good. No deaths were recorded and respiratory and enteric conditions were not reported to be a problem. Some calves showing poor thrive in summer 1997 had marginally low blood copper concentrations. No specific disease problems were reported in older growing stock.

Cow health was also generally good. Mastitis and lameness were the main adult animal disease problems recorded on the farm. Eleven cases of clinical mastitis were recorded in 1997. Laboratory investigations indicated involvement of *Staphylococcus aureus* - a common cause of infectious mastitis. Nineteen cases of lameness were recorded. Although relatively high at 1.6 cases per month, this is not an exceptional incidence.

Other problems reported at a low incidence included redwater, metritis, tail haemorrhage, vulval tear, pneumonia, grass tetany, and chronic nasal discharge. Severe fluke infestation was identified in a number of adult animals in the spring of 1998.

<u>Milk Production</u>

Milk production was poor on the farm in 1997 given the breed of cow and reported rates of concentrate supplementation. Average yield per cow was 4,028 kg on 634 kg concentrates. Analysis of monthly production records for 1997 indicated that many cows had exhibited a rapid decline from peak yields between April and June. A single specific cause of the poor results could not be identified. Factors which may have contributed included the relatively high incidences of mastitis and lameness.

The herdowner was also concerned that long-term effects of animal health problems experienced in 1994 and 1995 (*see* Retrospective Study), and which he considered may have been due to exposure to environmental pollution, could have had a permanent effect on the productive capabilities of the animals concerned. Although no specific evidence of underlying long-term health or developmental problems was observed in these animals in 1997, this was one of the issues to have been addressed had the study continued into 1998.

<u>Fertility</u>

A combination of natural and artificial insemination was used in the 1997 breeding season. The submission rate for the first three weeks of the breeding season was well below target. Conception performance could not be calculated as routine recording of services ceased once natural mating had commenced. Overall performance, at 83 *per cent* pregnant of served, was satisfactory.

<u>Blood Analysis Results</u>

Blood samples were collected on six occasions in 1997 from adult and growing animals. Haematology values were generally within normal ranges. Total white cell counts above the normal range were not detected in cows

at any time. Occasional raised counts in young stock were probably associated with intercurrent sub-clinical infections.

The majority of biochemical parameters were also within normal ranges. Variations in protein, phosphorus, βHB, and urea were probably metabolic in origin and related to changes in nutrition and production status and season. Occasional low phosphorus concentrations were seen in older cows or around peak milk yield. These were normal physiological responses to production demands.

Raised concentrations of the liver enzymes γGT and GLDH were detected in samples from some adult animals in the spring of 1998. Subsequent post-mortem investigations confirmed that they were due to fluke infestation.

Conclusion

Animal health overall was satisfactory on this farm during the 12-month period of the Longitudinal Study. The main problems encountered were stillbirths in calves and mastitis and lameness in cows. Milk production was also poor. While a number of probable contributory factors were identified, a full investigation planned for 1998 could not be undertaken owing to the farm's withdrawal from the study at the end of 1997. While fertility performance could not be accurately assessed owing to incomplete records, performance overall was satisfactory. Any blood analysis results outside normal ranges were consistent with production or other diseases commonly seen on commercial farms elsewhere.

Farm LS3

This was a medium-sized mixed dairy/suckler farm. The main animal health problems recorded in the Retrospective Study (Farm RS7) were perinatal calf mortality, infertility, and poor milk yield. No specific disease problems were reported at the time of the first visit of the Longitudinal Study in October 1996. High milk cell counts had been a problem in 1996 and production was reported to have been below expectations.

Animal Condition and Nutrition

Animal condition was generally good at the time of the initial visit. Recommendations for concentrate supplementation, based on analysis of samples from the 1996 silage crop, were largely implemented over the winter/spring of 1996/97. With the exception of a small number of imported Holstein cows which tended to have only poor to moderate condition, animal condition was generally satisfactory throughout the two-year period of the study.

Animal Health

The health of calves and growing stock was generally good throughout the two-year study. Three of the four stillbirths which occurred in 1997-98 were associated with difficult calvings. No post-perinatal mortalities were recorded in 1997. Two calves died of coli-septicaemia (a common peri-natal infection) in 1998.

Sub-clinical mastitis was the main animal health problem in cows. Although only four cases of clinical mastitis were recorded in 1997, the results of laboratory investigations in that year indicated widespread infection of the milking herd with *Staphylococcus aureus*. A comprehensive control programme was implemented which included dry cow therapy, modifications to the milking routine, and culling of persistently infected cows. While cell counts were lower throughout most of 1998, and only three cases of clinical mastitis were recorded, quarter-sampling at the end of the year indicated that infection with *Staphylococcus aureus* remained widespread.

Other conditions recorded at low incidences in 1997 and 1998 were metritis/vaginal discharge, retained placenta, lameness, and milk fever. Two cows died in 1997 and one in 1998. Straightforward diagnoses were made in all cases.

Fertility

Fertility was not reported to have been a problem on this farm in the years immediately preceding the Longitudinal Study. While insufficient records were available for a detailed analysis, results overall were satisfactory over the two-year period of the study.

Milk Production

Milk production was satisfactory in 1997 and 1998. Average yield per cow in 1997 was 4,078 kg on 519 kg concentrates. The comparable figure in 1998 was 4,210 kg on about 700 kg concentrates.

Blood Analysis Results

Blood samples were collected from selected young stock and cows on eight occasions throughout the two-year period. Haematology parameters were within normal ranges throughout. A single case of anaemia in a cow was possibly due to internal bleeding from an abomasal ulcer. Occasional raised white cell counts were consistent with intercurrent sub-clinical infections (e.g. mastitis). Biochemical parameters were also mostly within normal ranges throughout the period of observation. Raised globulin or GLDH (liver enzyme) concentrations recorded in individual samples on a number of occasions were not considered to be of clinical significance

Conclusion

Animal health and production was generally good on this farm throughout the study. A serious peri-natal calf mortality problem reported in previous years (*see* Retrospective Study) did not recur. Although inadequate records were available to make an accurate assessment, fertility performance appeared to have been good. Haematology and biochemistry results on blood samples collected from the monitor animals were generally within normal ranges.

Farm LS5

This was a large intensive dairy herd. The main problems reported in the Retrospective Study (Farm RS9) were infertility, perinatal calf mortality, and ill-health in calves. No specific disease problems were reported at the time of the first visit of the Longitudinal Study in December 1996.

Animal Condition and Nutrition

Excess condition in some dry cows and heifers – which resulted in a high incidence of dystocia (*see below*) - was a problem during the 1997 calving season. Animal condition otherwise was generally satisfactory throughout 1997 and 1998. Analysis of silage samples from the 1996 and 1997 crops indicated that the quality was good. Concentrate supplementation during the 1997 and 1998 milking seasons was largely in line with Teagasc recommendations.

Animal Health

Animal health performance overall was satisfactory during the two years of the study. The main problems in calves in 1997 were perinatal mortality and diarrhoea. The incidence of perinatal mortality (mainly stillbirths) was high owing to calving problems largely associated with the overfat condition of some cows and heifers (*see below*). An outbreak of diarrhoea in calves, due to cryptosporidial infection, occurred in January 1997. Several cases of diarrhoea and associated illthrift were recorded in weanlings at grass during the summer. An outbreak of respiratory disease, characterised by coughing and nasal discharge, occurred in September. The majority of the calves were affected. No specific bacterial pathogen was identified by a subsequent laboratory investigation. Although growth rates of some calves were reduced, no losses occurred and most had improved significantly by mid-November.

There were seven perinatal calf losses in 1998 – two of which were twin deliveries. Post-perinatal calf health was satisfactory in 1998. An outbreak of respiratory disease in the last batch of housed calves in the spring responded to antibiotic therapy. A further outbreak of respiratory disease in calves at grass following a spell of cold and wet weather also responded to antibiotic therapy. No losses were recorded in either outbreak.

The main health problem in adult animals was excess condition of cows and heifers in 1997 leading to a high incidence of dystocia and perinatal mortality. Dietary control measures were introduced during the calving season to address the problem. The incidences of retained foetal membranes and vaginal discharge/metritis were also above normal in 1997 as a direct result of the calving problems. The incidence of mastitis was within the normal range in 1997. The incidences of other conditions were within acceptable limits in 1997. Two cows died in 1997. Both were calving-related.

Inadequate information was available to assess disease incidences in cows in 1998. However, other than a serious mastitis problem in bought-in cows – and which had to be dealt with by radical culling - there were no reports of significant disease problems in adult stock in that year. The death rate for cows would appear to have been low and comparable to 1997.

Fertility

While heat detection results were good on this farm, conception performance was below target – particularly so in 1997. It is likely that performance in 1997 was significantly affected by the calving problems referred to above. While in-depth investigation of performance in 1998 was precluded by the absence of pregnancy diagnosis results, analysis of available records suggested that reduced accuracy of heat detection was likely to have been a contributory factor. Other factors which may contribute to reduced conception rates, but which cannot be quantified in this case, are bull fertility, early embryonic deaths, and high milk yield. Recent studies by Teagasc (O'Farrell *et al.*, 1997) have shown that conception performance can be significantly reduced in high yielding cows. The results of blood, soil, and herbage analyses carried out on this farm during the two-year Study provided no evidence to suggest that mineral deficiency had a significant effect on fertility performance.

Milk Production

Milk production was good on this farm in 1997 and 1998. Average yield per cow in 1997 was estimated to be 5,264 kg on 250 kg concentrates per head and an average lactation length of 277 days. The comparable figures for 1998 were 5,182 kg for 118 cows on 550 kg concentrates per head and an average lactation length of 287 days. It should be noted that the relatively moderate concentrate usage on this farm reflected the good quality of silage.

Blood Analysis Results

Blood samples were collected from young stock and cows on seven occasions throughout the two-year period. Haematology values were generally within normal ranges. Marginally raised white cell counts on occasions were consistent with systemic inflammatory responses. Biochemistry parameters were also generally within normal ranges throughout. No changes of clinical significance were noted.

Conclusion

Animal health and production were generally good on this farm. Peri-parturient problems in cows and calves were associated with excess condition. Calf diarrhoea problems were associated with infectious agents and there was no evidence of the involvement of unusual external factors. While fertility performance overall was satisfactory, conception rates were below target.

Overall Conclusion of Longitudinal Study

The findings of this study must be interpreted in the light of obvious limitations regarding the intensity of monitoring which could be implemented consistent with the private and commercial nature of the farming operations concerned. While herdowner compliance with the requirements of the study was generally good, the level of record-keeping varied considerably between herds - and even between years within herds. Fertility records, for example, were generally inadequate for a detailed assessment of performance and information on concentrate feeding was largely based on a herdowner's visual assessment of daily rates. Although silage analysis results were available for all four farms for the 1996 crop, they were not available for 1997.

Allowing for these constraints, the results of the Longitudinal Study showed no evidence that animal health or production on any of the four farms were subject to unusual adverse influences during the periods of observation. The incidences of diseases on each of the four farms were generally within acceptable limits and no serious outbreaks were encountered. The conditions reported largely comprised those commonly-observed on commercial farms elsewhere. While the causes of a number of outbreaks of respiratory disease in cows and calves on one farm (Farm LS1) were not identified, the cases were generally mild in nature and clinical and laboratory examinations did not reveal any unusual features.

RETROSPECTIVE STUDY ON TWO INDEX FARMS

The following paragraphs comprise a summary account and analysis of the historical animal health problems on the two Index Farms, i.e. prior to 1996. Information on animal health and production was collected as part of a Retrospective Study of 27 'problem' farms in the Askeaton area. The locations of the two Index Farms, as well as the other 25 'problem' farms (*see* following Section), are shown in Fig. 2.5.

Index Farm A (Farm RS1)

This was a dairy farm of approximately 24 statute hectares. Cow numbers on the farm between 1990 and 1995 ranged from a minimum of 28 in 1993 to a maximum of 36 in 1995 (EPA, 1995). The main source of information on the animal disease history for this farm comprised a diary of events kept by the herdowner, as well as the results of the interview carried out for the Retrospective Study (*see* Animal Health Volume).

Although the herdowner made available extensive animal health records for this farm, it is important to note that they were by no means comprehensive. As a result, accurate incidence rates could not be determined for most diseases reported.

Early Farm Investigations

Several farm investigations were carried out in 1993 which identified nutritional factors as contributing to animal health problems. The first of these, by the veterinary department of Limerick County Council in January 1993, concluded that there was evidence of iodine and selenium deficiency. The second, commissioned by Aughinish Alumina and carried out by a private laboratory in June 1993, concluded that the problems were due to 'impaired immune function' associated with inadequate availability of copper, iodine and selenium. The third investigation, also on behalf of Limerick County Council, commenced in August 1993 and concluded that many of the reported animal health and production problems were consistent with iodine deficiency. A fourth study, also on commission from Aughinish Alumina, was carried out by a second private laboratory in September 1993. The report of this investigation referred to evidence of inadequate copper and iodine and high selenium.

The findings of these reports in relation to mineral deficiency are discussed at some length in the Animal Health Volume. It is the conclusion of that analysis that, while marginal iodine, copper, and possibly also selenium status may, at times, have had a limiting effect on animal performance, it is highly unlikely that they could have been responsible for the severe disease problems reported on this farm between 1991 and 1995. This conclusion is based on interpretation of the reported blood and environmental concentrations of these metals as well as the absence of clear-cut signs of clinical deficiencies. As the First Interim Report stated "*... although herbage selenium, copper, iodine (and zinc) were lower than those considered adequate for animal nutrition, they were not abnormal in an Irish context*" (EPA, 1995).

EPA-Coordinated Investigations in 1995

Although reported animal losses were at their height on this farm in 1992 and 1993, conditions on the farm were not good when the EPA-coordinated investigation got underway in early 1995. The Teagasc report of the farm inspection of 22 March, 1995 (EPA, 1995) stated that it had been severely grazed in the previous months and there was heavy poaching of the pastures - particularly along boundaries and hedgerows. The latter were also said to have shown signs of grazing. The farm was also overstocked - largely owing to the inability of the herdowner to sell dry stock which were in poor condition. The report of a joint VLS/Teagasc visit to the farm on 23 March, 1995 refers to the generally poor condition of about 30 weanlings present on the farm at that time. Cows were reported to range from poor to good body condition. Other than patchy alopecia (hair loss) on some cows, which was probably due to lying in passageways, skin lesions were not a problem at the time.

Animal Health and Production Problems

The main problems reported by the herdowner were infertility, pining and mortality in cows and growing stock, increased perinatal calf mortality, diarrhoea in calves, skin lesions in cows and growing cattle, and irritability in cows at milking. While the exact time at which animal health performance deteriorated to a point where it was a matter of concern is not known, available records indicate that mortality on the farm was above average since 1988. The veterinary practitioners to this farm considered that there was an excess of animal health problems. They suggested that there was generally a poor response to treatment due to unknown underlying factors.

Infertility

Infertility was reported to have been a problem on Index Farm A since 1990. Both artificial insemination and a bull were used to serve cows in most years. The main problem appears to have been related to heat detection. Non-detected oestrus (i.e. missed heats) and submission rates were outside target in all years. According to the herdowner, repeat-breeding was also a problem – with cows repeating at irregular intervals.

Problems with heat detection are the commonest cause of reduced fertility performance on commercial farms. As discussed elsewhere, it is generally considered that the efficiency or otherwise of heat detection is largely a function of management. While this is not to say that external factors may not also play a role, there is no

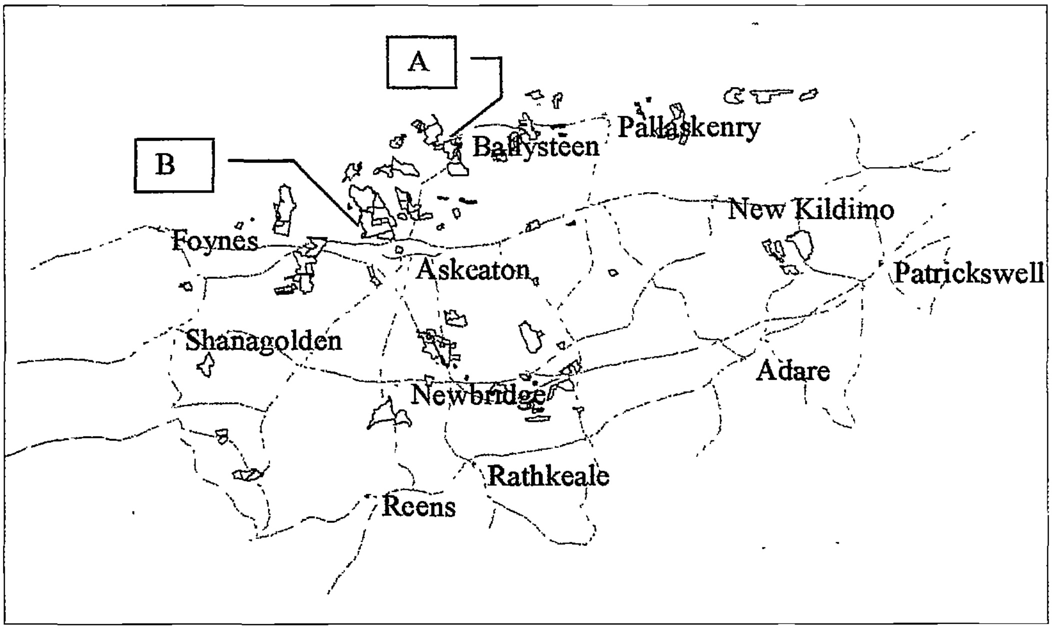

Fig. 2.5 Location of two Index Farms (A and B on map) and other farms reporting animal health problems in the Askeaton area.

specific evidence from the available records to suggest that such was the case on this farm. Conception performance (i.e. as measured by number of repeat breeders) is also dependent on a range of cow, bull, and management factors. While it is not possible at this remove to identify those responsible for reduced performance in the present case, the veterinary practitioner's comment that repeat-breeding "... *primarily affected cows following metritis with individual cows in poor body condition also affected*" is consistent with experience elsewhere (Ferguson, 1991). Although a bull was used in some years, the possible contribution of bull infertility to the problems cannot be determined as there is no record of fertility examinations having being carried out on bulls.

Calf Mortality

Calf mortality, both calving-associated and due to diarrhoea in the first few weeks of life, is reported to have been a problem in the six- to eight-year period up to and including 1995. However, little information is available regarding the circumstances or calving history of losses prior to 1994. While 45 calves are reported to have been lost between 1988 and 1995, insufficient information was available to determine what proportion of these were attributable to the immediate perinatal period and what to diarrhoea in the following weeks. In addition, little material was submitted for pathology examination. Although at least 38 calves were reported to have been lost in the period 1988 to 1993 inclusive, only two were submitted to the local Regional Veterinary Laboratory. Of the six calves which were reported to have died in 1994 - all of which were submitted for laboratory post-mortem examination - diagnoses consistent with a history of diarrhoea were made in four cases.

Although calf losses would appear to have been high on the farm in some years, there is no specific evidence from the available history to suggest that risk factors other than those normally cited, i.e. calving difficulty and unattended calvings in relation to perinatal losses, and infectious agents, feeding, and hygiene in relation to diarrhoea, were involved.

Pining and Mortality in Cows and Growing Stock

Although pining and mortality in cows and growing cattle is reported to have been a problem since 1991, there is evidence of significant adult losses from 1988. Three cow deaths are recorded for each of the years 1988, 1989, 1990 and 1991. In 1992, seven to nine of 33 cows and heifers were said to have been affected by pining and five died. None of these losses were submitted for laboratory examination. However, clinical diagnoses of mastitis, downer-cow and leg injuries were recorded. Of the nine adult animals which died in 1993, only three cows were submitted for laboratory post-mortem. Two of these had lesions of suppurative mastitis with secondary abscessation and a diagnosis of hypomagnesaemic tetany was made on the third. The cow that died in 1994 had lesions of multiple internal abscessation secondary to severe septic foot and skin infection. Of the

three terminally ill cows submitted for laboratory examination in 1995, one had lesions of parasite infestation and the other two were in very poor body condition and exhibited excessive tooth wear.

The clinical histories of these losses were varied and provided relatively little information of specific diagnostic value. According to the herdowner, pining occurred around calving with affected animals going down pre- or post-calving. The veterinary practitioner reported that cases were associated with bad winters, heavy rainfall, and yarded animals. Internal abscessation was suspected on clinical grounds as a cause in many cases and the response to treatment was poor.

Although growing animals were also said to have been affected, little information is available regarding signs or incidence. The only clinical description is that they " *were in poor body condition ... had poor coats, (and) ... no signs of respiratory disease or diarrhoea*". Other than a weanling with lesions of BVD virus infection in 1993, no animals in this age-group were submitted for laboratory post-mortem examination.

Owing to the anecdotal nature of the accounts, and the very limited nature of contemporary veterinary investigations, it is not possible at this remove to suggest diagnoses for the majority of these cases. While the histories indicate a relatively high adult bovine mortality rate on this farm over at least an eight-year period, there is no specific evidence from the available descriptions to suggest that all, or a majority, may have been due to a single underlying factor.

Skin Lesions in Cows and Growing Cattle

According to the herdowner, this problem began in 1990 and continued until 1994. Growing and adult stock were affected and it was at its worst in 1992 and 1993.

The descriptions are consistent with subcutaneous abscesses. They were reported to be of varying sizes and occurred on all areas of the body. Response to treatment was poor. Two affected cows were submitted for laboratory post-mortem examination in April 1993. Diagnoses of suppurative mastitis with secondary abscessation were made. Only *Streptococcus faecalis* (an opportunist invader or secondary contaminant) was isolated from swabs collected from affected animals during a field visit by VLS staff around the same time. The report of this visit concluded that the incidence of pyoderma was exceptional. Multiple internal abscessation secondary to severe septic foot and skin infection was recorded on a cow submitted for laboratory post-mortem examination in 1994. A diagnosis of shoulder abscess was made in relation to a cow submitted to UCD Veterinary Faculty Large Animal Clinic in July 1993.

Owing to the limited availability of contemporary clinical and pathology data, the underlying causes of the majority of cases must remain a matter of speculation. Although suppurative lesions generally involve an infectious agent, it is unlikely that infection was the primary cause of this outbreak. According to a standard veterinary pathology text (Jubb *et al.*, 1991), virtually all bacterial pyodermas (abscesses) are secondary to exogenous or endogenous triggering factors. The former include penetrative wounds to the skin such as injection site reactions and trauma against sharp objects (e.g. cubicle rails, door-posts or fencing), while the latter comprise suppurative conditions in other organs of the body (e.g. mastitis). Suppurative mastitis was undoubtedly responsible for a proportion of the cases – though how many, cannot be determined at this remove. However, these were probably only a minority as the predominant lesions were described as being superficial. While penetrative wounds may have initiated many of the lesions – i.e. as part of the normal trauma of everyday animal activity - their number and severity suggests the presence of factors which interfered with the normal healing response. This is discussed further below.

The cases of skin disease reported in 1994 appear to have been somewhat different to those in the previous years. The descriptions of a superficial lesion are consistent with those of *Dermatophilus congolensis* infection, which is most frequently associated with periods of wet weather (Scott, 1988). *Dermatophilus congolensis* was isolated from an animal submitted for post-mortem examination in 1994. The winter of 1993-94 and spring of 1994 were particularly wet. Rainfall was above normal in each of the five months from December 1993 to April 1994. Similar skin lesions were reported on cows on Index Farm B in the spring of 1994.

Irritability in Cows at Milking

A problem of irritability in cows at milking is said to have begun in 1992 and to have continued up to 1995. It was not observed during the Monitor Study in 1996 and 1997. While there are a variety of possible explanations for this behaviour (e.g. stray voltage, animal temperament, herding management) it is obviously not possible at this stage to make a diagnosis. As the problem was only said to affect a proportion of cows at any one time it is unlikely to have been environmental (i.e. atmospheric) in origin.

Mastitis

Although mastitis is not specifically referred to as a herd problem in the Retrospective Study, there is ample historical evidence that it was a significant factor in relation to the serious animal health problems between 1992 and 1994. The veterinary practitioners also considered mastitis to have been a problem on the farm and their call log indicates that approximately one third of all calls to the farm in 1994 and 1995 were to mastitis cases. Bulk milk cell counts (SCC) were also above 400,000 for each of the years 1992 – 1994 (range 402,000 – 701,000) which is consistent with a significant problem at herd level. Suppurative mastitis was also diagnosed in two cows submitted for laboratory post-mortem examination in 1993.

Reduced Milk Yield

Annual milk sales showed an overall decline from around 113,650 kg (25,000 gallons) in 1987 to 63,644 kg (14,000 gallons) in 1994. They reached their nadir in 1992 at around 60,000 kg with an estimated yield per cow of around 2,159 kg (475 gallons) for the year. While highly unsatisfactory, this performance is hardly surprising given the animal losses and health problems encountered during the same period. Specific factors which will have had a significant negative effect on milk yield include illnesses and mortality, replacement of cow losses with heifers, infertility leading to an extended calving season, and mastitis.

<u>Conclusion</u>

The foregoing descriptions provide clear evidence of a serious problem of superficial and systemic suppurative conditions in adult cattle on this farm. It is also clear that there was considerable overlap between this and the pining and deaths referred to earlier. The overall picture, therefore, is of adult animals under severe health stress over a relatively prolonged period of time. The question arises as to what may have been the underlying factors contributing to such a severe breakdown in animal health.

Given the diversity of reported syndromes, it is most unlikely that there was a single cause. However, the apparent involvement of infectious processes in many of the cases, i.e. suppurative mastitis, superficial and internal abscessation, suggests there may have been a reduction in the overall level of herd resistance to infectious disease over a period of time. The identity of such factors can only be a matter of speculation at this stage owing to the almost complete absence of laboratory or other specialist involvement throughout much of the period during which above-normal losses occurred.

The main factors which can serve to reduce an animal's resistance to infection comprise intercurrent disease (of any cause), inadequate nutrition, housing, hygiene, as well as exposure to prolonged periods of poor weather. However, insufficient information is available to determine which, if any of these, may have played a role in relation to the problems on this farm. Regarding specific infectious causes of immune suppression, tests carried out on samples collected from animals on the farm in 1995 showed no evidence of infection with Bovine Immunodeficiency Virus. Bovine virus diarrhoea (BVD) infection, which can also induce immune suppression, was diagnosed in weanlings in 1993 and 1994 and may have played a role in relation to some cases of disease in growing animals. Although inadequate nutrition was undoubtedly the main reason for the poor condition of animals on the farm at the start of the EPA investigation in 1995 (overstocking, severe poaching of land, grazing hedgerows, poor quality silage (EPA, 1995) the problem of mortality of adult stock was well past its peak at this stage. On the other hand, there is insufficient information to determine the nutritional state of stock on the farm in earlier years. While two of three silage samples analysed in 1993 were of poor quality (DMD 63.2% in April and 59.8% in October 1993), no information is available regarding concentrate supplementation which may have been provided to make up the deficit.

Although it cannot have been the primary cause, poor weather undoubtedly contributed to the severity of some of the problems described. As discussed elsewhere, weather conditions over the winter-spring periods of 1993-94 and 1994-95 were cold, wet, and windy. According to the veterinary practitioner, pining and deaths in cows were associated with "*... bad winters, heavy rainfall and yarded animals*". Poor weather also undoubtedly contributed to animal health problems on Index Farm B in 1994 (*see below*).

The suggestion that environmental pollution was responsible for the problems on this farm was the primary driving force behind the entire investigation of animal health in the Askeaton area. However, almost the sole apparent link with pollution throughout has been one of location, i.e. proximity to sources of potentially noxious emissions. On the other hand, no evidence was found either of the presence of potentially toxic concentrations of pollutants in the area, or of animal disease problems which could readily be identified with a specific toxic cause. While a variety of potential environmental pollutants could induce immune suppression, it would be difficult to propose a biological basis, in a farm context, for such an effect by either aluminium or sulphur dioxide – the two substances most frequently cited as potential causes of environmental pollution in the

Askeaton area. In addition, to attribute the incidence of severe suppurative conditions in adult animals on this farm to environmental pollution begs the question as to why the problems were not recorded elsewhere in the area between 1988 and 1993. Although a high incidence of adult losses also occurred on Index Farm B (*see below*), these were in 1994 and 1995 - which was after the period when a high incidence of unexplained losses occurred on Farm A. None of the other 25 farms investigated in the Retrospective Study reported problems of comparable type, severity and duration throughout this period (*see below*).

Index Farm B (Farm RS2)

This was a dairy farm of approximately 34 hectares. Cow numbers on the farm between 1990 and 1994 ranged from a minimum of 69 in 1990 to a maximum of 74 in 1991. Breeding replacements were generally bought-in annually. By 1995, there were only 52 cows on the farm due to non-replacement of animal losses (*see below*). Animal health and production records for this farm were far less extensive than those for Index Farm A. Although reference is made to disease problems extending back to the late 1980s, little information is available on animal disease and mortality prior to 1994. Even for 1994, the first year in which substantial losses were reported to have occurred, clinical details of disease incidents are scanty.

<u>EPA-coordinated investigations in 1995</u>

The VLS first became aware of the serious animal health problems on this farm in March 1995. Prior to that, the only submissions for laboratory examination had been an aborted foetus in November 1994 and a cow in February 1995. VLS and Teagasc investigations on the farm commenced in March 1995. The most significant findings were the generally poor condition and health of cows and other stock, as well as the very poor condition of pastures and evidence of overgrazing where stock had been outwintered. Further details of farm and animal health investigations in 1995 have been reported in the First Interim Report (EPA, 1995).

<u>Animal Health and Production Problems</u>

The main problems reported by the herdowner were illthrift, illness and mortality in cows and growing cattle; abortion, calving difficulty and infertility in cows; illness and deaths in calves. The veterinary practitioners also considered that there was an excess of animal health problems in the herd.

Abortion and Twinning

Abortions were reported to have occurred at the rate of one or two per year with a peak incidence of four in 1994. While these losses were unsatisfactory, neither their incidence nor occurrence was exceptional. The annual incidence of between 2 and 4 *per cent* is close to average rates reported elsewhere. *Listeria monocytogenes*, a common infectious cause of abortion, was isolated on a number of occasions. *Salmonella* infection was also present on the farm (*see below*) and it may have been responsible for some of the abortions.

Although there was said to have been a high incidence of twinning in the 1990s (approximately 5.4 - 11.5 *per cent* per annum), records are not available to confirm this. The possibility of a genetic component would have to be considered as they were all said to have been sired by the same bull.

Calf Diarrhoea and Pneumonia

Calf diarrhoea and pneumonia were reported to have been annual problems with losses at about six to seven calves per year. While unsatisfactory, at around 10 *per cent* per year, this is not exceptional. Pneumo-enteric conditions are the commonest infectious causes of calf losses world-wide. While it is not possible to make diagnoses at this remove as no carcasses or other clinical pathology material were submitted for laboratory examination between 1990 and 1995, reference is made in the Retrospective Study to suspected involvement of common infectious causes such as *Escherichia coli*, *Salmonella* and IBR virus.

Illthrift, Illness and Mortality in Cows and Growing Cattle

By far the most serious problem reported on this farm was illness and deaths of cows. During the early 1990's, one to three cows were reported to have died each year (1-4 *per cent*) - in most cases reportedly following milk fever or gangrenous mastitis. According to the herdowner, the first unexplained death occurred in 1993 when a cow was found dead in a field in December of that year. The herdowner's veterinary practitioner reported that while no obvious problems were noted in the cows at a herd TB test in October 1993, a dramatic deterioration in body condition score was noted at a visit in March 1994. The weather at the time was said to have been particularly severe. Despite the fact that 14 cows were reported to have died in 1994 - nine between January and

May – there are no reports of post-mortem examinations having been carried out and no cows were submitted for laboratory post-mortem examination.

Animal health problems were at their worst in the spring of 1995. The veterinary practitioners refer to cows with rapid, shallow breathing, nasal discharge, normal rectal temperature, lethargy and poor milk yield. Some cows also had alopecia and reddened skin and had a 'tender gait'. Such cows deteriorated and died within a month of showing such signs. The generally poor condition of stock recorded at inspections of the farm by VLS staff in March and May 1995 has also been described in the First Interim Report (EPA, 1995). Lactating cows were in poor body condition and weanlings and other stock were thin and undersized. Carcasses submitted for laboratory post-mortem examination in March 1995 showed severe body fat depletion.

While undoubtedly severe, it is almost impossible to determine the causes of losses in 1994 owing to the total absence of pathology submissions. With regard to the adult animal losses in 1995, specific diagnoses were made in most cases where carcasses were submitted for laboratory post-mortem examination. Seventeen cows, a bull and a weanling were said to have died or were euthanased *in-extremis* in 1995. Ten cows, the bull, and the weanling were submitted to Limerick RVL over a four-week period in February-March 1995. In the case of all except two, findings were consistent with diagnoses of severe acute or chronic inflammatory conditions of infectious origin. Six cows had lesions of pneumonia. Lesions of listeriosis and chronic fluke infestation were found in the bull. Recognised bacterial pathogens isolated from submissions included *Salmonella typhimurium* (isolated from three cows) *Listeria monocytogenes, Pasteurella,* and *Actinobacillus pyogenes*. All cases showed severe body fat depletion.

While the diseases diagnosed in the animals submitted for post-mortem examination in March 1995 were not unusual, their occurrence at such a high incidence in adult animals was most unusual. The most important question, therefore, relates to the underlying reasons for the poor condition and the high incidence of infections and losses of cows in the springs of 1994 and 1995. Predisposing factors for salmonellosis and pasteurellosis include the stresses of moving and mixing animals, poor housing conditions and hygiene, nutritional stress (i.e. food deprivation) and inclement weather (Blood and Radostits, 1990). There is evidence that all of these existed on this farm at the time of the most severe losses.

While it is not possible at this stage to draw up a comprehensive list, it is important to consider any identifiable factors which may have been involved. Poor weather was undoubtedly a contributory factor. The bulk of losses occurred during or following prolonged periods of bad weather in the winters and springs of 1994 and 1995. By March 1994, when the veterinary practitioners first noted a severe deterioration in cow body condition, the majority had been outwintered, in varying stages of pregnancy, over a period of particularly inclement weather. The months of December 1993 to April 1994, inclusive, were wet and windy. Similar weather, though colder, was prevalent in the winter-spring of 1994-95. The paddocks on which cows were outwintered in 1994-95 (and possibly 1993-94) were exposed to the prevailing westerly winds and had little shelter.

Under such conditions, it is inevitable that animals would have suffered a significant degree of stress. It is also of interest to note that some descriptions of the skin conditions which occurred around the same time were consistent with dermatophilosis which is associated with wet weather (Scott, 1988). Skin lesions and partial hair loss (alopecia) are also a non-specific accompaniment of debilitation (Blood and Radostits, 1990) which was widespread on this farm in the spring of 1995 and possibly also 1994.

While little information is available on the nutritive status of the herd in the winter-spring of 1993-94 - other than the veterinary practitioner's reference to animals being in poor body condition - inadequate nutrition combined with relative overstocking was undoubtedly a factor in the winter-spring of 1994-95. All of the cows and approximately 20 dry stock aged 10 months to two years were outwintered on poor quality silage, with no concentrate supplementation, during the winter of 1994-95 (EPA, 1995). As the nutrient requirements of animals are known to be increased under circumstances of inclement weather, the poor weather at this time would have involved added nutritional stress (Anon., 1989; Fox and Tylutki, 1998).

The Teagasc report on the farm inspection in March 1995 (EPA, 1995) also noted that in addition to severe poaching of the fields on which the cows had been outwintered, the pastures were bare and the hedgerows showed signs of grazing. Even by May 1995 there was little sign of grass growth. The fact that no preparations were made throughout 1995 for winter fodder production must raise further questions regarding feeding management on the farm.

Taking these two factors together, i.e. out-wintering in poor weather conditions and inadequate nutrition for dry cows, it would be inevitable that a substantial proportion would have calved down in very poor condition. It is highly significant, therefore, that virtually all of the cows submitted for post-mortem examination in the spring of 1995 had died close to or shortly after calving. The reports of large numbers of cows exhibiting difficulty

rising in the cubicle house in the winter-spring periods of 1993/94 and 1994/95 also suggest extreme weakness. While inadequate hoof care and trauma related to deficiencies in housing design were probably contributory factors, it is likely that in many cases the weakness was an expression of malaise in cows which were in general ill-health and condition.

Inadequate hygiene was undoubtedly a contributory factor in relation to the occurrence of *Salmonella* infection in cows. Despite a dry summer, the open slurry pit was reported by VLS staff to have overflowed in the autumn of 1995. If this had occurred during the wet winters of 1993-94 and 1994-95 – and it is difficult to see how it would not - then it would have greatly increased the risks of outbreaks of salmonellosis.

Fluke infestation may have played a contributory role in relation to some of the losses in 1994 and 1995 as these were periods of high fluke infestation nationally. Lesions of chronic fluke were detected in a number of the adult animals examined post-mortem in spring 1995 and no regular fluke control programme was reported to have been used on the farm.

In conclusion, therefore, the overall picture of this farm in 1995, and possibly also in 1994, is one of cows under severe environmental and nutritional stresses, the majority out-wintering in poor weather, calving down in poor condition, and succumbing to acute infectious conditions or prolonged post-calving recumbency. The calving difficulties reported for 1995 were clearly secondary to the intercurrent health and body condition problems. According to the veterinary practitioner, calving had to be induced in several downer cows in 1995.

Lameness

While lameness was reported to have been a problem, there is insufficient information to assess its incidence. Neither is there any specific evidence to suggest that unusual factors were involved. On the contrary, references to overgrown hooves and trauma in the cubicle-house, together with evidence of poor drainage from the holding yard (*see above*), indicate the presence of risk factors commonly associated with this problem.

Infertility

Although infertility is reported to have been a problem since 1990, very little can be said regarding performance as no breeding records were kept. The main problem was reported to have been one of heat detection – i.e. cows with short or no visible oestrus. However, despite the fact that all services had been by natural mating since 1989, there is no reference to fertility examination of bulls having been carried out. On the other hand, it is reported that one of the two bulls, the Simmental, had been lame in both legs since late 1993. This would undoubtedly have had a significant negative effect on his fertility performance. Following his withdrawal from service in 1994 only a nine-year-old Hereford bull was available. As the latter died in early 1995, it is not surprising that fertility performance in 1994 and 1995 was poor. The reported or confirmed poor condition of many cows in 1994 and 1995 would also have contributed to reduced fertility performance in these years.

Mastitis And Milk Yield

Although mastitis was said to have been an annual problem in the herd, little detailed information is available. However, there is no evidence to suggest that occurrence was exceptional. Recognised bacterial pathogens were isolated from four of five milk samples submitted for laboratory analysis in 1991. According to the veterinary practitioners, housing conditions (poor hygiene) may have contributed to the problem. The high age structure of the herd (*see page 11*), combined with the fact that involuntary losses in 1994 would have prevented selective culling, probably also resulted in a higher proportion of chronically affected animals in the herd in 1995. Investigations during the first year of the Monitor Study on the farm confirmed widespread sub-clinical infection of cows' udders (*see above*).

Milk yield is said to have decreased in the late 1980s and through the 1990s. However, there is no information on yield per cow prior to 1990. Although reported yields were at an only moderate 3,182 kg per cow from 1990 to 1993, inclusive, there is no evidence of a significant decline over the period. Factors which may have contributed to the relatively poor yields throughout this period include mastitis, infertility, grass management, and herd age structure. Yield per cow declined dramatically to 1,041 kg in 1995. However, this is hardly surprising given the severe disease problems and high mortality in these years (*see above*).

<u>Conclusion</u>

In conclusion, therefore, while there was undoubtedly a severe animal health problem on this farm in 1995 and probably also in 1994, it is likely that the diseases were multifactorial in origin. As with many outbreaks of severe disease - particularly those characterised by the presence of multiple syndromes - it is not possible to

definitively identify all of the underlying influences that may have acted to tip the balance from health to disease for so many animals on this farm. The combined effects of out-wintering pregnant cows during periods of particularly inclement weather in 1994 and 1995, together with inadequate pre-calving nutrition, will undoubtedly have increased the number of animals with a heightened susceptibility to disease around calving time.

Other than the proximity of a local source of industrial emissions, there is no evidence to suggest that the problems were due to environmental pollution. None of the main disease syndromes reported had features which would suggest a specific toxic aetiology. To the extent that there was evidence of a common underlying mechanism - i.e. increased susceptibility to infectious disease - the history, clinical, and post-mortem findings suggest that this was most likely secondary to chronic debilitation and environmental stress.

Overall Conclusion on Two Index Farms

The animal health and production problems on these two farms were undoubtedly severe - both in incidence and expression - at times over the eight-year period from about 1988 to 1995. However, there is little or no evidence to suggest either that they had a common cause or that they were due to environmental pollution. The most severe problems on each farm occurred at different time periods and there was little correspondence in terms of the clinical syndromes described. Although suppurative conditions in adult animals were a feature of reported cases on both farms (chronic in the case of Farm A, acute or sub-acute on Farm B), they were quite different in expression and there was little, if any, temporal overlap in relation to occurrence. While cow losses peaked on Index Farm A in 1992 and 1993, above-normal losses were not reported to have commenced until the spring of 1994 on Index Farm B.

Although both farms also reported pining and death of affected animals, these are not uncommon non-specific consequences of many chronic conditions. The only specific clinical syndrome which is likely to have occurred on both farms at around the same time was that of dermatophilosis (skin infection) in the spring of 1994 – and this most likely did have a common underlying cause, i.e. wet weather.

The absence of a clear relationship between disease occurrence on the two Index Farms and the 25 farms investigated as part of the Retrospective Study is discussed elsewhere (*see* following Section).

If environmental pollution were to have been responsible for the severe animal health problems on these two farms then the question must also be asked as to what pollutants were likely to have been involved. While a list of pollutants for which there are potential sources in the area has already been published (EPA, 1995), most attention in the Askeaton area was focused on the elements aluminium, fluorine and sulphur - the first two because of the proximity of an alumina production plant (mistakenly in relation to the second as aluminium oxide does not involve significant fluoride emissions) and sulphur because the plant – as well as a number of other, more distant, industries - generates sulphur dioxide emissions from the combustion of hydrocarbon fuels.

However, besides the fact that environmental and tissue analyses and monitoring showed no evidence that the farms were subject to excess deposition by any of these three substances - and in relation to fluorine the only identified source was natural geochemical deposits (EPA, 1995) - there is little or no clinical evidence that the disease outbreaks which were reported could be reasonably attributed to these compounds. Both aluminium and fluorine produce specific clinical syndromes. The former, while rare and difficult to reproduce in farm animals, is mediated *via* an induced phosphorus deficiency (and possibly magnesium) and the signs include joint stiffness and pica (Crowe *et al.*, 1990). Fluorine toxicity, or fluorosis, is a well-recognised syndrome which gives rise to bone and teeth abnormalities (Crook and Maylin, 1978).

The potential effects of excess sulphur deposition, while less easy to predict, are also mediated *via* interference with availability of other essential elements - in this case copper and possibly selenium (Suttle, 1974; Suttle, 1975; Poole and Rogers, 1989). Again, while *some* of the clinical signs reported on the two farms could have been due to inadequate copper or selenium supply, and as discussed above, natural shortages of these elements may have played a secondary role in relation to some of the problems, it is extremely unlikely that the main problems on the two farms, i.e. acute and chronic suppurative conditions in cows, pining and high mortality, could have been due to sulphur-induced deficiencies of copper or selenium. In the first case, neither the monitored nor likely sulphur emissions in the area would have been high enough to have had any significant effect in relation to uptake of these minerals (see external assessment by N. F. Suttle in Animal Health Volume). In the second case, neither contemporary nor subsequent animal, plant, and soil analyses showed evidence that the farms were likely to have suffered severe deficiency of either element. Even had there been marginal reduction of copper and selenium availability, the reported concentrate and mineral supplementation rates used on the two farms at various times would have been sufficient to prevent severe deficiency. In relation to the

potential effects of selenium deficiency it is worth noting that no signs of ill-health were noted in the selenium-deficient yearlings used in Part 3 of the Immunology Studies on Index Farm B in 1998 (*see below*).

In conclusion, while it is clear that the two farms suffered an excess of animal disease, straightforward explanations involving the commonly-accepted infectious, nutritional, management, and climatic risk factors could have applied in the majority of cases. The fact that definitive diagnoses could not be made in many cases related more to the very limited use of laboratory facilities by the herdowners concerned than to the unusual nature of the conditions. Although the severity of some of the conditions suggest that exceptional circumstances obtained at times on each of the farms, there was no specific clinical or environmental evidence to suggest that atmospheric pollution was involved.

RETROSPECTIVE STUDY ON 25 FARMS

Introduction and Background

A retrospective investigation of animal disease and production problems was carried out on 25 other farms in the Askeaton area commencing in December 1995. The overall purpose of the Retrospective Study was to determine if there was any evidence to substantiate claims that there had been an abnormal or unusual incidence of animal health problems in the wider Askeaton area and, if so, to attempt to identify the underlying causes.

The objectives of the Retrospective Study comprised:

- Identification by self-disclosure of all farms reported to have an excess of animal disease and to define their geographical distribution.
- Describe the clinical and other manifestations of the main disease problems reported on each farm.
- Determine whether or not the farms had one or more disease syndromes in common.
- Describe the temporal distributions of the disease syndromes, i.e. times of onset and duration.
- Compare incidences of particular animal diseases on affected farms with an appropriate reference population.
- Identify possible risk factors.

An interim report on the Retrospective Study has already been published (EPA, 1997). This report gave details of methodology relating to farm identification and data collection. It also gave summary descriptive statistics on farm size, production, and reported animal health problems. The present report comprises a condensed analysis of the reported problems together with an assessment of their incidence, severity and possible causation. Further details of factors which may have contributed to the incidence of animal disease and production problems on these farms are contained in Chapter Five of the Animal Health Volume.

The following descriptions of disease problems are based on the herdowners' accounts contained in the individual Retrospective Study Farm Reports (DAFRD, unpublished). For the purpose of the present analysis, a summary assessment is made in the case of each farm of the severity or otherwise of the problems reported and, where possible, an opinion is given regarding risk factors which are considered most likely to have been involved. The latter are based on the histories supplied and comprise those risk factors which are either most commonly associated with the conditions identified or, based on the available information, may have been involved in the specific cases under consideration. The list is not intended to be comprehensive or to exclude the possibility that other unidentified factors were also involved. In the case of each farm, an assessment is also made as to whether the problems occurred at an unusually high incidence (i.e. by reference to what could be expected on farms elsewhere), or were of an unusual nature.

Identification of Affected Farms and Definition of Study Area

Full details of the methodology used to identify farms for the Retrospective Study are given in the Animal Health Volume. Owing to resource and time limitations, a self-selection procedure was used rather than a more appropriate randomised methodology. In consultation with the local Askeaton and Ballysteen Animal Health Committee, farms were included in the survey on the basis that their herdowners considered that they had an excessive incidence of animal disease problems. While this obviously represented a highly biased sample, it was hoped that, for the purposes of the investigation, and given the heightened level of concern in the area regarding

animal health, the bias was sufficiently marked to allow the selected farms to be taken as a reasonable approximation of the total number of farms in the area whose herdowners considered they had an excessive incidence of animal disease problems. Twenty-five herds were identified by this means. The inclusion of the two index farms brought the total number of farms in the Retrospective Study to 27.

The study area was defined as the area comprising the District Electoral Divisions* (DEDs) in which herds with a reported excess of animal disease were identified. A map of the study area, together with the approximate location of the 27 farms, is shown above in Fig. 2.5.

Data Collection and Analysis

Each of the 27 farms was visited by a veterinary officer of the VLS in late 1995 or early 1996. Information was collected on management and nutrition under a comprehensive range of headings. The information was compiled into individual Farm Reports, copies of which were sent to the herdowners concerned for comment and correction in 1996 (EPA, 1997). Other sources of information which were available for the following analysis were the results of stock inspections carried out by an officer of DAFRD in 1996 to investigate claims of illthrift and stunting of cattle, as well as the results of VLS and Teagasc visits and investigations of the farms in 1997.

A discussion of the inherent limitations of this type of study in relation to determination of disease incidence, duration, and severity is contained in the Animal Health Volume. Briefly, owing to the fact that most of the information was based on individual recall, only estimates of these parameters could be made in most cases. In particular, it was not always possible to determine times of onset and duration of particular problems and whether problems reported in one year recurred in following years. The scope of the data is also likely to have been heavily weighted by recall bias due to the heightened concerns of herdowners in the area regarding animal health.

As noted in the Introduction to this Chapter, there is currently no comprehensive source of reference data on the occurrence of disease on Irish farms which could be used as a norm against which to compare the findings from the 27 Askeaton farms. References to normal ranges in the following analysis, therefore, refer to a compilation of published reports of disease incidence from the scientific literature (Appendix A).

Results

Farm RS05

This was a medium-sized dairy/store farm (Farm LS1 in the Longitudinal Study). The main animal health problems recorded in the Retrospective Study on this farm were infertility in cows and ill-thrift in calves and weanlings. The reported incidences of other conditions, i.e. downer cows, abortions, and stillbirths were not unusually high.

Fertility problems appear to have largely comprised a high rate of non-detected oestrus. As discussed elsewhere, on-farm heat detection procedures are generally regarded as the most important factors influencing the overall rate of heat detection. While it is not possible at this stage to determine the specific causes of the poor performance on this farm, there was no information in the available history to suggest that factors other than those normally cited, i.e. breeding management, nutrition, and environment, were involved. Aspects of the breeding management noted during the period of the Longitudinal Study which may have contributed to reduced performance included absence of a fixed-period heat observation routine, absence of artificial heat detection aids (i.e. tail-painting of cows or chin-ball markers on bulls), and incomplete breeding records.

Illthrift in calves and weanlings was reported to have been a problem since 1989. However, little information was available regarding numbers affected or severity of effect. The primary problem was reported to have been poor body condition at grass in summer and poor price at sale. No deaths were reported over the period. A variety of infectious conditions were reported to have been diagnosed which were all common causes of ill-thrift in young stock.

Overall, while this farm appears to have experienced significant production problems in the period 1989 to 1996 - mainly in relation to infertility and calf thrive – there is no evidence that these problems exhibited any specific features, either in terms of severity or expression, which would suggest that unusual factors such as

* Administrative units.

environmental pollution were involved. Animal health performance during the period of the Longitudinal Study has been discussed above.

Farm RS06

This was a medium-sized dairy/store farm (Farm LS2 in the Longitudinal Study). The farm had reportedly experienced a high incidence of animal health and production problems since the early 1990s. The most significant problems between 1992 and 1996 were cow deaths, pining, mastitis, infertility, lameness, skin lesions, poor milk yield, perinatal calf mortality, and an outbreak of a locomotor disorder in calves.

The health problems in cows were at their worst in 1994 and 1995. The herdowner considered that they were related and may have been associated with environmental pollution - citing as evidence damage to grass and trees in Spring 1994. Four cows were reported to have died in 1994. Reported contemporaneous diagnoses were milk fever, dystocia, and toxic mastitis.

Pining in cows after calving was also at its worst in 1994. However, owing to the non-specific nature of the reported clinical syndrome, and the limited amount of contemporary laboratory investigation, it is not possible at this stage to determine the possible causes. While environmental pollution remains a possible explanation for these problems, its likelihood must be weighed against the possibility of other factors such as infection, nutrition, and the effects of poor weather on out-wintered pregnant cows over the winter-spring of 1993/94 (*see* discussion of Retrospective Study on Index Farm B above regarding poor weather in winters of 1993/94 and 1994/95).

Toxic mastitis was reported to have been a particular problem in 1994 and 1995. From the history, the majority of cases would appear to have been what are termed environmental mastitis. The commonest cause is the bacterium *E. coli* and outbreaks are most likely to occur after calving. There is no specific reason to associate its occurrence with environmental pollution.

An outbreak of locomotor disorder occurred in calves in the spring of 1995 for which no specific diagnosis was made at the time. Again, while the possible involvement of environmental pollution cannot be ruled out, there is no specific evidence to suggest its involvement. The possible involvement of aluminium and fluoride toxicity can effectively be ruled out on the basis both of contemporary analytical results and clinical history.

While the incidence of perinatal calf mortality was above normal in some years it was not exceptionally so. There is also sufficient historical evidence to suggest the presence of risk factors normally associated with this condition, i.e. calving management and a relatively high proportion of first-calvers.

Fertility performance was also reported to have been a problem. However, it was not possible to define the exact nature or extent of the problem due to inadequate records. Despite the fact that there was a high degree of bull usage there was no record of bulls having been assessed for fertility. In the circumstances, and based on descriptions of the problem, there is no reason to suggest that factors other than those commonly associated with infertility problems in dairy herds elsewhere were involved.

Milk production was reported to have been poor from about 1993. Although it is not possible retrospectively to determine the precise causes, it would undoubtedly have been interrelated with some of the other problems reported, e.g. infertility, metritis, poor condition post-calving, and mastitis.

Other problems reported in cows on this farm were skin lesions, lameness and irritability at milking in cows. The outbreak of skin lesions occurred in the spring of 1995 and the description is consistent with an infectious weather-related condition called 'rain scald' (dermatophilosis) (*see* discussion on Index Farm B above regarding similar problem). The reports of lameness in cows were neither unusual nor of a particularly high incidence. Stray voltage in the milking parlour is a possible explanation for reports of irritability of cows.

In conclusion, while this farm undoubtedly appears to have had a higher than normal incidence of animal health and production problems at times during the period 1992 to 1996, the great majority of the problems were not, in themselves, unusual and neither was there any specific evidence to suggest the presence of a single underlying cause such as environmental pollution.

Farm RS07

This was a small dairy farm (Farm LS3 in the Longitudinal Study). The main problems were perinatal calf mortality, infertility, and poor milk yield. A significant perinatal mortality problem was reported to have existed from 1992 to 1995. Although insufficient information was available to comment on the bulk of cases, there was

evidence to indicate involvement of risk factors such as dystocia, a relatively high proportion of first calvers in some years, and premature intervention in calvings.

In the absence of breeding records, it was not possible to determine the nature or extent of the reported fertility problem. Factors which may have contributed to poor performance include herd age structure and cow type, bull fertility, and inadequate record-keeping.

Factors which may have contributed to poor milk yield included cow type, age distribution, mastitis, and infertility.

Farm RS08

This was a medium-sized dairy/beef farm (Farm LS4: withdrew from Longitudinal Study). The main problems reported were lameness, downer cows, infertility, calf diarrhoea and pneumonia. The lameness, downer cow and infertility problems were severe and were undoubtedly related. A severe lameness problem was investigated by VLS staff in 1996. The main contributory factors identified were poor condition of housing and roadway surfaces, absence of a suitable foot-care programme, and inadequate or inappropriate treatment of affected cows.

Although no fertility records were available, lameness was undoubtedly a major contributory factor to reported poor performance.

Although a severe annual problem of calf diarrhoea and pneumonia was also reported to have existed on the farm there was little veterinary or laboratory involvement in its investigation. However, based on available history, there is no reason to suggest that causes other than the usual risk factors for calf diarrhoea, i.e. infectious agents, management and housing, need be cited to account for its occurrence.

Farm RS09

This was a large dairy farm (Farm LS5 in the Longitudinal Study). The main problems reported in the Retrospective Study were infertility, perinatal calf mortality, and ill-health in calves. Infertility appears to have been largely characterised by reduced conception performance. Examination of the possible contributory factors provided no evidence to suggest that unusual factors were responsible for the problem (*see* Animal Health Volume).

Although perinatal calf mortality was reported to have been a problem on this farm since the early 1980s, there was little laboratory involvement in its investigation. Based on information in the Retrospective Survey farm report, a high rate of dystocia (calving difficulty) is likely to have been a significant contributory factor.

Calf diarrhoea was also reported to have been a problem on this farm since 1991. Recognised infectious pathogens – viruses and protozoa – were identified on several occasions by laboratory examination of clinical specimens. Evidence of widespread protozoal infection (cryptosporidia) was also detected during the Longitudinal Study in 1997. In the circumstances, there is no indication to suggest that factors other than those normally cited, i.e. infectious agents, diet, and build-up of environmental infection, were responsible for the incidence of calf diarrhoea on this farm.

Farm RS12

This was a small dairy farm. The main problem reported was infertility – primarily of cows repeating to service at regular and irregular intervals. Based on history, there was no evidence to suggest that factors other than those commonly involved on farms elsewhere were involved. The small size of the herd was also a contributory factor – heat detection is known to be more difficult in small herds.

Farm RS13

This was a small mixed farm. The main disease problem reported - which occurred exclusively on the outfarm - was an outbreak of illness in dry stock (bullocks and heifers) characterised by diarrhoea, ocular and nasal discharge, salivation, recumbency and death. All of 27 cattle at risk were affected and 16 died. A similar condition was reported in adult sheep and goats. All were affected and mortality was reported to be 100 *per cent.*

Despite its severity and duration (December 1991 to April 1992), there was minimal involvement of the herdowner's PVP and no consultation with the local Regional Veterinary Laboratory. Although no specific diagnosis was made at the time, or can be suggested at this stage, this was largely due to the limited nature of the contemporary investigations.

Farm RS14

This was a small suckler farm. The main problems reported were respiratory disease and diarrhoea in cattle. Based on the descriptions provided in the Retrospective Study Report, the incidents would not appear to have been unusual - either in type or severity - and their occurrence was consistent with an infectious aetiology.

Farm RS15

This was a medium-sized dairy farm. The main problems comprised infertility and an outbreak of ocular discharge in cows. However, insufficient breeding records were available to analyse fertility performance in any detail. The description of the outbreak of conjunctivitis was consistent with 'pinkeye' which is an infectious condition.

Farm RS16

This was a medium-sized dairy farm. Reported problems comprised a series of probably interrelated periparturient conditions, i.e. slow calving, sub-clinical milk fever, stillborn calves, downer cows, and infertility. A laboratory investigation on delayed calvings in 1997 concluded that it was associated with uterine inertia due to sub-clinical milk fever. There was also evidence of dystocia in heifers due to relative foetal oversize and premature assistance at calving.

A serious outbreak of virus-type pneumonia was reported to have occurred in 1997. A subsequent farm investigation indicated that calf housing may have been a contributory factor. Insufficient information was available to determine the extent or nature of a reported infertility problem.

Farm RS17

This was a medium-sized beef-suckler farm. The main problems reported were difficult calvings, calf mortality, and downer cows, and were undoubtedly inter-related. From the history, relative foetal oversize was obviously a major factor in the incidence of dystocia. There was also evidence of premature assistance in calvings. Most of the calf losses were perinatal and are likely to have been secondary to calving problems. Other reported conditions, such as calf pneumonia and diarrhoea and ill-thrift in yearling cattle, were unusual neither in incidence nor in type.

Farm RS18

This was a small dairy farm. Infertility, associated with non-detected oestrus, was the only significant problem reported. According to the herdowner, it had been a problem since at least 1989. In addition to the usual factors affecting heat detection, the small size of the herd must be taken into account in assessing performance.

Farm RS19

This was a medium-sized dairy farm. Infertility, associated with non-detected oestrus, was the only significant problem reported. Possible contributory factors included reduced bull fertility, breeding management, and molybdenum-induced copper deficiency.

Farm RS20

This was a medium-sized suckler-to-store farm. The main problems reported were an outbreak of respiratory disease in outwintered weanlings in November 1995 and an approximately 30 *per cent* mortality in home-bred and purchased calves in the spring of 1996. Based on history, an infectious cause is most likely for the former. Losses in the latter were said to have been due to a combination of difficult calvings (weak-born calves), diarrhoea, and virus pneumonia. The fact that both home-bred and bought-in calves were involved in the latter could have contributed to its severity. Mixing calves of different origins is a recognised risk factor for outbreaks of infectious disease.

Farm RS21

This was a medium-sized suckler-to-store cattle farm with sheep. The main problems reported were retained foetal membranes, grass tetany (hypomagnesaemia), infertility in cows, sore eyes in cattle, subcutaneous lumps in cows, illthrift in adult cattle, deformed calves and illthrift in lambs.

A high incidence of retained placenta in one year may have been associated with dystocia. The incidence of grass tetany was not unusual. Although fertility records were not maintained, the history suggested a problem with bull fertility in at least one year. The clinical descriptions of eye problems were consistent with infectious

conjunctivitis. Insufficient information was available to assess reports of an outbreak of subcutaneous lesions in cows, an annual problem of ill-thrift in adult cattle, and ill-thrift in lambs.

Farm RS22

This was a medium-to-large mixed dairy farm. Infertility was the main problem reported. While it was not possible to make an assessment of fertility performance owing to the absence of detailed breeding records, the reported infertile rate of around 5 *per cent* per year is well within acceptable limits for a herd of this size. A reported outbreak of respiratory disease in cows associated with a drop in milk yield was consistent with a viral infection.

Farm RS23

This was a medium-sized suckler farm. The main problems reported were respiratory disease in calves and weanlings, and an outbreak of locomotor disease in calves. While severe, the history and clinical descriptions of the respiratory problem are consistent with outbreaks seen elsewhere and which are usually associated with a combination of infectious and environmental (housing and weather) factors. Although no samples were submitted for laboratory investigation, the history suggests that mineral deficiency (copper and/or selenium) may have been responsible for an outbreak of locomotor disorder and deaths in calves in 1993/94.

Farm RS24

This was a medium-to-large suckler/store farm. The main problems reported were an outbreak of respiratory disease and diarrhoea in two-year-old cattle at grass, and pining and deaths in cows. No deaths resulted from the respiratory disease outbreak and no clinical samples were submitted for laboratory examination. Although the herdowner considered that atmospheric pollution was responsible for this outbreak of disease, there is no specific evidence to support this suggestion. The history is consistent with an infectious cause, e.g. parasites, bacteria or viruses.

One of four cows in poor body condition was reported to have died in the spring of 1995. While insufficient information was available to draw any conclusions, the history of outwintering in poor weather conditions without additional concentrate supplementation indicates that these must be considered as potential contributory factors.

Farm RS25

This was a medium-sized dairy/store farm. A high incidence of disease and production problems was reported to date from about 1989/90. The main problems reported were perinatal calf mortality, disease and illthrift in weanlings, mastitis, lameness, infertility, and unexplained deaths of animals of all ages. Problems continued into 1997 and 1998 and were the subject of a series of laboratory investigations at that time.

Despite the severity of the problems up to 1996, there was little laboratory involvement in their investigation. Although about 30 cattle were said to have died in 1996, for example, none were submitted for laboratory examination. Based on the history supplied, together with the results of the later laboratory investigations, they can largely be attributed to a combination of on-farm factors, i.e. infectious agents, management, and nutrition.

Farm RS26

This was a medium-sized suckler farm with sheep. The main problems reported were virus infection in calves, and calving problems in cows. The former was confirmed as BVD virus infection by laboratory tests. The latter was apparently largely attributed to bull conformation. In the circumstances, there is no indication to suggest additional involvement of unusual external factors such as environmental pollution.

Farm RS27

This was a medium-sized dairy farm. The main problems reported were infertility in cows, illthrift in growing cattle, and abortions in cows. In the absence of detailed breeding records it was not possible to determine the nature or extent of the fertility problem. As bulls were used extensively, any contemporary investigation would have required detailed information regarding their fertility status. Although illthrift was reported to have been a problem in growing animals in 1995, little information was available regarding the age or type of animals affected. Contributory factors may have included a reported earlier outbreak of viral pneumonia and poor grass growth during a period of summer drought.

Although no isolations were made on two foetuses submitted for laboratory examination, an outbreak of abortion in 1994/95 is consistent with infectious causes.

Farm RS29

This was a small mixed dairy/suckler farm. The main problem reported was illthrift and deaths in cows. It was said to have commenced in 1990 when six of 36 cows died, and to have continued at the rate of two or three deaths per year up to 1996. However, despite the reported severity of the problem, no animals were submitted for laboratory post-mortem examination prior to mid-1995. Clinical history regarding the nature of illnesses suffered prior to death is also sparse. Calls in the private veterinary practitioner's log refer to conditions such as redwater, milk fever, calving, and salmonellosis. In the circumstances, the possible causes of the animal health problems during this period can only remain a matter of speculation – though given the diagnoses recorded by the veterinary practitioner, there is no reason to suggest the presence of unusual underlying contributory factors. Of two cows submitted for laboratory post-mortem examination in 1995, a diagnosis of ragwort toxicity was made in one and the other was emaciated and had lesions secondary to prolonged recumbence. A third cow submitted in 1996 was emaciated and had lesions of mastitis and secondary abscessation.

Farm RS30

This was a medium-to-large pedigree beef farm. Although the main problem reported was infertility, the infertile rate of 10-12 *per cent* would not suggest a serious problem for an extensively managed suckler herd using natural service. A detailed fertility analysis could not be undertaken owing to the absence of breeding records.

Farm RS31

This was a small dairy/store farm. The main problems reported were respiratory disease in weanlings and cows, redwater in cows and heifers, downer cattle, infertility, abortion and perinatal calf mortality.

An outbreak of respiratory disease was reported to have affected over half of the dairy cows and all of the weanlings between April and September 1994. The private veterinary practitioner considered that the condition was infectious in origin. Reports of a high incidence of redwater in one year are consistent with increased tick activity (the causative agent is transmitted by ticks). Although infertility was also reported to have been a problem, the reported infertile rate was well within acceptable limits. Other reports of downer cows, abortions, and perinatal calf mortality were not unusual, either in incidence or manifestation, and there was no evidence to suggest that unusual factors need be adduced for their occurrence.

Farm RS32

This was a large mixed horse, cattle and sheep farm. The main problems reported were disease and deaths of calves, growing cattle, and cows; skin lesions in cows, growing cattle, and sheep; illthrift and deaths of lambs and infertility in sheep; disease and deaths of horses. While this farm had a history indicating serious disease problems from about 1991 to 1995, analysis and interpretation of problems prior to mid-1995 was impeded by the incomplete nature of records and the very limited recourse to laboratory or other veterinary assistance during that period. A report of a VLS equine specialist on two farm visits in May and June of 1995 concluded there was clinical evidence of a number of infectious conditions in horses. The most important of these were strangles and gastro-intestinal parasitism. The former was confirmed by isolation of the causative agent and the latter diagnosis was supported by the results of analyses of blood samples collected from horses during the June visit. VLS offers of more intensive farm studies to investigate the parasite and other problems were not taken up by the herdowners.

Evidence of parasitism was also reported by Fogarty *et al.* (1998) in all six horses submitted to the Irish Equine Centre for post mortem examination from late 1995 to mid-1996. Although no quantitative data were reported by the authors, the descriptions of the lesions in some cases were suggestive of severe infestation. While the paper also claimed an association between lesions in these horses and uptake of environmental aluminium, a response to this has been published by Collery *et al* (1999). The latter pointed to the lack of evidence presented by Fogarty *et al.* in support of their claim regarding aluminium and questioned the lack of emphasis in their paper on the possible role of parasitism in the development of the lesions in all six horses.

Results of Visits to Retrospective Study Farms in 1997

In addition to regular visits to the four farms in the Longitudinal Study, 17 of the Retrospective Study farms were re-visited in 1997. No serious problems were reported on the majority of farms and herdowners were

generally either satisfied with performance, or considered that under-performance, where it occurred, was due to on-farm factors. Six farms reported that fertility performance continued to be below target. Two farms reported recent serious outbreaks of calf disease. Based on histories, housing was identified as a probable contributory factor in both cases. Problems reported on other farms included difficult calvings, stillbirths, and BVD virus infection.

The main finding from analysis of blood samples collected during the visits was evidence of marginal to inadequate copper and selenium supply on some farms. Although a high proportion of blood samples submitted for analysis had iodine concentrations below the reference range (> 85 *per cent*), this was not an unexpected finding given that the majority were taken from unsupplemented grazing animals during summer and is unlikely to have been of clinical significance. All farms had mean blood phosphorus concentrations within the normal range.

Influence of Management and Other Factors on Animal Health in the Askeaton Area

Management and Nutrition

Management and nutrition undoubtedly played a role in relation to the occurrence of disease and production problems in the Askeaton area – as they do on all farming operations. However, while the nature of the selection process, i.e. 'problem' farms, inevitably ensured that the sample contained a proportion of farms whose management regimes were clearly inappropriate to maintain an adequate level of animal health and performance, there is no evidence to suggest that management practices overall were significantly different from what would be expected in a cross-section of comparable herds elsewhere.

Management and nutrition are likely to have had a significant effect on the incidence of conditions such as infertility, dystocia, lameness, respiratory disease in housed animals, and inadequate body condition in cows pre- and post-calving. This assessment is not unique to farms in Askeaton and would apply to any farms which experienced an above-normal incidence of these problems.

One aspect of nutrition which needs to be highlighted, and which is also unlikely to have been unique to Askeaton, relates to the possible effects of silage quality on animal health and performance over the winter/spring period of 1993-94 – a time when many of the farms reported problems were at their worst. Analysis of the 1997 silage crops on 21 of the Retrospective Study farms indicated that quality was less than adequate on many (*see* Soil, Herbage, Feed and Water Volume). Given the difficult growing conditions of 1993 (Keating and O'Kiely, 1997), it is likely that crops harvested in that year were, on average, of significantly poorer quality than 1997. This, together with the inclement weather of the winter/spring of 1993-94, and the restricted use of concentrate supplementation for out-wintered dry cows on some farms in the area, makes it likely that many cows calved down in relatively poor condition in the spring of 1994.

Milk Yields in the Askeaton Area

Annual milk yields per cow for each of the 18 dairy herds in the Retrospective Study were examined as a potential means of identifying the presence, on an area basis, of negative environmental influences (e.g. environmental pollution) on animal health and production. The results of this analysis showed no evidence of an overall downward trend affecting the majority of herds at any time over the period 1990 – 1995. While individual herds showed significant reductions in some years, these were generally consistent with problems specific to those farms rather than to factors affecting the wider Askeaton area (*see* Animal Health Volume).

Influence of Weather on Reported Problems

An analysis of weather patterns was carried out for the years 1990 to 1996 in order to identify any possible climatic factors which could have contributed to an increased disease incidence in the Askeaton area. The most significant feature over the period, and the only one which showed an obvious association with some of the reported disease problems, was the very poor weather conditions over the winter-spring periods of 1993-94 and 1994-95. Wind and rainfall were above normal in the five months from December to April in both periods. In addition, March/April 1995 was unseasonably cold with snow and sleet. These conditions are likely to have had a significant effect on animal health and production in an area where outwintering of unsupplemented dry (pregnant) cows was common. Cold wet weather probably also played an important role in relation to the development of some of the outbreaks of skin lesions reported in the springs of 1994 and 1995. The effects of poor weather conditions on cow performance in other areas of the country during those periods have been referred to by other workers (O'Farrell *et al.*, 1997; Dillon *et al.*, 1998).

<u>Private Veterinary Practitioner Calls</u>

An analysis of private veterinary practitioner calls to farms in the Retrospective Study was carried out to identify patterns of disease incidence. The results showed no evidence of a significant overall trend in relation either to call numbers or types over the period 1991 to 1995.

Conclusion

In the context of the overall Askeaton investigation, the main questions to be answered from the foregoing analysis of animal disease and production problems on the 25 self-selected surveyed farms in the area (plus the two Index Farms) are:

A. How many of the farms in the group could be said to have suffered an unusually high incidence of animal disease or production problems?

B. Was there any evidence that the surveyed farms suffered a significant incidence of unusual or unexplained diseases?

C. Was there any evidence for the presence of a common underlying factor contributing to disease incidence on the surveyed farms?

D. Do the results of the assessment of disease incidence on the surveyed farms indicate evidence of an unusually high incidence of animal disease or production problems in the Askeaton area as a whole?

<u>A – Evidence of an Unusually High Incidence of Disease on Surveyed Farms</u>

Despite the fact that the surveyed farms were selected on the basis that the herdowners concerned considered that they had suffered an excess of animal disease problems, it is clear from the above analysis that many of the problems were of a relatively mild degree. Only 16 farms could be said to have had one or more moderately severe or severe problems (*see* Table 5- 56 in Animal Health Volume).

The high incidence of reported or confirmed adult animal deaths on five of the surveyed farms was undoubtedly one of the most significant features of this investigation. However, the causes of deaths on the five farms concerned comprised a broad spectrum of commonly-seen conditions with little or no evidence of an underlying pattern. When classified under the most likely respective causes, the incidence rates were less exceptional.

Although infertility was reported to have been a problem in cattle on 18 farms, adequate data for analysis were only available from eight. Even within this group, the results of the analyses indicated that fertility performance was within normal ranges for about two-thirds of the 35 herd years examined (*see* Animal Health Volume). In the present analysis, four farms were considered to have suffered severe infertility problems. In so far as they could be characterised on the basis of available records, the problems identified on affected farms related mainly to heat detection – an area of fertility performance which is of concern on commercial farms world-wide (Esslemont and Kossaibati, 1996).

Six farms reported severe outbreaks of respiratory-enteric disease in calves. However, owing to its primarily infectious nature, and especially where inadequate housing is a contributory factor, high morbidity in outbreaks of infectious respiratory disease is not unusual (Roy, 1990). Mortality rates for respiratory disease elsewhere are reported as ranging from 0 – 60 *per cent* on an individual farm basis and from 2 - 20 *per cent* on an area basis (Bruning-Fann and Kaneene, 1992). Similar rates are reported for enteric diseases. In the circumstances, there is no reason to suggest that exceptional factors were involved in relation to the occurrence of respiratory-enteric disease of calves in the Askeaton area.

Perinatal calf mortality was reported to have been a severe problem on four farms – one of which was Index Farm A. However, while there were few laboratory submissions from any of the farms - and most of the information was based on individual recall - there is insufficient historical evidence to suggest either that the incidence was exceptionally high on an area basis or that unusual risk factors played a significant role in its occurrence.

<u>B – Evidence for Increased Incidence of Unusual or Undiagnosed Diseases</u>

The results of the foregoing descriptions and analysis of problems on the surveyed farms provide no evidence to indicate that there was a high incidence of *unusual* animal diseases in the Askeaton area over the period of the Retrospective Study. The diseases reported largely comprised those commonly seen on farms elsewhere, e.g. infertility, peri-parturient problems and respiratory-enteric disease of calves. Neither was there any evidence of

an abnormally high incidence of *undiagnosed* diseases. In most cases, straightforward explanations exist for the disease outbreaks. To the extent that some cases did remain undiagnosed, this was more often due more to the limited nature of the contemporary investigatory process than to the unusual nature of the outbreaks.

C - Evidence of Common Aetiology

In the absence of specific analytical or other evidence of the involvement of a common underlying factor (e.g. environmental pollution) contributing to disease incidence in the Askeaton area, its presence could possibly be adduced by one or more of the following:

i. Evidence of a temporal relationship in animal disease occurrence,

ii. Evidence of a spatial relationship between affected farms in terms of disease severity and incidence, or

iii. Evidence of a common disease syndrome - or group of related syndromes - on the affected farms.

Given that cause must precede effect - and that continued exposure to a putative risk factor should be accompanied by continued effect - it would be expected that there should be a strong degree of synchrony between farms in terms of onset and duration of problems which have a common cause.

While there was a peak of 20 in the number of farms reporting new problems in 1994 (Table 2.1), there was also a wide spread of reports over the eight-year period. Eleven or more farms reported commencement of new problems in six of the seven years from 1989 to 1995, inclusive. Although the peak year for the reported commencement of fertility problems was 1994 at five new cases, there were four new cases in 1988 and three each in 1990 and 1993. The peak year for onset of respiratory-enteric disease problems was 1995, while for illthrift it was 1991 and for mortality (all ages), 1994. Allowing for an inevitable degree of clustering inherent in the study design – i.e. its focus on a relatively short time-period - and the effects of herdowner recall bias, the data provide little evidence of any marked degree of synchrony in terms of the onset of specific animal health problems.

There was also little evidence of synchrony in terms of disease duration – other than that inherent in the study design. Durations of the three most commonly-reported conditions – infertility, perinatal calf mortality, and respiratory-enteric disease – ranged from one to over eight years (Tables 2.2-2.4).

(ii) The distribution of farms shows no obvious pattern in relation to their classification as severe *vs* non-severe *vis-à-vis* their distance or direction from the AAL plant. Such a relationship might have been expected if a significant proportion of the disease problems were causally-related to emissions from this site, i.e. the severity of problems should reduce as distance from the source of assumed pollutant increases. (The more remote sites of industrial emissions, i.e. Moneypoint and Tarbert generating stations, are not considered in this exercise as the predicted ambient concentrations of pollutants emitted from these sources are greatly reduced and of little significance in the Askeaton area – *see* Environmental Quality Volume).

(iii) Analysis of the problems reported on the surveyed farms shows no evidence that a common syndrome occurred on *all* 27 farms. The four most commonly-reported problems were infertility in cows (18 farms), bovine respiratory-enteric diseases (13 farms), perinatal calf mortality (7 farms), and mortality in cows (6 farms). However, due to the almost universal presence of the infectious, nutritional, and management risk factors with which they are generally associated, these are also common problems elsewhere. In the circumstances, it would be necessary to demonstrate a marked increase in their occurrence in a specified area to suggest that unusual underlying factors were contributing to their occurrence.

D - Disease Occurrence in the Askeaton Area as a Whole

As discussed in the introduction to this Report, it is not possible to make a definitive assessment of the normality or otherwise of disease incidence in the group of 27 surveyed farms as a whole owing to the absence of comparative national animal health baseline data. However, in so far as the group of farms may be said to represent an estimate of the total number of farms in the surveyed area with an excess of disease problems (*see* Introduction and Background to this Section above), it is clear that it is an overestimate. Based on the foregoing analysis of the individual Farm Reports, only just over half (16/27) of the surveyed farms were considered to have suffered moderately severe or severe problems.

Assuming that this reduced total is a reasonable estimate of the number of farms in the Askeaton area with a history of an excess of animal disease problems over the period of interest, and given a total farm population of

Table 2.1

Number of new cases per year of main animal health problems reported on the 27 survey farms

Year of Onset	<88	88	89	90	91	92	93	94	95
Abortion	1							2	
Behavioural						1			
BVD								1	
Conjunctivitis					1				1
Deformity								1	
Delayed calving						1			
Downer			1	1					1
Dystocia				1	1				1
Hypomagnesaemia							1		
Illthrift			2	1	1	1		1	2
Infertility	1		4	3	1	1	3	5	
Lameness			1		1	1		2	
Locomotor							2		1
Low milk yield	1				1		2		
Mastitis	1		1				1	1	
Mortality		1		1	1	1		4	
Perinatal calf mortality	1		2	1		2	1		
Redwater									1
Resp-enteric disease	2		1	1	5		1	2	3
Retained foetal membrane									1
Salmonella		1							
Skin				1				1	1
Twinning				1					
Total per Year	**7**	**2**	**12**	**11**	**12**	**8**	**11**	**20**	**12**

around 1,000 herds in the area encompassed by the Retrospective Study (Fig. 2.5), then this amounts to an estimated proportion of about 1.5 *per cent* 'problem farms' in the area.

The question then arises, '*could a similar proportion of problem farms be identified in other areas of the country?*'. While the information is not available to give a definitive answer to that question, neither the total number of problem farms (16 out of around 1,000), nor their relatively uniform distribution within the area, would provide strong evidence in support of the notion that the Askeaton area and surrounds were subject to unusual environmental influences which were detrimental to animal health.

General Conclusion

In conclusion, and in answer to the questions posed above

- There is no evidence that there was an unusually high incidence of animal health and production problems in the Askeaton area as a whole over the period of interest, i.e. approximately 1985 to 1995. While individual farms had significant animal disease problems – in particular the two Index Farms - the total number of farms affected by severe or moderately severe animal health or production problems amounted to only 16 of the originally- identified 27 farms. In so far as these 16 farms can be said to have been representative of the incidence of farms with an excess of animal disease in the area, then it does not appear to be exceptionally high.
- There is no evidence that there was a high incidence of unusual or undiagnosed diseases in the Askeaton area. The problems reported were of a type commonly seen elsewhere. To the extent that no

diagnoses were made or could be suggested in many cases, this was probably due more to the very limited contemporary involvement of laboratory or other expert resources in their investigation than to any inherently unusual features of the reported incidents.

- Other than infectious, management, and environmental factors which are common to most farms, there was no evidence of a common underlying factor having contributed to an increased incidence of animal disease in the Askeaton area. This assessment is based on:

    i. The absence of evidence of a significant degree of temporal or spatial clustering in relation to onset, duration and incidence of the most frequently-reported problems, and

    ii. The absence of evidence of a common syndrome on all or most of the 27 farms.

In summary, while there was undoubtedly an unacceptably high incidence of animal health and production problems on many of the surveyed farms in the Askeaton area, there is no specific evidence to indicate either that this was part of an area-wide phenomenon specific to the Askeaton area, or that herds had been subject to unusual environmental influences which had a negative effect on animal health.

Table 2.2

Infertility (cows): Onset and Duration on survey farms

Farm	<88	88	89	90	91	92	93	94	95	96	97
1				*	*	*	*	*	*		
2				*	*	*	*	*	*		
5			*	*	*	*	*	*	*	*	
6								*	*	*	*
7								*	*	*	*
8			*	*	*	*	*	*	*	*	*
9	*	*	*	*	*	*	*	*	*	*	*
12			*	*	*	*	*	*	*	*	
15				*	*	*	*	*	*	*	*
16							*	*	*	*	*
18			*	*	*	*	*	*	*	*	*
19						*	*	*	*	*	*
21							*	*	*	*	*
22					*	*	*	*	*	*	
25							*	*	*	*	*
27								*			*
30								*	*		*
31								*			

* Problem reported.

Table 2.3

Respiratory-enteric disease: Onset and Duration on survey farms.

Farm	Animal Type	<88	88	89	90	91	92	93	94	95	96	97
1	Calf	*	*	*	*	*	*	*	*	*		
2	Calf				*	*	*	*	*	*		
8	Calf			*	*	*	*	*	*	*	*	*
9	Calf					*	*	*	*	*	*	*
14	Growing cattle							*	*	*		
16	Calf											*
17	Calf, Growing cattle					*	*	*				
20	Calf									*	*	
22	Cows									*		
23	Calf					*	*	*	*	*	*	
25	Calf					*	*	*	*	*	*	*
24	Adult								*	*		
31	Cows, weanlings								*			

* Problem reported.

Table 2.4

Perinatal Calf Mortality: Onset and duration survey farms

Farm	<88	88	89	90	91	92	93	94	95	96	97
2			*	*	*	*	*	*	*		
6								*	*	*	*
7						*	*	*	*		
9	*	*	*	*	*	*	*	*	*	*	
16						*	*	*	*		
17				*	*	*	*	*			
25			*	*							

* Problem reported.

ANIMAL HEALTH SURVEY

A cross-sectional survey of animal health and production was administered to 680 farm households in six district electoral divisions (DEDs) in counties Limerick, Clare, and Tipperary (Fig. 2.6 and Table 2.5). The survey was carried out as part of a larger survey of human health commissioned by the Mid-Western Health Board. For the purposes of the survey, the 'exposed' region comprised areas A and B (Askeaton and surrounds - Areas 1 and 2 in Fig. 2.6) and the 'non-exposed' or control region comprised areas C, D and E (Areas 3, 4, and 5 in Fig. 2.6). Area F (Area 6 in Fig 2.6) - Clarecastle/Ennis rural – has been excluded from the 'non-exposed' or control region as it was originally included in the human health survey owing to local concerns regarding environmental pollution in the immediate locality and therefore could not be regarded as a control.

The purpose of the survey was to compare responses in the Askeaton area to those in the other areas. Information was collected on farm size, type, production, animal disease (reported numbers of treatments for diseases were used as a proxy for disease incidents), and deaths. A breakdown of the total numbers of responses to the human health questionnaire by area, together with the numbers of valid responses with farm stock, is given in Table 2.5.

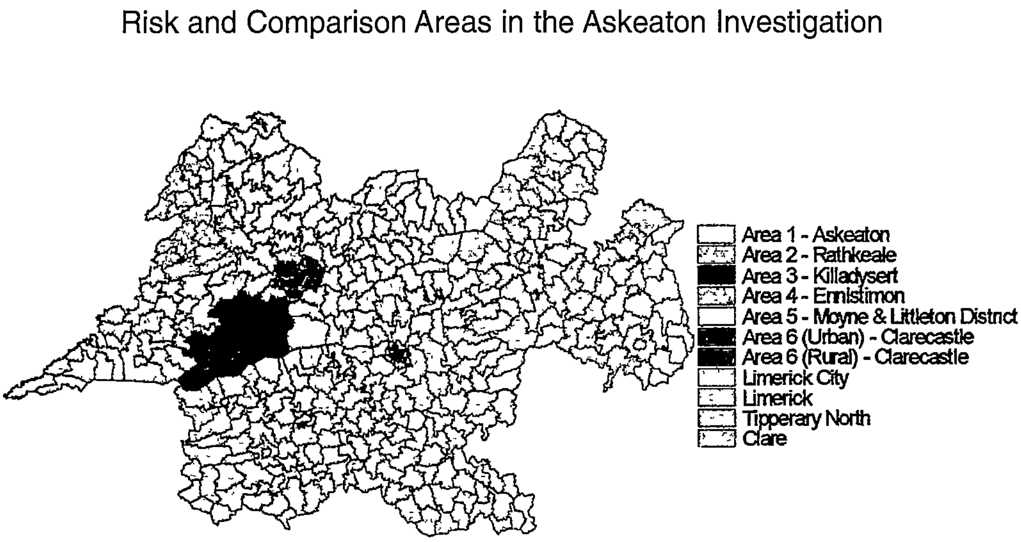

Fig. 2.6 Six survey areas in Askeaton Animal Health Investigation (Map MWHB)

Table 2.5

Survey areas – response details.

Area Code	**Area**	**Valid Responses**	Avg. farm size (hectares)	Stocking Rate[1]	Dairy (%)
A	Askeaton	87	42	0.76	51
B	Rathkeale/Newcastlewest	55	44	0.77	67
C	Killadysart rural	169	28	0.54	28
D	Ennistimon rural	154	32	0.51	21
E	Littleton/Moyne rural	90	49	0.77	51
F	Clarecastle/Ennis rural	35	45	0.62	11

[1]Animals per acre: *Cow = 1 unit, 1 – 2 yro bovine = 0 .75 unit, < 1 yro bovine = 0.33 unit, horse = 1 unit, sheep = 0.5 unit)*

Results

Production and Farm Management by Area

Following data validation, a total of 590 of the 680 returned questionnaires was suitable for further analysis. Results on farm size, stocking rate and proportion of dairy farms per area are given in Table 2.5. From this it can be seen that areas C and D contributed about half of the total valid farm responses of the survey. There were also significant differences between these two areas and the other three in relation to farm size and type. Average farm size was significantly smaller ($p < 0.05$), and a smaller proportion was described as dairy in areas C and D than in areas A, B, and E. Stocking rate was also lower in areas C and D.

Similar differences indicating more extensive farming in areas C and D were also apparent in relation to production. Less than a quarter of herds in these areas reported average annual milk yields per cow of over 4,546 kg (1,000 gallons) compared to almost a half of the herds in the other areas. Concentrate feeding also tended to be lower in the former two areas.

An exception to the tendency for greater extensification in areas C and D.was the relatively high proportion of cattle outwintered on farms in area A (Askeaton). On dairy farms, for example, 27 *per cent* of respondents in area A reported that over half of the herd was outwintered compared to less than 10 *per cent* in areas B, C, D,

and E. For suckler farms, the difference was even greater - 67 *per cent* of suckler farms in area A outwintered over half of the cattle compared to an average of 29 *per cent* in areas C, D and E combined.

The proportion of farms which had silage analysis carried out on a regular basis was low in all areas. Over a half of farms in the five surveyed areas had no silage analyses carried out in the previous three years – the figure for areas C and D was over 80 *per cent.* Even in the relatively more intensive areas, A and B, only a third of farms reported that silage analysis was performed on an annual basis.

Over three-quarters of farms in the six areas reported spring-calving with most of the remainder classified as mixed. Only 12 farms reported autumn calving.

<u>Animal Health in Exposed and Non-Exposed Regions</u>

Mean farm-level mortality rates by area and animal category for 1995 were generally comparable to those reported from studies elsewhere (Appendix A). Some significant ($p < 0.05$) differences, however, were noted between areas. Suckler cow mortality was significantly higher in area A (Askeaton) than in areas C and D and in area B (Rathkeale) than in areas C, D and F. Calf mortality in area C was significantly lower ($p < 0.05$) than in areas A, B, D, and E. No significant differences ($p < 0.05$) were noted by area between dairy cow and dry stock mortality rates. The numbers of farms with sheep and horses were too small to permit statistical comparisons between areas.

While farm-level mortality rates by exposure status (i.e. exposed *vs* non-exposed region) were generally within acceptable ranges, there were significant differences. Rates for cows (dairy and suckler) and calves were significantly higher in the exposed than the non-exposed group in 1995. The difference was most marked for suckler cow mortality where the rate in the exposed group at 4.2 *per cent* was over three times that in the non-exposed group. Rates for most categories in 1996 were lower which reflects the fact that they were for six months only (i.e. first six months of 1996 up the time of data collection).

In order to make a more meaningful comparison between the exposed and non-exposed areas in terms of animal deaths, farms were re-classified on the basis of their mortality rates relative to the overall median for all five areas (A – E). Herds were classified as having above-normal mortality for a particular animal type (i.e. suckler cow, dairy cow, etc.) if their respective farm-level mortality rates were above the combined median for that year.

Median mortality rates for farms in the exposed and non-exposed regions for 1995 and 1996 are shown in Table 2.6. With the exception of calves, which had median mortality rates of 4.17 per cent in 1995 and 2.5 per cent in 1996, median mortality rates for all other categories of livestock were zero. This meant that herds with any deaths in a category were classified as having above-median mortality (i.e. HIMORT95 or HIMORT96) for that category. The distributions of above-median (HIMORTxx) farms by exposure status are given in Table 2.7. Using this method, it was found that the odds of a herd having above-normal mortality were significantly greater in the exposed region for dairy and suckler cows, calves, and sheep in 1995 (Table 2.8).

In 1996, they were higher in the exposed region for dairy cows, dry stock, calves, and sheep. However, when the effect of farm size was controlled for, only the odds ratios for cow mortality (dairy and suckler) remained significant in 1995. In 1996, only the odds ratios for dry stock and calves remained significant following this adjustment.

The proportion of farms reporting some degree of ill-thrift was significantly higher (odds ratio analysis) in the exposed than the non-exposed region for both cows and dry stock – 12 *vs* 5 and 24 *vs* 6 *per cent*, respectively. There was also a clear association between ill-thrift and mortality in suckler cows in the exposed area but not in the non-exposed. Eight of 10 farms reporting ill-thrift in suckler cows in the exposed area also reported above-median suckler cow mortality (i.e. one or more cow deaths), compared to only 4 of 12 in the non-exposed. A similar association was not found between mortality and ill-thrift in either dairy cows or dry stock.

The section of the questionnaire intended to collect information on the incidence of animal treatments for disease was, in general, poorly completed and the results must be viewed with caution. There was considerable variation between the exposed and non-exposed regions in terms of treatment for disease with little evidence of an overall pattern. The main points of note were the higher incidences of treatments for mineral deficiencies and calving and lactation-related conditions in the exposed than in the non-exposed region.

The only significant differences noted between the exposed and non-exposed regions in relation to fertility and periparturient animal health were a higher percentage of cows open and a higher perinatal calf mortality rate in

Table 2. 6

Median farm-level mortality rates by exposure status (1995).

	Median Mortality Rate (%)					
	1995			1996		
	Exp	Non-exp	All	Exp	Non-exp	All
All Cows	1.14	0.00	0.00	0.00	0.00	0.00
Dairy Cows	1.25	0.00	0.00	0.00	0.00	0.00
Suckler Cows	0.00	0.00	0.00	0.00	0.00	0.00
Dry Stock	0.00	0.00	0.00	0.00	0.00	0.00
Calves	6.16	2.25	4.17	2.87	0.00	2.50
Sheep	5.44	0.00	0.00	0.00	0.00	0.00
Horses	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.7

Distribution of above-median (HIMORTxx[1]) farms by exposure status

	Percent (number) farms					
	Dcow	**Scow**	**Dry**	**Calves**	**Sheep**	**Horses**
1995						
Exp.	51.1 (45)	31.8 (21)	21.6 (29)	63.1 (82)	77.3 (17)	14.8 (4)
Non-exp.	24.4 (47)	14.1 (43)	14.0 (49)	44.8 (175)	36.2 (25)	8.2 (4)
1996						
Exp.	38.6 (34)	16.2 (11)	20.4 (28)	61.6 (69)	69.6 (16)	6.9 (2)
Non-exp.	19.4 (36)	9.7 (30)	7.9 (29)	46.2 (172)	39.7 (27)	3.8 (2)

[1] HIMORT = mortality > median rate (xx = '95 or '96).

the former region than in the latter. Differences between regions for other parameters - including abortion, assisted calvings, downer cows, twinning and congenital deformities - were not significant.

Discussion and Analysis

The purpose of this survey was to compare the farm-level incidence of selected animal health problems on farms in the Askeaton area and surrounds (exposed region) with farms elsewhere (non-exposed region). In the context of the wider Askeaton investigations, the objective was to determine if there was any evidence to support concerns that there had been an unusually high incidence of animal disease or deaths in the area.

Survey design issues which must be taken into consideration in relation to analysis and interpretation of the results include its observational nature (i.e. *causal* relationships cannot be adduced from the results – only associations), the fact that the original study population was chosen to investigate human health (*see below* regarding farm types), and problems associated with the collecting of responses to questions on animal treatments.

Production and Farm Management by Area

The results of the survey highlighted a number of important differences in terms of size and enterprise type between areas comprising the exposed and non-exposed regions. Average farm size in areas C and D, which accounted for over three-quarters of the non-exposed survey population, was significantly smaller, and a higher proportion were suckler, than in the exposed region (areas A and B). Other differences noted which support the picture of farms in areas C and D being less intensive, include lower milk yield, lower concentrate usage, and

Table 2.8

Odds ratios of above-median farm-level mortality (HIMORT[1]) for exposed *vs* non-exposed regions in each animal class in 1995 and 1996[2]

Model	Dairy Cows	Suckler Cows	Dry Stock	Calves	Sheep	Horses
1995						
Exposure alone						
Odd Ratios	3.36	3.05	1.46	2.05	5.07	3.22
95% Conf. Intervals	1.96–5.57	1.63 – 5.71	0.88 – 2.42	1.36 – 3.10	1.07 – 24.1	0.80 – 12.99
P	<0.0001	0.0004	0.1442	0.0711	0.0405	0.1009
Exposure + group size[3]						
Odd Ratios	2.13	3.34	1.23	1.48	4.15	1.57
95 % Conf. Intervals	1.18 – 3.86	1.70 – 6.55	0.73 – 2.1	0.95 – 2.31	0.85 – 20.33	0.28 – 8.94
P	0.0123	0.0004	0.4373	0.0828	0.0788	0.6092
1996						
Exposure alone						
Odd Ratios	3.29	1.81	2.61	2.16	3.72	3.19
95% Conf. Intervals	1.97 – 5.51	0.85 – 3.85	1.51 – 4.53	1.37 – 3.40	1.32 - 10.5	0.45 - 22.75
P	<0.0001	0.1232	0.0006	0.0009	0.0132	0.2485
Exposure + group size[3]						
Odd Ratios	1.35	1.66	2.11	1.52	2.92	1.17
95 % Conf. Intervals	0.70 – 2.60	0.75 – 3.69	1.19 – 3.75	1.03 – 1.07	0.97 - 8.79	0.09 - 15.79
P	0.5457	0.2118	0.0104	0.0402	0.0563	0.9058

[1] HIMORT = mortality > median rate. [2] Analysis excludes herds of < 4 animals per class except horses. [3]Number animals per class per farm.

lower frequency of silage analysis. These indicate significant differences in farm management between the exposed and non-exposed regions and, given the importance of farm management in relation to animal health and performance (Bruning-Fann and Kaneene, 1992) are likely to have had a significant influence on some of the results of the survey.

<u>Animal Health in Exposed and Non-Exposed Regions</u>

The farm-level mortality rates for dairy and suckler cows recorded in this survey (1.9 and 1.6 per cent, respectively in 1995 for all areas combined) are comparable to reports from elsewhere. Mean annual rates of from 1.0 to 1.6 per cent mortality were reported from the baseline survey of 25 farms (23 dairy, 2 suckler) carried out in the Aughinish/Askeaton area in 1979 – 1981 (Rogers and Poole, 1984). Menzies *et al.* (1995) reported an overall (i.e. as opposed to farm-level) dairy cow mortality value of 1.6 per cent for Northern Ireland and quoted a range of about 1.0 to 4.6 per cent from other surveys reported in the literature. They reported an overall mortality rate of 2.4 per cent for suckler cows in their own survey and quoted rates in the literature for 'range' (i.e. outdoor suckler) cows as from about 3.0 to 9.0 per cent.

The main finding of interest in relation to comparisons between the exposed and non-exposed regions was the higher suckler cow mortality in 1995 in the former. At 4.2 *per cent*, it was over three times the rate in the non-exposed region and almost twice the rate of 2.4 *per cent* quoted by Menzies *et al.* (1995) for suckler cows in Northern Ireland. Although the odds of above-median mortality for some other animal classes in 1995 and 1996 were also higher in the exposed region, farm-level rates were low and well within ranges reported on farms elsewhere and therefore no specific significance can be attached to the finding.

The difference between the two regions regarding suckler cow mortality related more to the number of farms which experienced *any* losses rather than to the numbers of farms with high mortality. While almost a third of farms in the exposed region experienced at least one suckler cow death compared to only 14 *per cent* of farms in the non-exposed region, farm-level mortality rates for farms which suffered any losses in the two regions were similar – 7.4 *per cent* in the exposed compared to 5.9 *per cent* in the non-exposed region.

The reasons for the differences in suckler cow mortality between the exposed and non-exposed regions in 1995 cannot be determined on the basis of data collected in the survey. The difference remained significant even after

accounting for differences in farm size and type (i.e. suckler cows on farms described as suckler or dairy) in the data analysis. The apparent association between mortality and ill-thrift is both interesting and biologically plausible. However, the finding does not shed any light on the possible underlying causes. One finding which may have had an effect on suckler cow health (i.e. ill-thrift and mortality) in the exposed region is the reportedly higher rate of outwintering stock in area A (Askeaton). The effects of outwintering in poor weather have been referred to elsewhere in this report. However, this association must be viewed with caution owing to the relatively small number of farms involved (total of 87 farms in area A).

Indices for fertility and periparturient animal health performance for the two regions were generally comparable to results reported elsewhere. Reported rates for abortion, congenital deformities, and calf deaths within the first month of calving were low compared to other reported values. Although there were significant differences between the two regions in relation to the proportion of cows open (i.e. infertile rate), as well as the incidence of perinatal calf mortality, values were within the range of rates reported from other studies. It is likely that a proportion of these differences could be accounted for by the observed differences in predominant farm type (i.e. degree of intensification) between the two regions. A similar explanation could probably account for the higher rate of reported treatments for calving and lactation-related conditions in the exposed region.

Other than the potential effects of outwintering referred to above, the reasons for the higher incidence of ill-thrift in the exposed region (cows or dry stock) cannot be determined on the basis of the available data. In the great majority of cases, the problem was said to have been of only moderate severity. Only two farms in each area (exposed and non-exposed) reported a severe problem with ill-thrift. Ill-thrift is a non-specific expression of any influence (infectious, environmental or other) which results in an animal's energy intake being insufficient to meet requirements. While ill-thrift has been reported as a finding in a wide variety of animal diseases (Blood and Radostits, 1990), there is little information in the literature on the occurrence of ill-thrift *per se*.

In conclusion, the most significant finding from this survey was the higher rate of suckler cow mortality in the exposed region in 1995 when compared to the non-exposed region. The reasons for this finding cannot be determined from the results of the survey. However, its significance must be viewed with caution in the light of the relatively small number of farms on which it was based as well as significant differences between the exposed and non-exposed regions in terms of the predominant farm types. Although attempts were made to control for differences in farm size and enterprise (dairy *vs* suckler), it is likely that other potentially important explanatory variables were unrecognised and therefore uncontrolled.

IMMUNOLOGY STUDIES

(P. Keating - UCD Department of Veterinary Microbiology).

The existence of animal health and productivity problems on farms in the vicinity of Askeaton led to speculation that the animals may have had altered immune function. Studies of immune function were initiated in accordance with the protocol drawn up by the Immunology Advisory Committee (EPA, 1995). The aim of this study was to assess the immune function of cattle on the farms under investigation.

Two separate studies were undertaken, one with cows and one with steers. Quantitative analysis of the cellular and humoral components of the immune system involved measuring the distribution of lymphocyte subsets within peripheral blood, serum antibody levels, and serum complement levels. The functional capacity of immune cells was also measured. Lymphocytes were assessed on their ability to proliferate in response to non-specific stimulation. Animals were immunised and the specific response of lymphocytes to antigen was measured in terms of antibody production, lymphocyte proliferation and lymphocyte γ–interferon production. Neutrophil function was also assessed.

The cow study was designed to determine whether there was any evidence that either origin (i.e. Askeaton or non-Askeaton) or location (i.e. Askeaton or outside Askeaton) had an effect on immune function. There were breed/strain differences between the Askeaton and non-Askeaton-origin cows (*see below*); thus, it must be recognised that any differences attributed to origin in the cow study will also be compounded with breed. Due to a range of factors such as breed, age, pregnancy and lactation, which may affect immune responses, a second study was undertaken using steers matched for age and weight to control for some of these variables.

Blood selenium concentrations in the Askeaton-based steers were found to be significantly lower than those outside Askeaton. As selenium concentrations in the diet are known to influence immune function, a third animal study was conducted to assess whether blood selenium concentrations influenced immune responsiveness to a particular antigen.

Methods

Lymphocyte cell subset distribution was assessed using monoclonal antibodies which recognise the following cell membrane antigens: CD4, CD8, TCR1 (γδ T cells), bovine B cells, and CD2.

The humoral immune components measured were IgG, IgM and complement. IgG was measured by radial immunodiffusion and IgM by sandwich ELISA. Serum complement activity was determined by haemolysis.

Neutrophil function was assessed by measuring oxidative burst and phagocytic activity. The former was measured using neutrophils incubated with heat-inactivated *E coli* and the latter with fluorescein labelled bacteria.

The functional capacity of lymphocytes was assessed by measuring their ability to proliferate *in-vitro* following mitogen stimulation. The mitogens used were concanavalin A (ConA), phytohaemaglutinin (PHA), and pokeweed mitogen (PWM).

The specific immune response was assessed in animals immunised with antigen. The antigen used was keyhole limpet haemocyanin (KLH). The proliferative response of lymphocytes to KLH was measured *in-vitro*. The specific antibody response to KLH was measured in serum from KLH-immunised animals using an indirect ELISA. γ–interferon production was also measured using lymphocytes from KLH-immunised animals. A skin test was carried out in KLH-immunised animals to assess the cell-mediated immune response *in-vivo*.

Results of experiments were statistically analysed by UCD Statistics Department.

Results

Cow Study

Forty-three Friesian cows, ranging in age from two to 13 years, were used. Cows of Askeaton origin were British Friesian and those of Abbotstown origin had a high Holstein Friesian component. The cows were assigned to four groups according to their origin and location (Table 2.9).

Table 2.9

Animal groups for cow Study

Group	Origin	Location	No. cows[1]
A	Abbotstown	Abbotstown	11
B	Askeaton	Abbotstown	10
C	Abbotstown	Askeaton	11
D	Askeaton	Askeaton	10

[1] Number at start of study

The relative distributions of lymphocyte sub-populations CD2, CD4, CD8, and γδ T cells, were similar to published results for cows (Bensaid and Hadam, 1991; Park *et al.*, 1992; Wilson *et al.*, 1996; Wyatt *et al.*, 1994). B lymphocyte percentages were found to fluctuate widely. There are no published values for B lymphocyte percentages with the antibody used in this study.

The CD2, CD4, CD8 and B lymphocyte values for each group were statistically analysed. Differences were observed between the groups on both first bleed and last bleed analysis. However, location was not considered responsible for the observed differences in proportions of lymphocyte phenotypes.

Analysis of serum samples for IgG and IgM showed no evidence of hypogammaglobulinaemia in animals from any of the four cow groups. IgG values were generally higher than the normal range of 17-23 mg/ml reported by Barta (1993). No consistent differences were noted between groups. IgM values were also higher than the range of 2.39-3.48 mg/ml reported by Barta. However, an ELISA was used to measure IgM levels in the present study. As this is a more sensitive technique, it may account for the higher values recorded. Higher mean values recorded for Group B between 20/1/97 and 11/5/97 are an indication of immunostimulation.

All animals had detectable levels of complement activity in their sera.

In the tests for lymphocyte responsiveness to non-specific stimulation, Group C and D animals showed a reduction in activity when tested with each mitogen on 5/12/96 (Fig. 2.7). This correlates with the reduced CD4 counts measured at the same time.

A baseline was not established for the PWM variable, thus it was not used as an indicator of immune function. Statistical analysis of the ConA and PHA stimulation revealed no significant differences between groups on first bleed results. Significant differences were noted between groups on analysis of the last bleed results. These differences did not appear to be related to location of the groups. When the results were analysed over time, age was found to have a significant effect on the PHA and ConA response, while pregnancy had a significant effect on the ConA response.

Neutrophil function assays were not conducted on samples from the cow groups as pregnancy has an immunosuppresive effect on neutrophil function (Kehrli *et al.*, 1989; Crouch *et al.*, 1995). However, all cows were assessed for the expression of the CD18 molecule. In bovine leucocyte adhesion factor deficiency (BLAD) affected animals this molecule is absent. Expression of CD18 was observed on the neutrophils of animals studied.

All animals immunised with KLH had a measurable lymphocyte proliferative response to the antigen. There was wide variation in the magnitude of responses observed (Fig. 2.8). Statistical analysis of the data found that groups B and D had a similar mean response and that both differed significantly from group A. Group C cows did not differ in mean response from group A. When the data for all cows were analysed on the basis of location and origin, origin appears to have contributed to the differences observed. No significant differences were noted between the groups in their ability to produce γIFN following KLH stimulation.

Statistical analysis of the results for specific antibody to KLH showed that Askeaton-origin animals located in Askeaton (group D) had a significantly weaker response compared to each of the other groups. This correlates with the earlier finding that origin of animals affected lymphocyte stimulation to KLH.

Changes in skin thickness were recorded 72 hours after administration of KLH. Negligible responses were measured in all animals.

Steer Study

For the steer study, 24 steers, matched according to age and weight were purchased outside the area of investigation. Twelve steers were placed on the Control farm at Abbotstown and twelve placed on Index Farm B in Askeaton.

All lymphocyte subsets were represented in blood samples collected from animals in both locations and deficits were not identified. The CD2, CD8, and CD4 lymphocyte subset profiles were similar to those reported for male cattle by Wilson *et al.* (1996). TCR1-positive cells were significantly higher than those for the cow groups. This is a reflection of their younger age profile (Hein and Mackay, 1991). The percentages of B cells fluctuated widely. No comparative values for B cell numbers are available from other studies.

Fluctuations in percentages of lymphocyte subsets occurred within the two groups over time. Statistical analysis showed no evidence to suggest that location (Askeaton *vs* Abbotstown) had a negative effect on proportions of lymphocyte subsets.

Mean serum IgG and IgM concentrations were within acceptable limits for both groups. No animal was identified in either group with complement deficiency. Blood samples from both groups were assayed for neutrophil phagocytic activity and oxidative burst activity. No animal was identified with persistent neutrophil deficiency when inter-assay comparisons were made. Because of the seven-hour delay involved in delivering samples from Askeaton to the laboratory, and the short-lived nature of neutrophils, it was not valid to make comparisons between the groups with respect to neutrophil function.

In-vitro stimulation with ConA, PWM, and PHA, induced a significant degree of lymphocyte proliferation in all the steers studied. Statistical analysis of the data found that there were no significant differences between the two groups with respect to ConA and PHA responses. As with the cows, the PWM response was not used as an indicator of immune function.

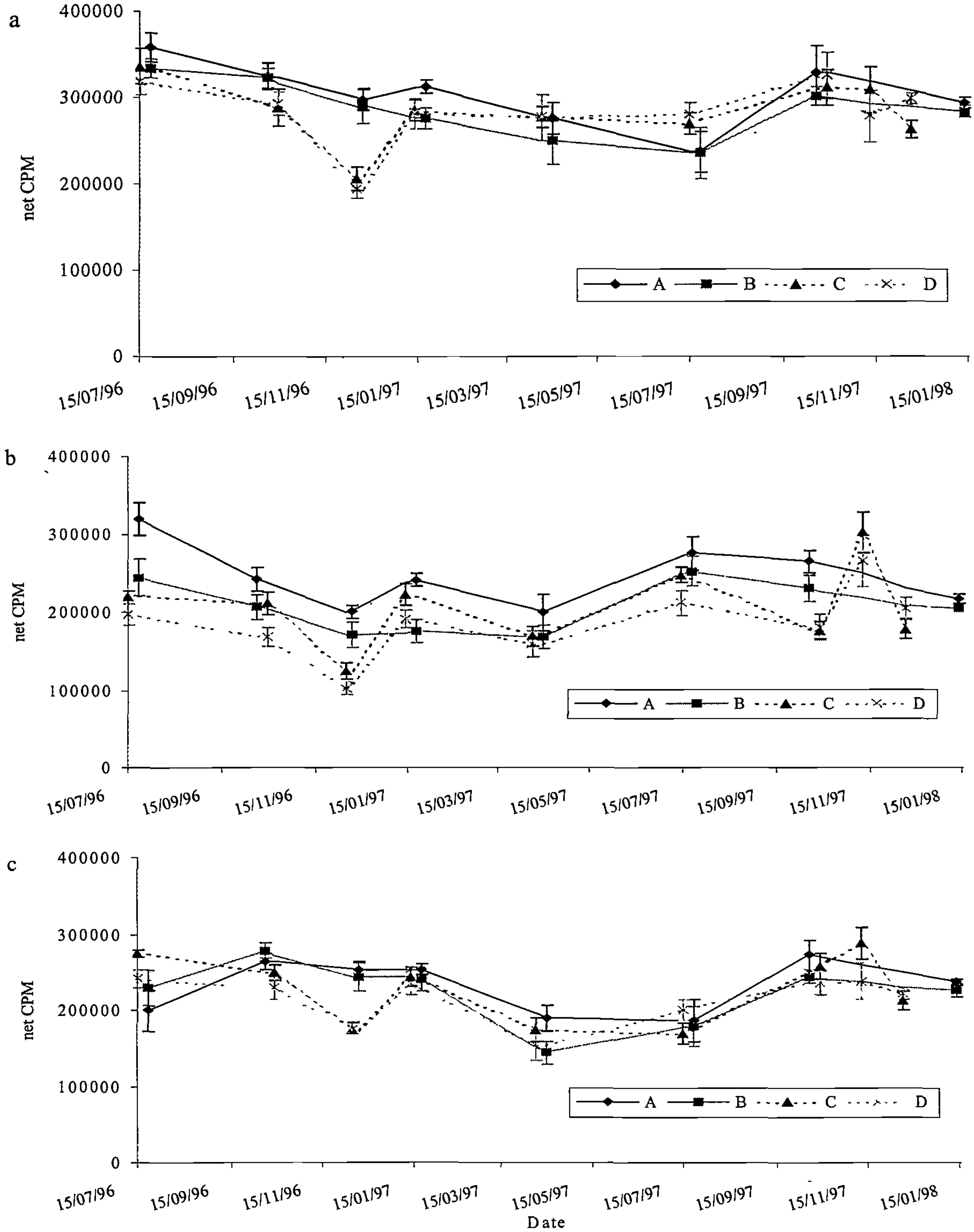

Fig. 2.7 Mean proliferative response of peripheral blood lymphocytes to stimulation with the mitogens, Con A (a), PWM (b) and PHA (c) for the cow groups. The different groupings are: A - VRL cows located at Abbotstown, B - Askeaton cows located at Abbotstown, C - VRL cows located at Askeaton, D - Askeaton cows located at Askeaton. Results are presented as the group mean of ^3H - thymidine incorporation.

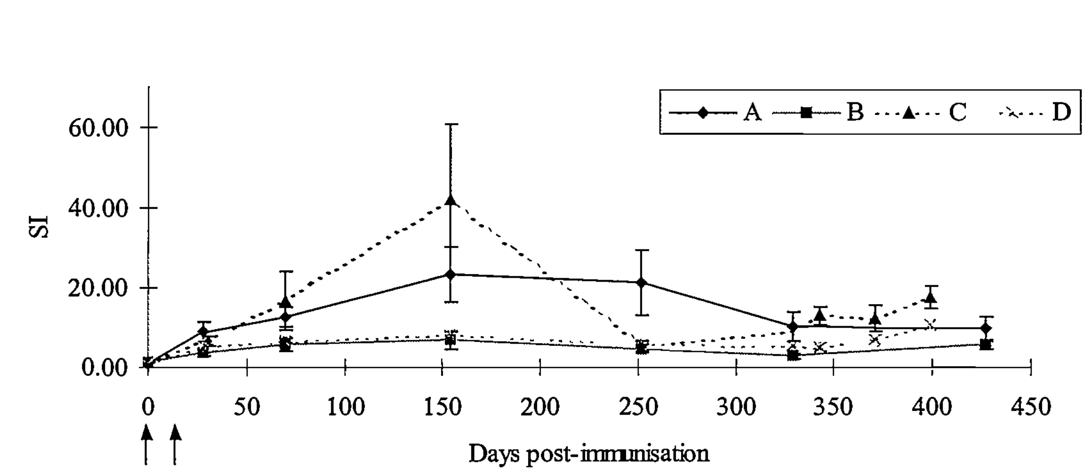

Fig. 2.8 The in vitro lymphocyte proliferative response to KLH for cow groups. Assays were conducted on blood prior to immunisation and at intervals thereafter. The proliferative response is presented as the mean stimulation index (SI) for each group. Arrows indicate time of first and second immunisation. The different groupings are: A - VRL cows located at Abbotstown, B - Askeaton cows located at Abbotstown, C - VRL cows located at Askeaton, D - Askeaton cows located at Askeaton

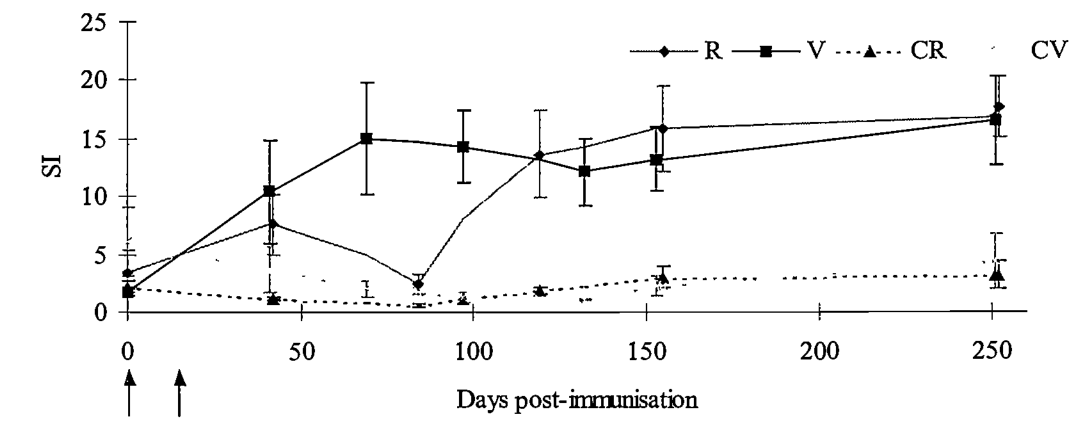

Fig. 2.9 The mean in vitro lymphocyte proliferative response to KLH for steers on the VRL (V) and Askeaton (R) farms and the mean response for control animals on the VRL (CV) and Askeaton (CR) farm. Assays were conducted on blood prior to immunisation with KLH and at intervals thereafter. The proliferative response is presented as the mean stimulation index (SI) for each of the groups over time. Arrows indicate time of first and second immunisation.

All of the KLH-immunised animals responded to KLH stimulation but there was wide variation in the magnitude of response (Fig. 2.9). There was a marked difference between the two groups in their ability to respond to KLH. Steers based on the Askeaton farm responded more slowly to antigen. This difference was significant ($p < 0.05$). The Askeaton-based steers also had a lower specific antibody response to KLH.

Effect of Selenium on the Immune Response

As steers on Index Farm B had significantly lower blood selenium concentrations than those at Abbotstown, an additional study was undertaken to investigate the possibility that selenium deficiency may have contributed to the observed differences in KLH response (*see above*) between the steer groups.

Sixteen female animals (approximately one year old – born and reared on Index Farm B) were divided into two groups – one of which received selenium supplementation. All animals were grazed on Index Farm B which was known to be of marginal selenium status (EPA, 1995).

Animals in the supplemented group were injected with barium selenate (1 mg/kg) two weeks prior to KLH inoculation. Mean blood selenium concentrations (in the supplemented and unsupplemented groups (0.43 and 0.41 μmol/l respectively) were not significantly different on the day of selenium supplementation. By the day of first KLH immunisation (day 0), the mean selenium concentration of the supplemented group, at 1.23 μmol/l was significantly higher than that of the unsupplemented group (0.42 μmol/l). By the last day of sampling (day 111), the mean blood selenium concentration of the supplemented group had risen to 1.76 μmol/l while the unsupplemented group had fallen to 0.30 μmol/l.

No significant differences were observed between the groups in terms of mean lymphocyte proliferative response to KLH or of mean anti-KLH antibody response. It was concluded that blood selenium within the range 0.2-1.8 μmol/l does not affect the specific immune response to KLH.

Discussion

This study was designed to investigate the immune status of cattle on farms in the Askeaton area where it was alleged that environmental factors had an adverse effect on immune function. The immune status of cattle on farms in Askeaton was compared with cattle on the Control farm at Abbotstown. The comparative investigations involved two studies, one with cows and a second with steers. As one of the Index Farms in Askeaton was known to be of marginal selenium status, a third study was undertaken to investigate the effects of selenium status on lymphocyte responsiveness to specific antigen.

The result of the lymphocyte subset investigations indicated that lymphocyte subsets were fully represented in the peripheral blood of all cattle studied. Although significant differences between cow groups were recorded, there was no evidence that these differences were due to location. Statistical analysis of the data revealed that age had a significant effect on the distribution of lymphocyte subsets. When measured over time, no definite trend emerged in lymphocyte subset proportions which might suggest an immunodeficiency.

Significant differences in relative proportions of lymphocyte subsets were also recorded between the steer groups although these animals were closely matched. However, no trend over time was apparent to indicate that location had a specific effect on the percentages of lymphocyte subsets in peripheral blood.

Concentrations of IgG for the cow groups at both locations (Askeaton and Abbotstown) were higher than the normal range described. Cows used in the study varied with respect to age, breed, stage of pregnancy and lactation, which may account for the observed deviation from the normal range. Concentrations for the steer groups fell within the normal range reported for cattle. No effect due to location was observed for the cow or steer groups.

Higher IgM concentrations in the steer and cow groups than those reported from studies elsewhere may reflect differences in the test methodology. Higher mean values of IgM recorded in the Askeaton-origin animals located in Abbotstown during a five-month period were indicative of immunostimulation. This observation was of short duration and unlikely to be related to environmental factors prevailing in Askeaton prior to their move.

No animal in the cow or steer groups was identified with complement deficiency.

Inter-group comparison of neutrophil function was not possible in the steer study owing to the distance between Askeaton and the laboratory where the analyses took place. Within-group results did not identify any animal which had consistently reduced phagocytic or oxidative burst activity.

The functional capacity of lymphocytes was assessed by measuring their proliferative response to the mitogens PWM, ConA, and PHA. Owing to its wide variability, PWM responsiveness was not considered a suitable indicator of immune function. No significant differences were observed between the steer groups for ConA and PHA responses. Thus, location did not influence the responses to ConA or PHA. With respect to the ConA and PHA responses for the cow groups, Askeaton-derived cows in Askeaton did not differ significantly from Abbotstown cows based in Abbotstown. Again this would indicate that location did not have a negative effect on these responses.

From the studies investigating the non-specific elements of the immune system i.e. serum immunoglobulin levels, lymphocyte responses to mitogen stimulation, peripheral blood lymphocyte percentages and serum complement levels, location did not appear to have a significant influence on immune parameters measured.

There were differences between the groups of steers and cows in the measurements of lymphocyte percentages and lymphocyte responses to mitogens. However, location could not be conclusively established as the cause of these differences. Pregnancy and age were factors included in the statistical tests for the cow study which had a significant effect on some of the variables measured. Overall, with regard to measurements of the baseline indicators of immune status, there was no apparent progressive decline. All animal groups had functional immune responses as determined by the tests of non-specific immunity.

Animals were immunised with the antigen KLH, and the humoral and cellular immune responses to KLH were assessed. Most animals in the cow and steer groups demonstrated the ability to mount both an antibody and cell-mediated immune response to the antigen. A number of animals responded poorly but these were not associated with any particular group. The ability of the animals to mount an immune response to KLH indicates that there was no defect in the recognition and presentation of antigen. The memory response to antigen was also effective, as demonstrated by *in-vitro* assays. Although there was considerable variation in the ability of individual animals to mount a KLH-specific response, the mean antibody and cellular responses to KLH for the Askeaton-based steer group were significantly lower than the means for the Abbotstown group.

Results from the cow study on specific immune response were not as clear-cut. Cows of Askeaton origin, whether located in Abbotstown or Askeaton had a lower cellular response to KLH compared to cows of Abbotstown origin. This suggests that the differences were origin-related. However, in relation to the measured antibody response to KLH, only Askeaton cows located in Askeaton had a significantly lower response compared to cows of Abbotstown origin. Thus, there is conflicting evidence with respect to the effect of origin and location on the KLH-specific antibody response in the cow groups.

Whether the altered response to KLH was due to differences between the groups in breed, or a consequence of some event that occurred prior to the commencement of the study, is unclear. It was not possible within the experimental design to differentiate between differences due to breed or a permanent impairment to the immune system that occurred prior to commencement of the study. However, apart from exposure to cytotoxic drugs or γ-irradiation, few external influences cause permanent impairment of the immune system. Furthermore, measurements of the non-specific immune response for Askeaton-derived animals in Abbotstown were not found to differ significantly compared to cows based in Abbotstown.

Blood selenium concentrations recorded for the steers based in Askeaton were considered to be marginal whereas those for the Abbotstown steers were at the higher end of the normal range. As blood selenium concentrations were found to differ significantly between the steer groups, an investigation was conducted to establish whether selenium influenced the KLH-specific immune response. The results from this study indicate that marginal blood selenium status does not appear to affect the immune response of cattle to the antigen KLH when compared to cattle with normal blood selenium concentrations. However, the steers on the Abbotstown farm had higher concentrations of blood selenium than the normal range described. It is possible that the higher blood selenium concentrations reported for the Abbotstown steers may have augmented their response to KLH.

Another possible reason for the altered immune response to KLH recorded for the Askeaton-based steers may be an effect of transport. Blood samples taken from the Askeaton-based animals took up to seven hours – including a three-hour train journey - to reach the laboratory where assays were conducted. Samples from the Abbotstown herd were not subjected to the same conditions. However, a laboratory study which attempted to simulate train transport by mechanical sample agitation gave conflicting results. While one experiment found a significant effect on KLH induced proliferative response, no significant effect was noted in a repeat experiment.

Conclusion

The immune system is required for both protection from infection and for clearance of infectious agents once infection has occurred. Any interference in immune function would be expected to increase the probability of infectious agents gaining a foothold in the host. Evidence that Askeaton-based steers had a weaker KLH-specific immune response is a significant finding. It is possible that these animals might be more susceptible to infections. However, the clinical data recorded for the steers did not indicate that these animals suffered from chronic or recurring infections. In spite of the lower KLH-specific immune response, no direct correlation with increased prevalence of disease was reported..Indeed, all steers were considered to be in a healthy condition when measured in terms of production performance. This indicates that these animals did not suffer from immunosuppression.

In conclusion, there was no evidence of immunodeficiency from measurements taken to assess non-specific immunity. There was variability in the parameters measured but no consistent pattern emerged suggesting a progressive decline in immune function. Askeaton-based cows and steers did differ from control animals in their

specific immune response to the KLH antigen. However, the animals showed no clinical evidence of altered immune competence. For the cow study these differences may have been influenced by differences in breed, age and pregnancy. The reasons for the differences in KLH responses in the steer study could not be determined. Although the results of a supplementary experiment showed no evidence of an effect of marginal selenium blood status on KLH-specific responses, the possibility that the high-normal selenium status of the Abbotstown steers had an enhancing effect on responses cannot be ruled out. The results of an experiment to investigate the effects of sample transport on the KLH tests were inconclusive.

RAT FEEDING TRIAL

(P. Nowlan - Bio-Resources Unit, Trinity College Dublin)

A laboratory-rat feeding trial was undertaken to investigate the possibility that soil from the Askeaton area might contain quantities of pollutant which would have a significant negative effect on rat health when compared to the effects of feeding soil from a remote control site.

The trial had two parts:

- Trial I to examine the effects of soil-feeding on the reproductive performance of rats.
- Trial II to examine the effects of soil-feeding on the growth of litters born to females from Trial I .

For Trials I and II, three separate feeds were made up. These comprised a) soil from Index Farm A in Askeaton added to a standard laboratory rat diet at a rate of 15 *per cent*, b) soil from a control site (Johnstown Castle farm) added to rat ration at 15 *per cent*, and c) rat ration alone.

In Trial I, each ration was fed to one of three groups of 16 female virgin rats for a three-month period. They were mated two months after the start of feeding. Food and water intake was measured daily and animals weighed weekly. All animals were observed daily for any abnormalities. Subsequent litter sizes were recorded and litters observed for 21 days - at which point they were weighed, euthanased, and a post-mortem examination performed on each pup. The livers were weighed and samples taken from 60 randomly-chosen pups for enzyme analysis.

The second-litter rats were weighed at 21 days (weaning) after which they were used in Trial II. Following weaning, the original females were euthanased and a post-mortem examination carried out.

As a supplementary study to determine the effects of the soil-feeding on the activities of the liver enzymes phenylalanine hydroxylase and glutathione peroxidase (*see* next section – Vole Study), livers from some rat dams and new-born male rats were analysed for these enzymes.

Results and Discussion

In Trial I, no significant signs of ill health were noted in the first-generation female rats and none died during the period of the trial. There was also no evidence of a significant difference in reproductive capabilities between the three groups as evidenced by second-litter numbers, size, sex-ratio, feed intake, or weight gain of first- or second-litter members. A difference in first-litter numbers was recorded due to breeding problems with a male rat.

For Trial II, 96 animals - evenly distributed by sex and group - were chosen at random from the animals of the second litter. The animals were weighed weekly and the food and water consumption was measured. No significant differences in growth rates were noted between the groups.

In the enzyme study (phenylalanine hydroxylase and glutathione peroxidase), no significant differences were noted in the activities of either enzyme in the livers of rats from the soil feeding trial.

Conclusion

The results of the study showed no evidence that feeding of soil from Index Farm A in Askeaton had a significant negative effect on the reproductive or growth performance of rats when compared to rats fed soil from a control source.

VOLE STUDIES

(J. Donlon, Biochemistry Department, University College Galway in collaboration with CVL Abbotstown and Teagasc Johnstown Castle Analytical Services Laboratory)

A study was commissioned by DAFRD to investigate a suggested association by Fallon *et al.* (1997) between suspected environmental pollution and the activities of the liver enzymes phenylalanine hydroxylase and glutathione peroxidase in voles collected in the Askeaton area. The authors of that study postulated that lower enzyme activities in the Askeaton voles, compared to those from a remote site, were secondary to a suggested decline in herbage selenium in the area. Based on an implied connection between the decline in herbage selenium and the presence of environmental pollution, they also suggested that measurement of the activities of these enzymes in wild rodents could be used as biomarkers of pollution.

The purpose of the present study was to investigate the possibility that the variations in liver enzyme activities could have been associated with natural variations in environmental (herbage) selenium concentrations. The latter are known to vary widely throughout the country (Fleming, 1962) and these were not measured in the study by Fallon *et al.* (1997).

The study involved the measurement of phenylalanine hydroxylase and glutathione peroxidase activities, as well as selenium concentrations, in the livers of voles collected at the original Askeaton site and two remote control sites. Soil and herbage samples collected at these sites were also analysed for selenium content.

In a further study, liver phenylalanine hydroxylase and glutathione peroxidase activities were also determined on rats used in the soil feeding trial (*see above*) to determine if there was any significant effect on the activity of these enzymes as a result of feeding soil from Index Farm A.

Results and Discussion

Fifty voles were collected from the Askeaton and control sites. As in the earlier study by Fallon *et al*, (1997) liver glutathione peroxidase activity was significantly lower in voles from Askeaton than in voles from the two control sites (41 *vs* 51 and 95 nmol/min/mg). Liver and herbage selenium concentrations were also significantly lower at the Askeaton site. In contrast to the earlier study, phenylalanine hydroxylase activity was higher in voles from the Askeaton site.

These results, which indicate that variations in the activity of the liver enzyme glutathione peroxidase reflected variations in environmental (herbage) selenium availability, are in agreement with findings in other species (Hafeman *et al.*, 1974; Whanger *et al.*, 1977; Paynter, 1979; Beckett *et al.*, 1990) and are not unexpected given that selenium is an essential component of the enzyme (Rotruck *et al.*, 1973).

On the other hand, the finding that phenylalanine hydroxylase activities were higher in voles from the Askeaton area would not support the view of Fallon *et al.* (1997) that lower activities of this enzyme in the earlier study were secondary to lower concentrations of glutathione peroxidase.

Conclusion

In the absence of any published evidence to support either the suggestion of a decline in soil selenium in the Askeaton area, or of an association between environmental selenium concentrations and pollution, the results of the present study suggest that variations in the activity of liver glutathione peroxidase are more likely to be due to natural variations in the environmental availability of selenium than to environmental pollution.

ANIMAL TISSUE ANALYSIS RESULTS

Analyses for a range of potentially toxic metals were carried out on animal blood and tissue samples collected during the course of the animal health investigations in the Askeaton area. Samples were analysed for aluminium, arsenic, cadmium, fluorine, iron, copper, cobalt, lead, zinc, and selenium. Results on tissue analyses performed during the latter part of 1995 have already been published in the First Interim Report (EPA, 1995).

Tissues and blood samples for analysis originated from animals on the two Index Farms in Askeaton, the Control Farm at Abbotstown, and other farms in the Askeaton area with reported animal health problems. Analyses were performed in the Limerick RVL, the Central Veterinary Laboratory (CVL) Abbotstown, and ADAS laboratories in the UK.

Results and Discussion

Summary results of all tissue and blood analyses performed on samples collected between November 1995 and October 1999 are given in the Animal Health Volume. All tissue and blood samples had aluminium, fluoride, and arsenic concentrations within reference ranges. Some tissue cadmium, cobalt, selenium, zinc, and iron concentrations above published reference ranges were recorded. However, all were well below toxic concentrations and were not of clinical significance.

The only heavy metal analysis result consistent with toxicity in the entire investigation was a single case of an elevated lead concentration in a kidney sample from a bull. The animal in question originated from Index Farm A in Askeaton but had been located on the Control Farm at Abbotstown for seven months prior to sampling post slaughter. The animal had not previously shown any clinical signs of lead toxicity.

Although aluminium was one of the first environmental pollutants to be considered in the Askeaton investigation owing to the proximity of an alumina production plant (bauxite refining), it should be noted that aluminium is generally regarded to be of low toxicity in farm animals. While interference with the metabolism of essential elements such as phosphorus and magnesium has been demonstrated in experimental feeding trials with aluminium (Crowe *et al.*, 1990), there was no evidence from the present investigations that clinical deficiencies of these elements were a significant factor in the reported animal health and production problems in the Askeaton area. Neither was there any environmental or animal analytical evidence of excess aluminium deposition.

The absence of any analytical evidence of fluoride toxicity in farm animals in the area is also in accordance with the results of the animal health and environmental investigations. There were neither reports of fluorosis in the area nor was there any evidence either of environmental contamination with fluoride or of a potential industrial source. Fluoride emissions are not a significant by-product of bauxite refining (EPA, 1995).

Conclusions

Overall, the results of these analyses do not provide any evidence to suggest that the animals sampled had been exposed to toxic concentrations of the metals concerned on a significant scale. This conclusion is further supported by the absence of clinical reports of classical metal toxicity in animals as well as by the environmental investigations in the area which showed no evidence of significant heavy metal contamination.

SUMMARY OF CONCLUSIONS

Monitor Study on the Two Index Farms and a Control Farm

Animal Health

- The overall incidence of disease and mortality was low on the two Index Farms in Askeaton and the Control Farm in Abbotstown over the two years of the Monitor Study (April 1996 –March 1998).
- There was no evidence of a recurrence of the severe animal health problems of previous years on the two Index Farms and no outbreaks of unusual or undiagnosed disease were encountered.
- Although problems were experienced with mastitis and lameness (the latter only on Askeaton farms), incidences were close to or within reported reference ranges for farms elsewhere and causation could be attributed to risk factors which are commonly associated with these conditions.

Production

- Animal production was generally satisfactory on the three farms.
- Milk production and body condition performance of both Askeaton- and non-Askeaton-origin cows ranged from moderate on the two Askeaton farms to good on the Control Farm.
- While fertility performance was below target at times on the two Askeaton farms, problems largely related to heat detection and there was no evidence to suggest that other unusual factors were involved.

Longitudinal Study on Four Farms

Animal Health

- The results of the study showed no evidence that animal health or production on any of the four farms were subject to unusual adverse influences during the periods of observation (1997/98).
- The incidence of disease on each of the four farms was generally within acceptable limits and no serious outbreaks of disease were encountered. The conditions reported largely comprised those commonly-observed on commercial farms, *viz.* stillbirths and neonatal diseases in calves, mastitis, lameness and infertility in cows.
- There was no evidence of an unusually high incidence of undiagnosed diseases. While the causes of a number of outbreaks of respiratory disease in cows and calves on one farm were not identified, the cases were generally mild in nature and clinical and laboratory examinations did not reveal any unusual features.

Production

- Milk production was acceptable on three of the four farms. A full investigation of poor production on one farm was precluded by its withdrawal from the study.
- Fertility performance on the four farms ranged from moderate to good and fertility indices were generally within reference ranges. Specific fertility problems identified were similar in type and degree to those seen on farms elsewhere.

Retrospective Study on Two Index Farms

- The animal health and production problems on these two farms were undoubtedly severe at times over the eight-year period from about 1988 to 1995.
- There is little evidence to suggest there was a high incidence of unusual disease problems on either farm. Most of the problems reported are seen on farms elsewhere.
- From the available evidence, straightforward explanations involving the commonly accepted infectious, nutritional, and management risk factors can be adduced for the majority of the reported problems on the two farms.
- The fact that many of the problems were undiagnosed relates more to the very limited contemporary use of professional veterinary and laboratory expertise than to unusual features of the conditions themselves.
- There is little evidence to suggest a common cause for the high incidence of disease on the two farms. The most severe problems on each farm occurred at different time periods and there was little overlap in terms of the clinical syndromes described.
- The severity of some of the conditions suggest that exceptional circumstances obtained at times on each of the farms. In relation to Index Farm A, these are largely a matter of speculation for the period when most of the losses occurred (i.e. prior to 1994). Factors which are likely to have contributed to the severity of the problems on Index Farm B include:
  - poor condition of cows at calving due to:
    - a) out-wintering in prolonged inclement weather,
    - b) concentrate supplementation inadequate to compensate for poor silage quality.
  - An outbreak of salmonellosis in adult cattle.
  - Inadequate contemporary use of laboratory and other sources of specialist diagnostic expertise.
- There is no clinical, pathological or analytical evidence to suggest the involvement of environmental pollution in relation to the occurrence of animal health and production problems on these two farms. While the possibility of its involvement cannot be absolutely ruled out, none of the main clinical

conditions reported were suggestive of recognised toxic syndromes and environmental and animal analyses failed to reveal any evidence of toxicological significance.

Retrospective Study on 25 Farms

- While individual farms undoubtedly had a higher than normal incidence of animal disease and production problems over the period of interest, i.e. approximately 1985 to 1995, there was insufficient evidence to suggest that this was indicative of an unusually high incidence of problems in the Askeaton area as a whole. Only just over a half of the originally identified 'problem' farms could be said to have had moderately severe or severe animal health or production problems.
- There is no evidence that there was a high incidence of unusual or undiagnosed diseases in the Askeaton area. The bulk of the problems reported were of types commonly seen on farms elsewhere. In many cases where diagnoses were not made this was probably due more to the very limited contemporary involvement of laboratory or other expert resources in their investigation than to any inherently unusual features of the reported incidents.
- Other than infectious, management, and environmental factors which are common to most farms, there was no evidence of a common underlying factor (e.g. environmental pollution) having contributed to an increased incidence of animal disease in the Askeaton area. This assessment was based on:

  a) absence of evidence of a marked degree of temporal or spatial clustering in relation to onset, duration, and incidence of the most frequently-reported problems, and

  b) absence of evidence of a common syndrome on most or all of the 27 problem farms. Problems such as infertility and respiratory-enteric disease which were common to many of the farms, are also common on farms elsewhere.

Animal Health Survey

- The results of the survey identified clear differences between the exposed and non-exposed regions in terms of farm size and enterprise type. Farms in the exposed area (Askeaton and surrounds) were, on average, larger and a higher proportion were dairy, than those in the non-exposed region. These findings are likely to have had a significant influence on the results of the survey.
- Reported suckler cow mortality in 1995 in the exposed region, at 4.5 *per cent*, was significantly higher than in the non-exposed region.
- Reported mortality rates for other animal types in the exposed and non-exposed regions were generally within reference ranges reported for farms elsewhere.
- Reported fertility and production indices for the two regions were generally within reference ranges. Inter-region differences noted were consistent with differences in predominant farm type.
- A significantly higher proportion of farms in the exposed region reported some degree of ill-thrift in cows or dry stock.
- A significantly higher proportion of cattle (dairy and suckler farms) were reported as being outwintered in one of the two areas (area A – Askeaton DED) comprising the exposed region than in the other areas.

Immunology Study

- The multi-location cow and steer studies showed no evidence of immunodeficiency in animals located in, or originating from, Askeaton.
- While variability was recorded in measured parameters between locations, there was no evidence of a deficiency in immune function in animals located at either of the Askeaton locations or the remote Control Farm.
- Animals at the Askeaton locations showed significantly lower activity of one of the immune functions measured (*in-vitro* KLH-specific response). While the specific reasons for these differences could not be

determined from the study results, there was no evidence that the finding was of clinical significance. Animals at both sites were in good health throughout the two studies.

Rat Feeding Trial

- The results of the study showed no evidence that feeding soil from Index Farm A in Askeaton had a significant negative effect on the reproductive or growth performance of rats when compared to rats fed soil from a control source.

Vole Studies

- The results of the study demonstrated that lower hepatic glutathione peroxidase activity in voles collected at an Askeaton site, than at two remote control sites, was associated with a lower dietary (herbage) selenium availability at the Askeaton site.

Animal Tissue Analysis Results

- Aluminium, fluorine, and arsenic concentrations were within reference ranges in all tissue and blood samples examined.

- Some tissue cadmium, cobalt, selenium, zinc and iron concentrations above published reference ranges were recorded. They were well below toxic concentrations and were not considered to be of toxicological significance.

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APPENDIX A

DISEASE INCIDENCE TABLES

(*See* Animal Health Volume for reference sources of data).

Table A1

Abortion and Periparturient Conditions

Condition	Incidence (%)	Country/Region
Abortion	2 – 2.5	International
Abortion	1.6	Ireland
Abortion	2 – 4	Ireland
Abortion	2.6	Ireland
Abortion	2	UK
Abortion	2.2	Switzerland
Dystocia	10	US
Dystocia	13.6	Switzerland
Dystocia	9	Ireland
Dystocia	10	Canada
Dystocia	5.8 (median)	Canada
Dystocia (all ages)	13 (2 – 36)	UK
Dystocia (heifers)	18	UK
Dystocia (parity > 1)	9	UK
Dystocia	8.7 (1–27)	UK
Downer cow	2.1	USA
Milk Fever	9	Canada
Milk Fever	9.4 (6-18)	UK
Milk Fever	7.6	UK
Milk Fever	7.7	UK
Metritis	10.1	UK
Metritis	4.7	UK
Metritis	7.5	Canada
Metritis	15	UK
RFM[1]	4.4 (1-25)	UK
RFM	4.7	US
RFM	10	Canada
RFM	1.3 (0-22)	UK
RFM	3.6 (0 – 19)	UK
Stillbirth	5	Ireland
Stillbirth	2.8 (median)	Canada
Stillbirth	6.3	Switzerland
Stillbirth	3.7	Switzerland
Stillbirth	4.7	Ireland
Stillbirth	6.3	

[1]RFM = Retained foetal membrane

Table A2

Twinning and Congenital Abnormalities

CONDITION	Incidence (%)	Country/Region
Twinning	2.6	UK
"	3.3	UK
"	4.1 (1– 10)	UK
"	2.5	Ireland
"	1 – 6	Worldwide
Misc. defects	1.5	Ireland

Table A3

Cow Morbidity and Mortality

Condition	Age/Type	Incidence (%)	Country
Mortality	Dairy	2.4	Ireland
Mortality	Dairy	2.0	US
Mortality	Suckler	1.6	Ireland
Mortality	Calved	1.6	UK
Non-detected oestrus	Dairy	37 (27-50)	UK
Non-detected oestrus	Dairy	46.4 (17 – 90)	UK
Ovarian cyst	Dairy	6.7	UK
Lameness	All	23	Ireland
Lameness	All	17 (5– 48)	UK
Lameness	All	17 (8-28)	UK
Lameness	All	25	UK
Mastitis	All	14.4	UK
Mastitis	All	20.2	Switzerland
Mastitis	All	13	Canada
Mastitis	All	30	US
Mastitis	All	23	UK
Mastitis	All	33	UK
Conjunctivitis	All	Present in 50% of herds	US
Culling rate	Dairy	30.5	IRL
Culling rate	Dairy	23	UK
Culling rate	Dairy	25	US

Table A4

Mortality in Stores and Growing Animals

Condition	Age/Type	Incidence (%)	Country
Mortality	1 – 5 months	1.02	Ireland
Mortality	6 – 24 months	0.82	Ireland
Mortality	6 – 24 months	1.2	US

Table A5

Calf Morbidity and Mortality

Condition	Age/Type	Incidence (%)	Country
Diarrhoea	Calf	15 – 20	International
Diarrhoea	birth to 8 wks	25	USA
Diarrhoea	birth to weaning	20	Canada
Diarrhoea	0 – 90 days	15	US
Diarrhoea	0 – 14 days	10	US
Diarrhoea	15 - 90 days	5	US
Resp dis	Calf	7 – 15	
Resp dis.	0 – 8 wks	10	USA
Resp dis.	0 – 90 days	7	US
Resp. dis.	0 – 7 days	1 6	US
Mortality	Calf	15.8 – 27 2	USA
Mortality	< 24 hrs	3 1	Switzerland
Mortality	pre-wean calf	6.0	Switzerland
Mortality	< 24 hrs	3.5 – 5	
Mortality	< 24 hrs	1 3 – 26	
Mortality	0 – 28 days	3	
Mortality	0 – 28 days	3	Ireland
Mortality	0 – 6 months	21	
Mortality	pre-weaning (excl stillbirth)	9 4	US (1,685 dairy herds)
Mortality	pre-weaning	5	Switzerland
Mortality	birth to 8 wks	7 – 8	USA
Mortality	0 – 24 hrs	6 1	UK
Mortality	0 – 24 hrs	7 8 (1 – 20)	UK

Bovine Fertility Performance Indices

Table A6

Target and intervention levels for fertility indices by herd size*.

Herd Size	Preg. Rate[1]	18-24day return	S/C[2]	CSI[3]	CCI[4]	SR[5]	NDO[6]	IR[7]	HDR[8]	HDE[9]
Target.										
	60%	60%	1 65	65	85	80%	10%	10%	80%	50%
Intervention.										
10-20 cows	<30	<30	>3 13	>76	>94	<53	>24	>24	<53	<20
20-50 cows	<40	<40	>2 38	>75	>94	<62	>18	>18	<62	<30
50-75 cows	<48	<48	>2 08	>75	>93	<69	>16	>16	<69	<37
75-100 cows	<50	<50	>1 96	>75	>93	<71	>15	>15	<71	<39
> 100 cows	<52	<52	>1 92	>75	>93	<73	>15	>15	<73	<41

*Based on DairyMIS herds – (O'Farrell and Harrington, 1999)
[1]Conception to first service. [2]Services per conception [3]Calving to first service interval [4]Calving to conception interval [5]Submission rate [6]Non-detected oestrus. [7]Infertile rate [8]Heat detection rate [9]Heat detection efficiency

Table A7

Average, target and intervention fertility performance for DAISY (UK) herds*

	Actual (average)	Target	Interference
Calve to first service	71.7	67	70
Submission rate	52	56	50
Overall conception rate	49	55	48
Conceived of served	90	93	90
Calving to conception	99	89	94
Calving interval	380	370	377
Total culling	23	16	22
Culling for infertility	10	7	11

* Esslemont and Peeler (1993).

Bovine Haematology and Biochemistry Reference Ranges

Table A8

Haematology reference ranges for cattle

Test name	Abbrev.	Min.	Max.	Units
Packed cell volume	PCV	24	40	%
Red cell count	RBC	5	9	10^{12}/l
Haemoglobin	Hb	8	14	g/dl
Mean corpuscular haemoglobin concentration	MCHC	30	34	g%
Mean corpuscular volume	MCV	40	60	fl
White cell count	WBC	4	10.5	10^9/l

Table A9

Blood biochemistry reference ranges for cattle

Test name	Abbrev.	Min.	Max.	Units
Calcium	Ca	2.1	3.1	mmol/l
Copper	Cu	9.4	24	μmol/l
Magnesium	Mg	0.65	1.2	mmol/l
Potassium	K	3.6	5.6	mmol/l
Selenium	Se	0.75	3	μmol/l
Sodium	Na	136	145	mmol/l
Zinc	Zn	5	25	μmol/l
Iodine	I	20	300	μg/l
Aluminium	Al	2	100	μg/l
Albumin	Alb	23	37	g/l
Total protein	TP	57	83	g/l
Urea	Urea	2.65	6.89	mmol/l
Phosphorus	P	1.4	2.5	mmol/l
Chloride	Cl	97	111	mmol/l
Glucose	Gluc	2.5	4.16	mmol/l
γ-Glutamyl transferase	γGT	18	55	iu/l
Fluorine	F	40	140	μg/l
Aspartate aminotransferase	AST	38	120	iu/l
Thyroxine	T_4	45	100	nmol/l
Creatine phospho-kinase	CPK	50	130	iu/l
Glutamate dehydrogenase	GLDH	0	25	iu/l
β-hydroxybutyrate	βHB	0	0.9	mmol/l
Globulin	Glb	31	51	g/l
Albumin:globulin ratio	A/G	0.5	1.5	Ratio

Chapter Three

SOIL, HERBAGE, FEED AND WATER

D. McGrath, O. T. Carton, S. Diamond, and A. O'Sullivan

NATURE OF THE INVESTIGATION

This field investigation was conducted to obtain evidence of previous inputs to soil, herbage and water that may have contributed to the animal health problems on farms in the Askeaton area. Since soil acts as a long-term reservoir, soil analysis can provide evidence of historical inputs. Soil also provides an indication of possible plant nutritional factors (mineral excesses or deficiencies) that may contribute to animal health problems. Herbage and fodder (silage and hay) act as a short-term reservoir thereby providing evidence of more recent inputs. Herbage and fodder analysis also provides an indicator of potential animal dietary/nutritional problems.

SCOPE OF THE INVESTIGATION

The investigation was structured to include the following:

1) In relation to three farms (the Somers, Ryan and Control) :
   a) Soil survey, classification and evaluation of production potential (1995).
   b) Soil sampling and chemical analysis for a range of inorganic components (1995 – 1998).
   c) Herbage sampling and chemical analysis (1995 – 1998).
   d) Water analysis (1995).
   e) Concentrate and mineral mix analysis (1995).
   f) Fodder analysis.
   g) Botanical evaluation of herbage and of vegetation (1995/1999).

2) In relation to Longitudinal Study of animal health and production (*see* Chapter Two): analysis of soil, herbage and fodder (1997 – 1998).

3) In relation to Retrospective Study of animal disease and production problems (*see* Chapter Two): analysis of soil, herbage and fodder (1997 – 1998).

In addition to the above, Teagasc provided advice during the development of the protocols for Monitor, Retrospective and Longitudinal studies. During the course of the Monitor Study, Teagasc advisory staff provided advice in relation to the upgrading of the farm facilities and day-to-day management, including grassland and animal nutrition. This was achieved by regular visits by the local Teagasc adviser or a specialist dairy adviser. When required, these personnel were supported by visits from Teagasc research staff.

A Teagasc dairy specialist visited the farms participating in the Longitudinal and Retrospective studies to supply advice in relation to farm facilities and current management practices.

BACKGROUND

The following are brief descriptions of the Somers and Ryan farms.

The Somers Farm

The Somers farm is a typical County Limerick dairy farm. It forms one compact unit and the western edge borders the public road from Askeaton to Ballysteen. The farmyard and new farmhouse are at the northwest corner of the farm. The farm is all at an elevation of between 20 and 30 m. There is a small hill of 30 m height in the south west of the farm topped by a pre-historic ringfort. There is flat, open country as far as the Shannon

to the west of this hillock and indeed of the farm generally.

The area of the farm was *ca* 19.9 ha (*ca*. 18.7 ha adjusted) which carried 20 dairy cows and followers in earlier years. Up to the early eighties, the farm was run in the traditional manner where the cows were housed in a tie up byre, fed on hay and milked using a bucket type milking machine. Cow numbers increased gradually to reach a herd size of thirty producing approximately 127 t (28,000 gallons) of milk by the early eighties. The introduction of milk quotas in 1983 has restricted milk production to this level. Efficient and effective farm practices were adopted during the period of herd expansion. A central farm roadway with paddocks, piped water and mains electric fencing allowed stock to be grazed on a rotational basis. The old buildings were replaced by a 32-cow cubicle shed, roofed silo, exercise yard and dungstead. Silage rather than hay became the primary source of winter-feed. Lime and fertiliser use increased with an associated cost of £ 143/ha in 1986. This reflects high usage compared with similarly stocked farms but these inputs were in line with Teagasc recommendations. Average stocking rate was approximately 2.02 livestock units (LU)/ha in 1986.

In the late eighties an additional *ca* 4 ha were acquired bringing the farm size to *ca* 23.9 ha. Extra calves were reared and kept on the farm until they were 12 to 18 months old resulting in a stocking rate increase to 2.2 LU/ ha at the start of the investigation in 1995. It should be noted that the animal health problem made normal stock sales difficult. No animals were bought onto the farm at any time during the previous 30 years, with the exception of a bull.

The Ryan Farm

The Ryan farm was a 34 ha dairy farm near Askeaton, County Limerick. It was in one compact unit on both sides of a public road from Askeaton to Massy's Quay, with a long border on the east with the tidal estuary of the River Deel, a tributary of the Shannon. The farmyard and new farmhouse were at the extreme southern end of the farm which was all at an elevation of between 20 to 40 m. Originally the farm was in two separate parts. A Land Commission settlement (land swap) in the early seventies made the farm a single unit. A further 14 ha was purchased in 1972, financed by the sale of a site for industrial development purposes. At this time the farming system was mixed. By the mid seventies it was an all grassland farm and had changed over completely to dairying.

The herd consisted of approximately 60 cows and was maintained at this level between 1985 and 1995 .The calves were generally fed fresh milk and sold at 1 to 2 months of age. Replacement heifers were purchased. The system developed was an intensive, low cost one. A New Zealand type herringbone-milking parlour was erected in 1974. It was one of the first of this popular system in the county. The milk quota for the farm was 204.5 t (45,000 gallons). This was a respectable milk output considering that whole milk was fed to calves and the low input character of the system. The cows were calved predominantly between January and March. In 1988/89 a bull was introduced instead of artificial insemination and the herd calving date was delayed further into spring.

Hay was the main winter forage until 1982. Subsequently baled silage was used. The farm was the first in the area to buy a round baler to make baled silage. Up to 1988, the cows received no meal supplementation while on grass, but subsequently summer meal feeding was practised. The stocking rate was consistently in the region of 2.1 LU/ha and nitrogen use on pasture ground was in the region of 625 kg of calcium ammonium nitrate/ha (172 kg nitrogen/ha), which is more than adequate for the stocking rate.

The Askeaton Control Farm

A Control farm in the Askeaton area was introduced to serve as a possible standard in the event of a striking difference in the results from either or both the Somers and Ryan farms. The Control farm is a dairy farm situated between the Somers and Ryan farms and was reporting no serious animal health problem in 1995. The farm is in three separate units, all of which are close to the farmyard and new farmhouse. There are eight fields but some of them are divided by fences into smaller paddocks. The three highest fields are at an altitude of about 30 m and all the others are at an altitude of between 15 and 20 m. The general topography of the farm is flattish to gently sloping.

RESULTS AND DISCUSSION

The following consists of a summary report of each component of the Teagasc investigation including

- Soil Survey
- Soil Analysis
- Herbage and Miscellaneous Biological Sample Analysis
- Water Analysis
- Concentrate and Mineral Mix Analysis
- Fodder Analysis
- Analysis from Longitudinal Study
- Analysis from Retrospective Study
- Botanical Analysis

The work was undertaken primarily in 1995. Monitoring of herbage on the Somers farms together with analysis of soil and herbage samples from the Longitudinal and Retrospective Studies (see Chapter Two) and some botanical analysis were undertaken between 1996 and 1999. Sampling locations and detailed results may be found in the Soil, Herbage, Feed and Water Volume.

Soil Survey

General Comment

A soil survey of the three farms was carried out on March 21, 22 and 23, 1995. The purpose of the survey was to identify the soil types and assess the land quality on the farms. Approximately 70 auger borings were made, up to a depth of 1 m. This forms a detailed survey. Profile development, parent material, drainage and texture are the main characteristics used in the classification. The soil series definitions established by the National Soil Survey were used to name the soils.

Parent Material

The three farms overlie Carboniferous limestone bedrock. Lower Carboniferous earthy limestone underlies the Somers farm. Unbedded reef limestones, which reflect clear water marine sedimentation, underlie the Ryan and Control farms (O'Meara, 1966; Geological Survey of Ireland, 1969. Till, comprising mainly Carboniferous limestone, covers the Somers and Control farms and the western part of the Ryan farm (Synge, 1966) . The eastern part of the Ryan farm consists of rock waste or thin drift cover. The three farms occur within the Fedamore stage of the Weichsel glaciation (Midlandian advance) during which ice came from the north or northeast. This indicates that black shales that occur to the west in Limerick and to the northwest in Clare are unlikely constituents of the till. A section examined at a site beside the Somers farm consisted of calcareous gravely till composed predominantly of limestone with very small amounts of sandstone and shale.

Alluvium occurs in a small basin (3.8 ha) on the Somers farm and in a small (1.5 ha) narrow strip along the western margin of the Control farm. These deposits occur in small catchments that lie within the limestone region and are derived from the local limestone till.

Soil Series

The National Soil Survey has previously classified all the soils found on the three farms. A key to the Soil Series showing their differentiating characteristics is presented in Table 3.1. These soils are widespread in the central plain (Finch and Ryan, 1966; Finch, 1977; Conry, 1987) where, with the exception of molybdenum, they do not show naturally elevated mineral values.

The proportion of each Soil Series on the farms together with the soil suitability class is shown in Table 3.2. Free draining soils predominate on all farms ranging from about 0.75 on the Ryan and Somers farm to 1.0 on the Control farm. Remaining soils consist of wetland on the Somers farm and rocky land on the Ryan farm (Table 3.2). At the time of the survey, surface poaching was extensive on wet and free draining land on Somers farm and occurred to a lesser extent on the Ryan farm. On the Control farm there was very little surface poaching. Evidence of anaerobic conditions was found in the top soil (A horizons) at nearly every site. This reflects structural damage caused by animal or machine traffic.

Soil Suitability

Soil suitability is an evaluation of the degree of suitability of each soil unit for a given use. It is an interpretative classification that involves estimates of the relative degree of limitation. In this case the relevant land use type is confined to grassland. The limitations on the farms are wetness (w), drought (d) and rockiness (r). The soils are

grouped into five classes designated A (good), B, C, D, E (very poor) for grassland. Productivity is the dominant criterion in the suitability for grassland and the suitability classes parallel the grazing capacity classes. Table 3.2 shows the distribution of the suitability classes on the farms. The Control farm consists entirely of Class A land. The Somers farm is predominately (0.75) Class A land. Wetness is the principal limitation on this farm. The wet Coolalough unit is assigned to class Ew and comprises 0.04 of the farm. Class A land occupies 0.50 of the Ryan farm. The Kinvarra soils on the Ryan farm have drought limitations and are assigned to Class Bd. Rockiness is the major limitation on this farm and affects 0.20 of its area.

Table 3.1

Soil series and their characteristics found on the Somers, Ryan and Control farms.

Soil Series	Characteristics
Patrickswell	Grey Brown Podzolic/Brown Earth derived from calcareous gravely till, loam, well drained solum 400-850 mm
Elton	Similar to Patrickswell. Solum >850 mm
Kinvarra	Brown Earth derived from calcareous gravely till or weathered limestone, loam. Well drained. Solum < 400 mm.
Rocky land	Kinvarra soils with abundant outcrops of limestone bedrock.
Mylerstown	Gley derived from calcareous gravely till, loam, imperfect to poorly drained. Solum < 850 mm.
Ballyshear	Peaty gley derived from calcareous gravely till, loam, poorly drained.
Coolalough	Peaty gley derived from calcareous alluvium silt loam, poor to very poorly drained, high water table.
Camoge	Gley derived from river alluvium, silt loam, poorly drained.

Table 3.2

The soil suitability class and the proportion of each Soil Series on the Somers, Ryan and Control farms. (Suitability classes - A (good) to E (very poor) and limitations - wetness (w), drought (d) and rockiness (r)).

Soil Series	Soil suitability class	Somers	Ryan	Control
Patrickswell	A	0.75	0.50	1.00
Kinvarra	B_{d*}	0.00	0.26	0.00
Mylerstown	C_{w*}	0.09	0.00	0.00
Camoge	C_{w*}	0.00	0.05	0.00
Coolalough/Ballyshear	D_{w*}	0.12	0.00	0.00
Rocky Land	E_{r*}	0.00	0.20	0.00
Coolalough	E_{w*}	0.04	0.00	0.00
		1.00	1.00	1.00

*d = drought; w = wetness; r = rockiness limitations

A comparison of the relative stocking rate capacity (proportion of farm that is assigned to each soil series multiplied by the stocking rate of the series) for the three farms is shown in Table 3.3

The stocking rates assigned to the soils are values published previously for these soils (Lee and Diamond, 1972). This indicates that for similar inputs and feed supply the ratio of the stocking rate on the Somers and Ryan farms compared with the Control farm are 0.92 and 0.87, respectively. The stocking rate for the Somers and Ryan farms at the start of the investigation marginally exceeded the estimated stock carrying capacity of the land (Table 3.3).

Table 3.3

Estimated relative stocking rate capacity (LU / ha) on the Somers, Ryan and Control farms

Soil Series	**Stocking Rate***	**Somers**	**Ryan**	**Control**
Patrickswell	2.20	1.66	1.10	2.20
Kinvarra	2.00	0.00	0.52	0.00
Mylerstown	1.73	0.15	0.00	0.00
Camoge	1.73	0.00	0.08	0.00
Coolalough/Ballyshear	1.48	0.17	0.00	0.00
Rocky Land	1.10	0.00	0.22	0.00
Coolalough	1.10	0.05	0.00	0.00
Total (LU/ha)		2.03	1.91	2.20
Ratio (Control =1)		0.92	0.87	1.00

*Assigned to each soil series

To summarise, the National Soil Survey had previously classified all soil types that were identified on the Somers, Ryan and the Control farms. Free draining soils predominate on all farms with a proportion ranging from 0.76 of the total on Ryan's farm to 1.00 on the Control farm. The remaining soils consist of either wet or rocky land. The stock carrying capacities of the Somers, Ryan and Control farms, respectively, were estimated at 2.03, 1.91 and 2.20 Livestock Units/ha.

Analysis Of Soil

Background

Major and Trace Elements in Soils (and Plants)
Soil is an essential medium for the growth of plants and for the breakdown and recycling of organic matter. It is now considered the most important environmental compartment functioning as a sink for trace elements (Senesi *et al.*, 1999). Changes in soil properties such as in pH, redox potential and moisture status can affect the bioavailability and form of the elemental components of the soil. Soils are reasonably stable but become progressively more acid due to the action of dissolved carbon dioxide. Acidity (low soil pH) can be adjusted to optimum levels for crop production by additions of lime. Metal cations are more active under acid conditions and increases in pH reduce their bioavailability. Conversely, anions, e.g. molybdate, become more available with increase in pH.

Large transfer of elements, including metals to soil systems, will not only change the chemical properties, but will also influence the physical and biological properties of the soil. Certain metals, including copper, zinc and nickel at moderate levels, are also harmful to microorganisms and may affect essential soil processes (McGrath *et al.*, 1995).

Metal pollution can produce two categories of harmful effects in grassland agriculture. In the first category the concentration in a plant or in the soil may reduce growth of the vegetation by phytotoxic effects. Secondly, the concentration present may not affect the growth of vegetation but may constitute a health hazard to animals that

ingest it.

Elemental uptake by plants is affected by factors controlling

(1) The level and chemical form of the element (speciation) in the soil
(2) The movement of the element to the root
(3) The absorption of the element into the root and
(4) The translocation from the root to the plant shoot

In addition to root absorption, plants can also take in significant amounts of elements by leaf absorption and this can be the route of entry for atmospheric pollutants. The readiness of aerosol deposited particles to enter through the leaf surface depends on the particular metal; e.g., zinc can enter plants more readily through foliar absorption than can lead.

Nearly 90 chemical elements are found in soils and plants. For convenience, elements are divided into major elements and trace elements. The dividing line is usually set at a tissue concentration of 1,000 mg/kg. This is a purely arbitrary division. Many elements may be quite toxic even at low levels of intake, whereas others are relatively innocuous. The elements that are essential for life are those which cannot be wholly replaced by any other element. If a particular organism does not have a certain minimum supply of an essential element it cannot complete its life cycle. In this respect the trace elements are as important as the major elements - the only difference is that they are required in much lower quantities.

Ranges of Elements in Soils
As may be expected, elements vary in concentration in different soils. In the case of trace elements this variation may often be 100-fold or more. The ranges (Parle, 1995; McGrath and McCormack, 1999) in the expected concentrations of a number of elements in Irish soils are shown in Tables 3.4 and 3.5. Values are given in g/kg

Table 3.4

Typical ranges (g/kg) of major elements in non-polluted Irish agricultural soils (total contents).

Element	Symbol	Range 1*	Range 2**
Aluminium	Al	10-80	7-89
Calcium	Ca	5-30	-
Iron	Fe	10-50	3-59
Magnesium	Mg	1-15	0.4-18
Nitrogen	N	1-4	-
Phosphorus	P	0.2-2.0	-
Potassium	K	1-30	3-25
Silicon	Si	150-400	-
Sodium	Na	0.5-15.0	-
Sulphur	S	0.2-1.50	-

*Range 1: P. Parle, *personal communication*, 1995
**Range 2: McGrath and McCormack, 1999

for the major elements and as mg/kg for the trace elements. Data on some of these elements in Irish soils are relatively limited. The ranges given are those encountered in Irish agricultural soils. Much higher levels may be encountered in the vicinity of worked ore deposits (DAFRD, 2000) and in industrial areas. Urban soils, particularly those from old gardens, tend to have relatively high metal contents (McGrath, 1994).

Extractable Trace Elements in Soils
The total content of an element in soil - whether major or trace - is not a good guide regarding its availability to the growing plant. Therefore, empirically derived extraction procedures have been developed internationally to simulate the availability of elements to plants. The extraction techniques used for soils employ reagents whose extractable content correlates with the plant-available content of the soil and so can be used to predict plant uptake or the possibility of deficiency or toxicity symptoms occurring in plants or animals.

The reagents used are relatively mild extractants and they may vary for each element. It is important to realise

that, whereas extractable contents may provide a better index of availability than total contents, they are by no means perfect and their ability to predict likely plant contents is influenced by a number of soil factors, e.g. pH, organic matter content, and soil texture. The normal ranges of elements extracted with conventional extractants are shown in Table 3.6. These data have been accumulated over many years and represent the current state of knowledge. They provide, in essence, a measure of the bio-availability of elements.

Table 3.5

Typical ranges (mg/kg) of total trace elements in non-polluted Irish agricultural soils.

Element	Symbol	Range 1*	Range 2**
Antimony	Sb	0.2-3.0	-
Arsenic	As	1-50	3-104
Boron	B	20-100	-
Cadmium	Cd	0.1-1	0.01-3.2
Chlorine	Cl	30-300	-
Chromium	Cr	5-250	3-323
Cobalt	Co	1-25	1-53
Copper	Cu	2-100	2-73
Fluorine	F	20-700	-
Iodine	I	2 – 20	2.5-16
Lead	Pb	2-80	10-100
Manganese	Mn	20-3000	20-5167
Mercury	Hg	0.03-0.8	0.03-1.0
Molybdenum	Mo	0.2-3	
Nickel	Ni	0.5-100	1-150
Selenium	Se	0.2-2	0.2-9.7
Thallium	Tl	0.1-0.5	-
Tin	Sn	1-40	-
Uranium	U	1-10	-
Vanadium	V	20-250	-
Zinc	Zn	10-200	4-239

*Range 1: P. Parle, *personal communication*, 1995
**Range 2:McGrath and McCormack, 1999.

Table 3.6

Elements, their extractants and typical ranges of extractable elements found in non-polluted Irish agricultural soils.

Element	Extractant	Range (mg/kg)
Phosphorus	Acetic acid – sodium acetate	1 – 20
Potassium	Morgan's reagent (pH 4.8)	50 – 300
Magnesium	Do.	30 – 400
Sodium	Ammonium acetate	20 – 100
Sulphur	Calcium phosphate	<10 - 50
Manganese (easily Reducible)	Calcium nitrate and 0.2% Quinol	10 – 600
Copper	EDTA (pH 7.0)	1 – 20
Zinc	Do.	2- 15
Molybdenum	Tamms reagent (pH 7.3) Ammonium oxalate/oxalic acid	1 –1.0
Boron	Hot water	0.1- 4.0

Effects of Pollution on Soil and Herbage
In the following sections, the types of pollution which are likely to be experienced on farms and which may lead to an increase of chemicals (mainly inorganic) in soil and herbage, are considered. Overt operations including dumping and fertiliser/pesticide application to soil are disregarded. More attention is paid to inorganic than to organic substances for a number of reasons. There was a difficulty in selecting organic pollutants to analyse for, which would match with the industrial activities in the area. The composition of both soil and herbage can vary quite considerably with the variability of the former being generally much greater than that of the latter. There is no such thing as a standard soil and many soils have an excess or deficiency within the normal productive range of one or more elements that are required for good plant growth and animal health.

In suspected soil and herbage contamination cases, especially where animal ill-health or death occurs, at least three scenarios fall within the remit of the chemist. These comprise (1) events involving emission and deposition, (2) natural (geochemical) pollution or pollution by mining or dumping and (3) direct or induced mineral deficiencies.

Pollution of Soil and Herbage by Aerial Deposition
Industry has been and still is responsible for the emission of a wide range of solids and gases (Burton, 1986). The former include largely inert materials from earth moving activities (quarrying, mining) but may also include mining residues containing heavy metals, or products of incomplete combustion, i.e. soot. Gaseous emissions include oxides of sulphur and nitrogen, hydrofluoric acid, hydrochloric acid and ozone. All of the above, at a sufficiently high concentration, can have a visible effect on plants (Guderian, 1977). Most, with the possible exception of nitrogen oxides, and ozone may in practice affect animals and have been implicated in incidents involving farm and wild animals (Samiullah, 1990; National Research Council, 1991).

Smelting and combustion may also cause the volatilisation of some metals especially mercury, cadmium and lead in addition to acid gases. Insecticides, especially, are continually being implicated in acute toxicity events particularly in underdeveloped countries (Knott and Day, 2000). Immediate effects following explosive dispersion of chemicals, as in Bhopal in 1984 and Seveso in 1976, have received widespread publicity, but are of infrequent occurrence. Emissions from discarded solvents and from petroleum refineries have been implicated in reported chronic incidents. When it comes to long-term chronic effects, the list of possible toxic emissions lengthens for animals, especially humans, but not to the same extent for plants and often involves halogenated organic compounds.

In Ireland a number of proven instances of emissions influencing soil or herbage have been documented. Greatly increased levels of lead in soil have been demonstrated for one mining area (DAFRD, 2000); deposited lead on herbage has been reported in another (Donovan *et al.*, 1969). Animal deaths had been authenticated in both these areas and were attributed to lead poisoning. Also in Ireland, significant gaseous emissions have been found for hydrofluoric acid (used for glass-etching) and in earlier years to sulphur dioxide escape during sulphuric acid production from pyrites and also during superphosphate production. The former presented a risk to animal health from excess fluoride on vegetation. High sulphur dioxide levels, associated with superphosphate production, are known to have caused considerable damage to vegetation.

Gaseous emissions tend to leave only a minor impression on soil compared to herbage. Very high soil sulphate levels have, however, been found (Meshalkina *et al.*, 1996) in affected areas in Russia. Sulphur acid deposition also causes acidification of soils. This can result in leaching of essential elements especially in light textured soils.

Overall, outside of long established heavy, dirty, industry and perhaps in areas with high population and transport densities, aerial emissions occurring in amounts sufficient to affect soil and vegetation are rare. The impacts also tend to be obvious. In recent years Teagasc experience is that chemically measurable effects on herbage from industry have been largely confined to the action of dust or soil from mine working and also that of fugitive emissions of hydrofluoric acid.Vegetation is susceptible to a large number of effects, physical, climatic, seasonal and disease. Visible symptoms displayed by plants are much more likely to result from these causes than from polluting influences in most Irish situations.

Geochemical Pollution
Some soils contain harmful levels of mineral substances as a consequence of their natural composition. In mining areas it is difficult to separate this natural geochemical pollution from pollution caused by historic mining activities, especially in areas that have been naturalized over the years. Some of this pollution is quite extensive

but some occurs in small pockets. Levels of some metals, (*e.g.* lead, zinc and copper) can be sufficiently high to affect animals *via* ingestion of soil but not normally of soil free herbage. Parts of the country exhibit low-level enrichment of these and other metals in soil. Such areas include parts of Limerick and Clare as well as some midland counties. A special instance of poisoning is the accumulation of selenium in small soil pockets with high organic matter, especially in Counties Limerick and Meath. Consumption of high-selenium herbage grown in these areas can cause sporadic injury and even death to cattle. Other metals and especially cadmium have also been found at potentially dangerous levels in these soil areas. Frequency of occurrence of any of these pollutants in toxic amounts is not large but effects can be serious. Perhaps a milder but much more extensive level of pollution relates to molybdenum, which interferes with copper absorption by ruminants, and this will be referred to below.

Mineral deficiency
Trace element contents in Irish mineral soils are generally sufficient to sustain grass growth. However, mineral deficiencies may occur on farms and may impinge on animal performance and health. They include principally cobalt, selenium, iodine and copper (Rogers and Keating, 1994). Other soil components interact with these nutrients, at plant or animal level. Interactions include interference by manganese in soil with cobalt uptake by plants and interference by molybdenum, zinc, iron and sulphate with absorption of copper by animals from ingested herbage. Most soil elements, both major and trace, need replenishment to varying degrees depending on removal rate if productivity is to be maintained.

Whereas some industrial pollutants and particularly those with major visible impact are deposited close to their emission point, many have long range and often transboundary effects. Some are noxious but others may have a positive effect. Among the former may be listed lead, (from petrol additive), mercury and perhaps sulphur. Selenium and iodine may be included among the positives. Many would now transfer sulphur to the positive list, as sulphur deficiency in grassland is recognised in Ireland for many years (Murphy and Boggan, 1988) and is now regarded as commonplace even in industrialised areas (Bristow and Garwood, 1984).

Soil Analysis

General Comments
Soil sampling procedures vary in respect of a) sampling depth; b) area represented by each sample and c) number of sub-samples in each sample. The actual procedure used is generally tailored to the circumstances of each case.

For agronomic purposes, Teagasc stipulates that i) samples be taken to a depth of 100 mm; (ii) the maximum area represented by each sample is an area of 2 to 5 ha or one enclosure, whichever is the smaller and (iii) at least 20 cores be taken in a W-shaped pattern across each sampled area and combined to constitute a single sample. In the present case, the fields on the three farms were inspected and divided into 2 to 3 ha sized units before sampling. The outlines of each area were measured and marked off on the appropriate farm map. The number of samples amounted to 16, 19 and 15, respectively, for the Somers, Ryan and Control farms.

In 1995 soils were sampled to a depth of 50 mm. At least 100 soil cores were taken from each sampling unit. The primary objective was to obtain evidence of aerial deposition of contaminants. A depth of 50 mm was the minimum that could be conveniently and accurately sampled. This was the sampling depth used in previous baseline surveys conducted in the area. However, it meant some loss of comparability against standard Johnstown Castle agronomic data for grassland soils. This loss will be more important for pH and extractable phosphorus and potassium than for other soil chemical parameters. pH is normally lower in the 0 to 50 mm horizon than in the 50 to 100 mm horizon. Phosphorus and potassium levels will be higher at 0 to 50 mm compared with the 0 to 100 mm layer as a consequence of on-going fertiliser applications.

Soil samples were individually analysed for a wide range of parameters (*see* Soil, Herbage Feed and Water Volume). Only summary results are presented here.

pH, Lime Requirement and Extractable Macronutrients
On the Somers farm soil pH values (6.1 –7.1) were optimum for grass growth: lime application to this farm had been made in the mid-eighties. About one third of samples from the Ryan farm and all the samples from the Control farm fell into the low pH categories.

About 0.30 of samples on the Control farm were low with respect to phosphorus ($\leq$3 mg /kg), and 0.2 were low

with respect to potassium (<100 mg /kg). Magnesium, sodium and sulphur soil values were satisfactory on all three farms.

Overall, soil pH, soil organic matter content, levels of extractable phosphorus, potassium, sulphur, magnesium and sodium on the Somers, Ryan and Control farms were all within the expected range for Irish soils.

Extractable Soil Trace Elements

The mean levels of extractable manganese on the three farms were satisfactory (200 – 400 mg/l) from an agronomic perspective. The values obtained were lower on the Somers than on the Ryan and Control farms. This is mainly a reflection of the higher pH values on the Somers farm.

In general, the soil copper levels on the three farms appear adequate (>3 mg/l) to meet the needs of grass for growth and the nutritional requirements of the animals grazing the pasture. However, two samples from the Ryan farm (0.1 of samples) had marginally low copper levels.

The mean molybdenum values (<0.3 mg/l) on the Ryan and Control farms were satisfactory and similar to the mean value obtained by Brogan *et al.* (1973) in a countrywide survey. Soil samples taken from the low-lying area of the Somers farm had higher (0.44 – 0.67 mg/l) molybdenum levels.

Extractable zinc values on the Somers farm were lower than on the other two farms. This is a reflection of the higher pH values on this farm.

Boron levels (*ca* 1.0 mg/kg) on the three farms fell within the normal range of occurrence for typical Irish soils and may be considered satisfactory.

In general, the levels of extractable manganese, copper, molybdenum, zinc and boron in the soils analysed from the Somers, Ryan and Control farms fell within the normal range. In particular there were no values that were likely to cause abnormal levels of these elements in herbage.

Total Soil Trace Elements

As there are no fully evaluated extractants for iodine, selenium and fluorine, their contents are reported as total values. Total cobalt levels in the soil, when viewed in conjunction with total manganese values provide a good guide to uptake of cobalt by plants.

Iodine values (*ca* 6-8 mg/kg in soil) on the three farms were consistent with Irish soil values reported by McGrath and Fleming (1988).

Selenium content of most of the soils from the three farms (0.35-1.10 mg/kg) was mainly low but fell within the range obtained for non-seleniferous Irish soils (Parle *et al.*, 1995). Three samples, from the low-lying area of the Somers farm, that were enriched in soil organic matter, had elevated values (2.4 – 3.9 mg/kg). These higher values were below those (Mayland, 1994) that could constitute an animal health problem.

Soils on the Control and Somers farms were satisfactory with regard to cobalt status (7.1 and 8.0 mg/kg). Although the soils from the Ryan farm had adequate cobalt, the high manganese (oxides) levels in these soils would reduce the cobalt availability to plants (Fleming, 1983).

Mean fluorine values for the soils from the three farms were 984, 675 and 697 mg/kg, respectively. These values appear high compared to mean values of 300-400 mg/kg for UK soils (Fuge and Andrews, 1988). No reliable information was available on fluorine levels in Irish soils. Therefore, as part of this investigation, fifteen additional samples were selected at random from soil received for analysis at Johnstown Castle analytical laboratories and were analysed. The mean value for soil fluorine was 461 mg/kg (ranging from 310-700 mg/kg). The latter values were comparable with most of those from the UK. However, the levels in the Limerick soils were consistently higher than most others. A further series of fluorine determinations were made from archived soil samples, that had been taken from points immediately north, south, east and west of each of the Askeaton farms. These soils had been sampled in 1979 as part of the Aughinish baseline survey (Fleming and Parle, 1983). They were found to have significantly elevated fluorine levels with means of 760, 578 and 760 mg/kg for the Somers, Ryan and Control farms, respectively. It should be noted that this fluorine is of geochemical origin and, being largely unavailable to plants and animals, is therefore of little toxicological significance.

In summary, iodine, cobalt and selenium levels were within the expected range for Irish soils. Both low and slightly elevated levels were found but were not considered unusual. Relatively high soil fluorine levels (> 650 mg/kg) were found to be a feature of the area.

Iron, Aluminium and Titanium
Average values of *ca* 20, 40 and 6 g/kg were found for iron, aluminium and titanium, respectively. These were within the typical ranges reported for Irish soils, with little variation between the soils from the three farms. Aluminium is toxic to plants in very acid soils. Its toxicity is essentially pH dependent and increases exponentially below a pH of 4.5 (Anderson, 1988). Symptoms of toxicity develop initially in the roots: subsequent effects vary with plant species but generally resemble those associated with nutrient deficiency, particularly that of phosphorus. The level of soil acidity that is required before aluminium toxicity could be envisaged was not found on any of the farms investigated.

In general, the analyses show that values for total soil iron, aluminum and titanium on the three farms were within the typical Irish range.

Heavy Metal Concentration in Soil
Values for total copper, zinc, chromium, nickel, vanadium, cadmium, lead, mercury and arsenic in the soil samples fell within typical ranges for these elements in Irish pastures soils (Table 3.7). There is a distinct area, representing about 0.3 of the farm area, on the western side of the Ryan farm, where zinc, cadmium, lead and arsenic values were somewhat elevated compared to other soils in the area. This was considered to have no significance and probably reflects geochemical contamination. Nickel values were higher than in most Irish soils but amounts were not unlike those in soils of South Kildare (McGrath and McCormack, 1999).

Table 3.7

Mean total heavy metal concentrations (mg/kg) of copper (Cu), zinc (Zn), chromium (Cr), nickel (Ni), vanadium (V), cadmium (Cd), lead (Pb), mercury (Hg) and arsenic (As) in soil on the Somers, Ryan and Control farms compared with typical values for Irish pasture soils.

Element	Somers	Ryan	Control	Typical pasture soils*
Cu	22.5	16.6	17.2	18.0
Zn	78	106	94	73
Cr	60	43	47	49
Ni	50	43	45	13
V	69	56	46	-
Cd	0.45	0.62	0.38	0.52
Pb	20	38	25	30
Hg	0.12	0.10	0.08	0.11
As	12.7	15.4	13.5	15.7

*McGrath and McCormack (1999)

Selenium and Fluorine in Soil Profiles
In order to confirm that the mild enrichment by selenium and fluorine of soils on the Somers farm was not due to aerial deposition, soils from two profiles were taken to two depths (175 and 225 mm – roughly equivalent to the plough layer). Neither selenium nor fluorine content varied with depth. This showed that selenium and fluorine had not significantly increased in this soil since it was last tilled.

Re-Sampling and Re-Analysis of Soils on the Somers Farm - November 1997
The Somers farm was re-sampled in November 1997. The sampling procedure was similar to that used in 1995, except that the cores were taken to a depth of 100 mm instead of 50 mm. Soils were analysed for extractable major and trace nutrients and for cobalt and manganese. The objective was to ensure that the fertility status of the soil on the farm had not been depressed since 1995.

The re-sampling and re-analysis of soils from the Somers farm two years after the initial sampling showed good agreement for each parameter indicating no major changes in soil fertility levels on the farm.

Sediment Samples
On the Somers farm two sediment samples were taken – one from a stream and the other from a drain. On the Ryan farm three samples were taken, one from a stream and two from water troughs. On the Control farm one sample was taken from a water trough.

The following elements were determined in the sediments - mercury, selenium, arsenic, chromium, lead, iron, nickel, cadmium, cobalt, vanadium, titanium and thallium. All values fell well within the ranges for soil samples received at the Johnstown Castle Analytical Laboratories. An elevated selenium value of 2.65 mg/kg was obtained for the sediment from the stream on the Ryan farm. A second elevated selenium value of 4.65 mg/kg was recorded for the sediment in the water trough on the Control farm. Selenium values in excess of 100 mg/kg have been reported for West Limerick stream sediments (Webb and Atkinson, 1965).

In summary, heavy metals concentrations in the six sediment samples taken from streams, drains and water troughs were not dissimilar to those reported for typical Irish soils..

Sampling and Analysis for Persistent Organic Compounds
Samples of soil were taken from the three farms and analysed for dioxins/furans and PAHs by the GfA laboratory in Germany (*see* Chapter Five) and for polychlorinated biphenyls (PCBs) by Teagasc. The two sampling locations on the Somers, Ryan and Control farms were in each case at a high elevation and open to the north and northwest. The samples were taken to a depth of 50 mm using a trowel.

The PCB analysis was conducted by the method described by McGrath (1994). Values of 0.79 and 0.71, 0.98 and 0.66, and 1.54 and 1.20 μg/kg were obtained for the samples from the Somers, Ryan and Control farms, respectively. These values are typical of those previously reported (McGrath, 1995) for Irish agricultural soils and were not indicative of pollution.

Analysis Of Herbage And Miscellaneous Biological Samples

<u>Background</u>

General Comments
Both herbage and fodder (silage and hay) samples were taken from the three farms for analysis. Even under controlled conditions, pasture herbage varies in mineral content throughout the year. Fertiliser treatment will obviously affect the mineral content of herbage but, even in the absence of applied fertiliser, seasonal and stage of growth effects combine to alter mineral composition. The magnitude of such changes varies depending on the element. In a study such as the present one where material consists of different herbage species at different stages of growth and from diverse pasture management systems, major element composition may vary by as much as twofold between maximum and minimum (Fleming and Murphy, 1968). Trace metals composition of herbage may vary even more, especially following contamination of herbage by soil.

Ranges of Elements in Pastures
At the present time it is known that for healthy growth plants need 19 elements, whereas 26 are needed by animals. The following elements are those required by plants:-

> carbon, hydrogen, oxygen, nitrogen, calcium, potassium, magnesium, phosphorus, sulphur, boron, chlorine, copper, iron, manganese, molybdenum, zinc, cobalt, silicon and sodium.

Cobalt is intimately connected with nitrogen fixation in legumes and therefore has been included in the list. Silicon is known to be essential for rice, and sodium is essential for plants adapted to saline environments. These two elements, though invariably present in normal herbage species, do not appear to be essential for their growth. In the case of animals, all the elements listed above are required together with the following

> arsenic, chromium, fluorine, iodine, nickel, selenium and vanadium.

The ranges of the above elements - with the exception of carbon, hydrogen and oxygen - normally found in Irish pasture herbage are shown in Tables 3.8 (major nutrients) and Table 3.9 (trace elements). An estimate of animal

Table 3.8

Typical ranges (g/kg) of major elements in non-polluted Irish pasture and recommended animal (cow, pregnant, non-lactating) requirements.

Element	Symbol	Herbage content	Typical concentration*	Animal requirement*
Calcium	Ca	2.0-17.0	6	2.9
Chlorine	Cl	2.0-20.0	3.5	2.0
Magnesium	Mg	0.8-5.0	2	1.6
Nitrogen	N	10.0-50.0	28	19.2
Phosphorus	P	1.0-5.0	4	2.3
Potassium	K	8.0-40.0	25	6.5
Silicon	Si	1.0-2.0	-	-
Sodium	Na	0.1-6.0	2.5	1.0
Sulphur	S	1.5-3.5	3.5	1.6

A dash (-) indicates lack of data : *Whitehead (2000).

Table 3.9

Typical ranges (mg/kg) of trace elements in non-polluted Irish pastures and recommended animal requirements.

Element	Symbol	Herbage content	Typical concentration*	Animal requirement*
Antimony	Sb	0.05-0.3	-	nil
Arsenic	As	0.05-0.3	-	-
Boron	B	1-20	5	nil
Cadmium	Cd	0.01-0.3	-	nil
Chromium	Cr	0.1-0.3	-	-
Cobalt	Co	0.03-0.2	0.1	0.10
Copper	Cu	2-15	-	-
Fluorine	F	0.5-10	9	-
Iodine	I	0.05-0.3	-	0.60
Iron	Fe	20-300	0.2	50
Lead	Pb	0.5-20	-	nil
Manganese	Mn	20-300	165	40
Mercury	Hg	0.01-0.05	-	nil
Molybdenum	Mo	0.05-2	0.8	0.2
Nickel	Ni	0.5-3	-	-
Selenium	Se	0.03-0.5	0.05	0.3
Thallium	Tl	<0.1	-	nil
Tin	Sn	0.1-0.5	-	-
Titanium	Ti	1-5	-	nil
Uranium	U	<0.05	-	nil
Vanadium	V	0.05-0.5	-	-
Zinc	Zn	20-60	37	40

A dash (-) indicates lack of data :*Whitehead (2000)

requirement for individual nutrients in herbage is also given (Whitehead, 2000). The latter figures only serve as a general guide as animal requirements vary with animal type, age and stage of development.

Seasonal Variation and Stage of Maturity

Changes in mineral composition of pasture plants occur over the growing season. The magnitudes of these changes differ with plant species, and not all elements are affected to the same extent. Management practices have a major influence on the variation in content, as do factors such as soil temperature, rainfall and fertiliser

applications. The growth of plants affects mineral content due to a dilution process. Fleming and Murphy (1968) and Fleming (1973) have described these effects.

Soil Contamination of Herbage
It is relatively simple to take an uncontaminated soil sample but it is much more difficult to obtain a soil-free herbage sample. Soil contamination of herbage can result from (1) trampling by grazing animals, particularly under intensive grazing; (2) splashing during rainfall and (3) dust deposition following a prolonged dry period.

The degree of contamination by an element will depend, not only on the proportion of soil present, but also on the ratio of the element in soil to that in the plant. It is possible to evaluate the extent of soil contamination of a pasture herbage sample by using the apparent content in herbage of elements with high soil/plant ratios. The most suitable element for this purpose is titanium for which a ratio as high as 10,000:1 has been demonstrated (Mitchell, 1960). In this investigation no attempt was made to separate plant from adhering soil. This was in order to ensure that whatever was on offer to animals should also be subjected to analysis.

Toxicity
A number of elements necessary for plant and/or animal health may be present in herbage in amounts sufficient to cause harm to grazing stock. Similar remarks apply to a number of "contaminant" elements, i.e. elements that fulfil no known useful function in plant or animal nutrition. It is not possible to give precise values for toxic elements in herbage for a number of reasons, including the fact that their toxicities may be enhanced or mitigated by the presence of other elements. A clear distinction must be drawn between toxicity of elements to animals and to plants. Susceptibility of a plant to a contaminant does not necessarily imply susceptibility of other plant species, nor of an animal species.

Herbage Sampling and Analysis

Sampling and Analytical Procedures
Grass was sampled close to ground level using an electric shears, taking care not to include excess soil. Sampled locations were the same as those used for soils. Samples from the one enclosure were bulked to comprise a single plot sample. These were dried at 104°C for general analysis and at 40°C for selenium, arsenic and mercury analysis. Procedures generally involved strong acid digestion and estimation by flame- or electrothermal- atomic absorption analysis, as appropriate (Byrne, 1979). Full results of the analyses are presented in the Soil, Herbage, Feed and Water Volume.

Herbage - Macronutrients
The herbage concentrations measured were within the typical ranges found on grassland farms. Phosphorus and calcium levels on the Control farm were low. Sulphur levels of the herbages, and in particular the nitrogen/sulphur ratio (averaging about 10), were considered normal for all three farms. On the Ryan farm sulphur levels in the herbage from fields on the eastern side of the farm were higher than those on the western side. Nitrogen levels were also elevated in this particular sample, which suggests a fertiliser effect.

Herbage sulphur values obtained in 1995 indicated no increase compared with the data obtained in the baseline studies for AAL in 1979 (Fleming and Parle, 1981) and the ESB Moneypoint plant in 1981 (Fleming and Parle, 1984) herbage samples. However, they conflict with the high herbage sulphur levels (5.0 g/ kg) determined in the area in 1994 (*Analytical results*, Johnstown Castle).

In summary, the nitrogen, sulphur and other macronutrients concentrations in the Askeaton herbage samples were typical of those in herbage from Irish grassland soils.

Herbage Sulphur
Background During the course of this investigation considerable attention has been devoted to the role that sulphur emissions could have in raising the sulphur content of herbage and thus influencing the nutrition of animals - particularly through reducing availability of copper and selenium. The perception that herbage sulphur was in fact elevated in the Askeaton area was given substance by a sampling conducted in 1994 on 14 farms surrounding the Somers farm. Analyses of herbage gave a mean value of 5.0 g/kg for herbage sulphur in that investigation. In this discussion, three aspects are considered (i) factors that influence herbage sulphur; (ii) normal sulphur levels in Ireland and (iii) analytical aspects.

Factors Influencing Herbage Sulphur Sulphur content of herbage is influenced by many factors including

stage of growth, and by plant, soil and climatic factors as well as by the amount of sulphur available from soil and atmospheric sources. Since both sulphur and nitrogen are components of plant proteins, amounts of both elements in the plant will tend to increase or decrease in parallel. The ratio of nitrogen to sulphur (N/S) in herbage is normally about 10:1. Thus wider ratios suggest sulphur deficiencies whereas narrower ratios suggest an excess of sulphur. Sulphur levels in herbage are generally within the range 2.7-6.7 g/kg (Whitehead, 2000). In recent years considerable attention in Ireland and elsewhere is directed to ensuring a sufficiency of sulphur for optimum herbage growth and quality. This is largely because atmospheric levels of sulphur have been reducing over the last 20 years in Western Europe and also because superphosphate (which can contain more sulphur than phosphorus) is no longer extensively used as a fertiliser.

Atmospheric sulphur dioxide concentration in the air averages about 6 $\mu g/m^3$ over much of the UK at the present time: in the 1970s it was *ca* 30 $\mu g/m^3$ even in rural areas (Campbell and Smith, 1996). Mean annual values for the Somers and Ryan farms for 1997 and 1998 were between 5 and 11 $\mu g/m^3$ (*see* Chapter Five), which is slightly higher than the UK value. However, it has been calculated (Bristow and Garwood, 1984) that mean sulphur dioxide values less than 17 $\mu g/m^3$ are unlikely to be sufficient to meet the sulphur requirement of grassland, in the absence of supplementary sulphur fertilization. Such considerations are necessarily crude and are subject to many influences but are more indicative of a sulphur deficit rather than a surplus for the growth of herbage in the Askeaton area.

In Ireland as much as 30 per cent of Irish grassland is believed to receive sulphur in amounts that are insufficient for optimum growth (Murphy and Boggan, 1988). Sulphur is now added to many nitrogenous fertilisers, although perhaps not yet in amounts sufficient to ensure a balance of sulphur and nitrogen.

Since many factors influence sulphur level in plants, herbage is considered to be a very poor indicator of atmospheric sulphur levels. However, herbage sulphur has a use, under controlled circumstances employing uniform swards in small experimental pots, for the determination of sulphur gradients with the objective of pinpointing an emission source. The objective here was to compare herbage sulphur levels in the Askeaton area with levels elsewhere using available Irish data. Excess dietary sulphur, particularly in association with high molybdenum intakes, inhibits copper absorption by the animal (as does high soil intakes). Sulphur also acts to reduce selenium absorption, in an incompletely comprehended fashion (Ryssen *et al.*, 1998). Fortunately in intensive agriculture, supplementation of feed with copper and other minerals is an economic and efficient way to ensure an adequate level of nutrition (Rogers and Gately, 1998).

Normal Herbage Sulphur Levels Data available at Teagasc, Johnstown Castle was compiled with a view to determining whether there has been any change in herbage sulphur nation-wide over the last 20 years and whether there was any evidence of a departure from the norm in the Askeaton area (Table 3.10). Information sources included (a) earlier baseline studies for Moneypoint and AAL; (b) similar studies for a number of mining developments; (c) a north Wexford farm and (d) a National Farm Profile compilation.

The herbage sulphur data pertaining to the Askeaton area are summarized in Table 3.11. They include (a) the sampling of 1994 that produced high sulphur values; (b) analyses conducted on the three farms in1995; (c) the monitoring program of 1995-1998, and (d) a set of herbage data from 12 locations (five farms). The latter were from the farms participating in the Retrospective Survey (*see* Chapter Two) and which were on record as having been received for analysis at Johnstown Castle between 1990 and 1994. It should be noted that Nutrient Profile Farms, which were generally high output farms, had high nitrogen usage and were thus disposed towards high nitrogen and consequently sulphur in the herbage. In all investigations the mean sulphur value equalled or exceeded 3.0 mg/kg, the maximum considered desirable for ruminants (Whitehead, 2000).

The frequency distribution of both sulphur concentrations (Table 3.12) and the nitrogen/sulphur ratios (Table 3.13) were examined for the AAL Baseline Survey, the Farm Nutrient Profile, the Somers, Ryan and Control farms and the results from monitoring Askeaton herbage between 1995 and 1998. Some high sulphur values and some low nitrogen/sulphur (sulphur enriched) ratios were found in all surveys. The greater proportion of sulphur-enriched samples was found in the Farm Nutrient Profile Survey. This survey had samples that were taken countrywide. The highest proportion of samples with low nitrogen/sulphur ratios were obtained for the samples from the AAL Baseline Survey in 1979. There is no evidence in the data to suggest that Askeaton herbages were more enriched with sulphur in 1995 than in 1979.

Sulphur Analytical Aspects One group, the set of 14 from the Askeaton area sampled in June 1994, did have anomalously high sulphur values and were difficult to explain (Table 3.11). These high sulphur herbage samples

Table 3.10

Nitrogen and sulphur levels and the nitrogen /sulphur ratio (N/S) in grazed pastures from a number of sources.

Source	Date Conducted	Number of samples	Nitrogen (g/kg)	Sulphur (g/kg)	N/S Ratio
(a) Moneypoint	**1981[1]**	**216**	**29**	**3.0**	**10.1**
	1982 (July/Aug)[1]	**49**	**31**	**3.0**	**10.3**
	1993 (Re-sampling)[2]	**52**	**30**	**2.9**	**10.8**
AAL	1979[3]	113	26	3.3	8.4
(b) Galmoy	1993 (April/May)[4]	154	39	3.6	10.9
	1993 (Sept/Oct)[4]	155	29	3.7	8.2
Lisheen	1991 (May/June)[4]	181	30	3.3	9.4
	1991 (October)[4]	185	32	3.4	9.2
(c) N. Wexford farm	1990 (June)[4]	36	31	3.7	8.8
	1990 (October)[4]	36	26	3.1	8.4
(d) Farm Nutrient Profile Survey	1991-1992[5]				
	March/June	57	39	4.1	9.7
	July/August	19	37	4.3	8.8
	Sept/Oct	72	40	4.3	9.4

[1] Fleming and Parle (1984)
[2] Coulter *et al.* (1994)
[3] Parle, *personal communication*
[4] Fleming and Parle, (1983)
[5] Gately and Blagden (1993)

Table 3.11

Summary of the sulphur and nitrogen levels and the nitrogen/sulphur (N/S) ratios in herbage samples from the Askeaton area.

Source	Date	Sample numbers	Nitrogen (g/kg)	Sulphur (g/kg)	N/S Ratio
(a) Adjacent to Somers Farm	July 1994	14	29.0	5.0	5.9
(b) Askeaton Somers Farm	May 1995	16	31.4	2.8	11.0
Ryan Farm		19	31.6	3.8	8.3
Control		15	29.5	2.9	10.2
(c) Monitoring Somers Farm	Nov. 1995-	72	37.5	3.6	10.5
Ryan Farm	Feb 1998	69	36.9	3.8	9.9
(d)Askeaton Retrospective*	1990-1994	12	28.9	3.6	8.6

*From Johnstown Castle archival data on samples received for analysis (B.S. Coulter, *personal communication*, 1998)

Table 3.12

Frequency distribution of herbage sulphur concentration from the Aughinish Baseline Survey - 1979, the Teagasc Farm Nutrient Profile Survey and samples from the Somers, Ryan, and Control farms, May 1995, and from monitoring Askeaton herbage between 1995 and 1998.

Range of sulphur (g/kg)	Aughinish Baseline Survey 1979	Farm Nutrient Profile Survey 1991 – 1992	Somers, Ryan and Control farms May 1995	Askeaton Herbage 1995 – 1998
<1.6	0.000	0.000	0.020	0.000
1.6 – 2.0	0.026	0.000	0.080	0.021
2.1 – 2.4	0.097	0.000	0.100	0.043
2.5 – 2.8	0.319	0.019	0.120	0.085
2.9 – 3.2	0.186	0.056	0.180	0.121
3.3 – 3.6	0.115	0.150	0.220	0.206
3.7 – 4.0	0.080	0.231	0.140	0.241
4.1 – 4.4	0.071	0.188	0.080	0.121
4.5 – 4.8	0.027	0.169	0.020	0.057
4.9 – 5.2	0.035	0.112	0.040	0.057
5.3 – 5.6	0.018	0.056	0.000	0.028
5.7 – 6.0	0.000	0.012	0.000	0.021
>6.1	0.027	0.006	0.000	0.000

Table 3.13

Frequency distribution of herbage nitrogen/sulphur ratio from the Aughinish Baseline Survey in 1979, the Teagasc Farm Nutrient Profile Survey and samples from the Somers, Ryan and Control farms, May 1995, and from monitoring Askeaton herbage between 1995 and 1998.

Nitrogen/ Sulphur Ratio	Aughinish Baseline Survey 1979	Farm Nutrient Profile Survey 1991 – 1992	Somers, Ryan and Control farms May 1995	Askeaton Herbage 1995 - 1998
3.1 – 4.0	0.009	0.000	0.000	0.000
4.1 – 5.0	0.044	0.000	0.000	0.007
5.1 – 6.0	0.080	0.012	0.000	0.007
6.1 – 7.0	0.097	0.062	0.080	0.071
7.1 – 8.0	0.204	0.119	0.100	0.078
8.1 – 9.0	0.265	0.219	0.200	0.163
9.1 – 10.0	0.133	0.250	0.220	0.156
10.1 – 11.0	0.071	0.162	0.140	0.149
11.1 – 12.0	0.053	0.075	0.080	0.156
12.1 – 13.0	0.027	0.056	0.080	0.106
13.1 – 14.0	0.000	0.018	0.060	0.078
>14.0	0.018	0.025	0.040	0.028

had been obtained from grazed paddocks adjacent to the Somers farm, before Teagasc began their systematic sampling of the three farms. Values were similar to those reported for areas in the UK where severe hypocupraemia occurs (Leech and Thornton, 1987). These 1994 herbage samples were subjected to re-analysis in 1995. The results are presented in Table 3.14. The results of the re-analysis were more typical even though their sulphur/nitrogen ratios were still slightly higher than normal.

It is possible to speculate on the reason for this, e.g. soil contamination of the 1994 samples or incorrect analytical procedures. The quantification of sulphur, as sulphate, involved measurement by nephelometry (turbidity) of barium sulphate in suspension.

Table 3.14

Mean sulphur values from analysis of herbage samples from Askeaton in July 1994 and from re-analysis in 1995.

Analysis Date	Year	Number of Samples	Sulphur (g/kg)
July 1994	1994	14	5.0
Re-analysis 1995	1995	13*	3.4

*Insufficient material for re-analysis of one sample

A characteristic of these 1994 herbage samples was their visibly high degree of contamination with soil. It would be reasonable to assume that contaminant soil, especially if it contained a high proportion of fine particles as would be expected in mid-summer (McGrath *et al.*, 1982), could interfere with sulphur estimation (since the process depends on the formation of a colloidal suspension of barium sulphate). However, no mention of this was found in the literature. Soil contamination also helps to explain the variability of the results that were experienced on repeat analysis. The performance of the laboratory during the period 1995 – 1997 has been subjected to evaluation in an international analytical programme with more than 50 participating laboratories. For sulphur in vegetation, the mean departure of the Johnstown Laboratory from the norm was 0.09.

There was no bias, as the departure from the mean was less than 0.01 when the direction of the error was considered. However, these results must be treated with caution, having regard to the fact that the original high sulphur values could not be substantiated and the unsatisfactory nature of the samples (they were seriously contaminated by soil).

In summary, there was no consistent evidence of elevated sulphur in the herbage samples from the Askeaton area. This accords with the conclusion of the external assessment undertaken by Dr N. F. Suttle (*see* Appendix 15, Animal Health volume) that the levels of atmospheric SO_2 in the Askeaton area are unlikely to be harmful to livestock or humans and, in particular, that "...the amounts of sulphur deposited from the atmosphere from combined industrial and marine sources are unlikely to raise herbage sulphur or lower herbage selenium to extents which have either physiologically or clinically detectabe effects in livestock". The elevated levels reported from the herbage sampling in 1994 are at variance with those recorded prior to and during the investigation. Re-analysis of the 1994 herbage samples did not support the original results. Therefore, the original analytical results must be regarded as unreliable.

Herbage – Trace Elements

Generally, the manganese concentrations in excess of 40 mg/kg were probably sufficient to satisfy animal needs (Radostits *et al.*, 1994). However, two paddocks on the Somers farm yielded herbage with low manganese values (35 and 45 mg/kg). Calcium values for herbage from this farm were high. It is believed that high calcium in herbage can depress manganese absorption by the animal (Cowgill *et al.*, 1980).

Copper, molybdenum and sulphur are considered together because of their interrelationships in animal nutrition. Copper values in herbage can be taken in general to be satisfactory as the mean values for the three farms are just slightly below the suggested requirement for animals, *i.e.* 10 mg/kg. Herbage samples from the Somers farm had lower copper values (< 8.0 mg/kg) reflecting the higher pH values.

Approximately half of the herbage samples from the Somers and Ryan farms had slightly elevated (*ca* 2 mg/kg) molybdenum values. These are such that they are unlikely to cause copper problems in animals. The lower molybdenum values on the Control farm again reflect the lower soil pH values.

Mean selenium levels in the herbage on all three farms were low (0.13, 0.07 and 0.04 mg/kg on the Somers, Ryan and Control farms, respectively). Almost half of the samples analysed from the Somers farm had very low values (<0.04 mg/kg). However, there were also some high values for herbage samples taken from a low-lying area, which was found to have elevated soil selenium.

Iodine values on the Somers and Control farms fell below accepted standards (Whitehead, 2000) but are typical for uncontaminated Irish herbage (McGrath and Fleming, 1988). The mean value for the Ryan farm is high

because some of the herbage samples were soil contaminated.

The zinc values on the Ryan and Control farms were within the typical range. However, half of the herbage samples from the Somers farm were decidedly low in zinc and 0.25 were at a level associated with animal health problems (Whitehead, 2000).

Boron levels in the herbage were satisfactory on all farms. Fluorine levels in the herbage from both the Somers and Ryan farms were somewhat elevated relative to those from the Control and reflect the extent to which herbage was contaminated by soil on these farms.

In summary, trace element levels in the herbage from the three farms were typical in an Irish context. It should be noted that some selenium, copper, iodine and zinc values were lower than those generally considered optimum for the nutrition of ruminants.

Herbage - Heavy Metals
The mean heavy metal composition of herbages from all farms was unexceptional (Table 3.15). Soil contamination

Table 3.15

Mean arsenic (As), mercury (Hg), lead (Pb), chromium (Cr), cadmium (Cd), nickel (Ni), iron (Fe), titanium (Ti), aluminium (Al) and vanadium (V) concentrations (mg/kg) of herbage samples from the Somers, Ryan and Control farms.

Element	Somers farm	Ryan farm	Control farm
As	0.54	0.58	0.19
Hg	0.02	0.02	0.02
Pb	1.23	2.72	1.58
Cr	0.67	0.96	0.48
Cd	0.09	0.16	0.08
Ni	1.70	2.93	2.33
Fe	309	432	158
Ti	33.3	71.4	21.2
Al	376	572	209
V	1.70	3.77	0.79

was clearly a factor where herbage samples tended to have high levels of some elements including iron, aluminum and titanium but also others such as iodine and fluorine. The fact that increases in all these elements invariably occurred concomitantly points to soil rather than aerial deposition as being the cause of such increases.

In summary, the heavy metal composition of herbages from all farms was unexceptional. No evidence was found to suggest aerial pollution of herbage by any element. Soil contamination of herbage accounted for any elevation of metals (e.g. iron, aluminum and titanium) encountered.

Miscellaneous Biological Samples
Two samples, (a) an aquatic plant from a stream and (b) an "algal mat" from a water trough were taken in March 1995 from the Ryan farm and analysed. The possibility existed that levels of elements in these samples might provide an indication of pollution. The calcium values were high in both samples (126 and 38 g/kg for the aquatic plant and algal mat, respectively). The calcium content of the aquatic plant was much higher than that reported for more familiar grass species and may indicate the presence of non-plant material. Sulphur values were elevated in both samples (7.8 and 8.2 g/kg, respectively) but were still comparable with those reported for some broad leaved plants as distinct from grasses which have relatively low sulphur contents. However, comparative information on sulphur content of these species is not available. The high titanium and elevated iron and aluminium values in the two samples suggest that both were contaminated with soil or sediment.

Monitoring of Herbage on the Somers and Ryan Farms, November 1995 - February 1998
Herbage was sampled (cut to ground level on four pre-selected paddocks at 4-8 weekly intervals) between November 1995 and February 1998 on the Somers and Ryan farms. Samples were analysed for nitrogen, sulphur, selenium and molybdenum. The results are summarised in Table 3.16.

Sulphur content of herbage averaged 3.5 g/kg which would be considered high by some animal nutritionists. Mean sulphur levels (with standard deviation) on the four individually sampled sites were 3.86 (0.77), 3.64 (0.73), 3.68 (0.86) and 3.29 (0.99) g/kg on the Somers farm and 4.04 (0.90), 3.66 (0.75), 3.52 (0.74) and 3.97 (0.86) mg/kg on the Ryan farm. On the Somers farm, higher values tended to be associated with proximity to the roadway and on the Ryan farm, with proximity to the mud flats on the River Deel, which bordered the eastern side of the farm, but none of these differences were statistically significant.

Individual sulphur values varied with nitrogen. Both herbage nitrogen and sulphur in samples, taken on the same occasion from different fields, differed sometimes by as much as two-fold. Winter values tended to be higher than summer values on average. In general, the ranges and mean values were similar to those previously encountered (Tables 3.11 and 3.12). There was no evidence that herbage on either farm, at any time between

November 1995 and February 1998, had unusually high sulphur content even though single field values as high as 5.7 and 5.6 mg/kg, respectively, were recorded on the Somers and Ryan farms.

Mean selenium levels (with SD) on the four individual sampled sites were 0.079 (0.044), 0.189 (0.076), 0.162 (0.099), and 0.100 (0.093) mg/kg on the Somers farm and 0.066 (0.038), 0.067 (0.045), 0.066 (0.027) and 0.070 (0.035) mg/kg on the Ryan farm. Differences between some of the sites on the Somers farm were statistically significant ($P \leq 0.05$) with higher levels on two paddocks.

Selenium values were generally higher on the Somers compared with the Ryan farm as anticipated (Table 3.16). Mean values were similar to or higher than mean Irish values (Table 3.17).

Table 3.16

Mean, maximum and minimum herbage sulphur (S) (g/kg), nitrogen (N) (g/kg), selenium (Se) (mg/kg) and molybdenum (Mo) (mg/kg) on the Somers and Ryan farms, 1995-1998. (For typical concentrations *see* Tables 3.8 and 3.9)

	Somers farm				**Ryan farm**			
	S	**N**	**Se**	**Mo**	**S**	**N**	**Se**	**Mo**
Mean	3.6	37.6	0.13	1.52	3.8	30.9	0.07	1.04
Maximum	5.2	49.0	0.28	2.34	5.2	52.0	0.15	2.78
Minimum	2.4	24.6	0.07	0.97	2.4	23.7	0.03	0.52

Table 3.17

The frequency distribution of selenium (mg/kg) levels in Irish pastures* 1986-1993.

	Range				
	0-0.05	**0.05-0.07**	**0.07-0.10**	**0.10-0.15**	**0.15-0.5**
Proportion of Samples	0.264	0.329	0.18	0.129	0.097

*Samples received for analysis at Johnstown Castle (P. Parle, personal *communication*, 1995)

Replicate selenium values for either farm on the same occasion varied considerably - by a factor of as much as five-fold. Indeed in their survey of the Askeaton area, Rogers and Poole (1984) have already highlighted the variation in herbage selenium within farms and between years. Winter values were higher than summer values, a fact that Haygarth *et al.* (1993) have also noted. Regression analysis showed that increase in herbage selenium was unrelated to increases in herbage sulphur.. A similar situation has been reported for atmospheric levels of these elements in areas suffering from low levels of pollution. A highly significant relationship between the two elements occurred when pollution levels were high and sources numerous (Eldred, 1997). Much of plant sulphur (Whitehead, 2000) and selenium (Haygarth, *et al.*, 1993) is derived from atmospheric sources. The pattern of relationships in Askeaton was considered to be consistent with a comparatively small number of local emission sources for both elements, for example, households and small industries rather than large industries.

Levels of selenium on all parts of the Ryan farm were generally low with means of 0.06 - 0.07 mg/kg over the period. Levels during the grazing season generally ranged from 0.04 to 0.06mg/ kg. These values, which might be considered low by some animal nutritionists, are not unexpected in the Irish (Table 3.17) or Scottish (Price, 1989) contexts. Indeed, Price has argued that the risk of selenium responsive disorders developing in ruminants is not significant at dietary selenium levels as low as 0.03 mg/kg in herbage.

Molybdenum values varied to a similar extent to selenium. Mean farm values (1.5 and 1.0 mg/kg) were lower than had previously been found for the same plots in May 1995 (1.8 and 2.0 g/kg). On both the Somers and Ryan farms molybdenum values were never so high as to present a serious risk of affecting copper absorption by the animal.

In summary, monitoring of herbage nitrogen, sulphur, selenium and molybdenum from November 1995 to February 1998 on the Somers and Ryan farms confirmed that mean levels of these elements were essentially similar to those reported in the initial herbage sampling of May 1995. However, variations in the element levels occurred depending on sampling time and location.

Water Analysis

Farm Tap Water

Water samples were taken from farmyard locations in March 1995. Samples were analysed for bacterial and chemical constituents including heavy metals. Results were compared with Maximum Allowable Concentrations (MAC) as given in the Drinking Water Regulations (Minister for the Environment, 1988).

Somers Farm
Total and faecal coliforms values were above the MAC value. This would normally render the sample unsuitable for drinking. The sample contained 18 mg/l of suspended solids, which was also outside the MAC. It is possible that the contamination came from the black plastic tube that was loosely connected to the tap and trailed along the ground.

Ryan Farm
All analyses were below the MACs.

Control Farm
Potassium was higher than the MAC. Coliforms exceeded the MAC. The possible cause of the contamination appears to be a plastic tube, very similar to the situation on the Somers farm noted above.

Water from the taps at the Somers and Control farms was re-sampled in August 1995. Results showed that there was some bacterial contamination of the tap water on both farms. The reason for the elevated potassium on the Control Farm was not discovered.

Stream and Drain Water

Water samples were taken and analysed from the streams running through the Somers and Ryan farms, together with a sample from the drain on Somers Farm. The results were compared with the national standards set for surface water used as a source of public supply in the Surface Water Regulations (Minister for the Environment, 1989). Drain water from Somers farm were slightly above the limit value for BOD. The chemical properties for stream and drain waters were within the limit values for surface water. There were total and faecal coliforms

present which was indicative of bacterial contamination.

Trough Water

Samples were taken from the water troughs on all three farms. On the Ryan farm, three animal drinking troughs were sampled. The results were compared with MACs for drinking water. All samples were within MACs with the following exceptions. The coliforms in the samples from the Somers farm and from one trough on the Ryan farm exceeded the MAC. There was a low level of BOD present in all troughs sampled. Potassium was higher than the limit on the Control farm sample and there were suspended solids in samples from the Ryan and Control farm drinking troughs. A second trough on the Ryan farm was just outside the MAC for manganese.

In summary, no evidence was found of contaminants in the water samples collected from farm taps, streams/drains, and farm water troughs on the Somers, Ryan and Control farms other than bacterial contamination of some tap and stream water supplies.

Concentrates and Mineral Mixtures

Samples of the following concentrate feed and mineral mixtures samples were taken from farms.

Somers farm	-	Concentrates – Beef nuts, beef/dairy nuts, calf nuts.
		Mineral mixture – Dairy mix and Calf/beef mix.
Ryan farm	-	Concentrates – Beef dairy nuts
		Mineral mixtures - Dairy & Suckler (precalving) mix.

Analytical data for the three concentrates and for two mineral mixtures from the Somers farm and for one concentrate and one mix from the Ryan farm were compared with the manufacturers' certified values. Values obtained fall within the acceptable parameters for these products, except for the cadmium, which was slightly elevated in the concentrates and was elevated in a Calf/beef mix and particularly so in a Dairy mix (1.80 mg/kg). Use of this material will however have little effect on the cadmium intake of the animal.

In general, results of chemical analysis of feed and mineral mixtures obtained from the Somers and Ryan farms were in agreement with the manufacturer's certified values.

Fodder Analysis

In 1995, two samples of first cut silage (presumably made in 1994) were taken from the Somers farm, one baled and one from the pit face. A sample of a second cut silage was taken from a pit. Two samples of first cut were taken from the Ryan farm - both baled. Two samples of first cut were taken from the Control farm - both from the pit face. This silage may have been imported from an area outside the Control farm itself. A sample of hay was taken from both the Somers and Ryan farms.

In general, the nutritive value of silage - dry matter digestibility (DMD) - from the Somers and Ryan farms must be regarded as low at 650 and 600 g/kg, respectively. A survey of silage quality for samples received at Grange (Keating and O'Kiely, 1997a) has shown that mean DMD for first-cut silage was 637, 692, 678 and 695 g/kg, respectively, for the years 1993, 1994, 1995 and 1996. Digestibility of second cut silage was about 10 units lower than first cut silage and baled silage was 20 units lower (Keating and O'Kiely, 1997b). Silage from County Limerick was the third lowest ranked by county and averaged 647 g/kg for first cut over the period. Thus, the nutritive value of silages from the Somers and Ryan farms may be regarded as low in the national context but locally normal.

The concentrations of chromium, nickel, aluminium, titanium, iron and vanadium in the Somers and Ryan farm silages were indicative of a high degree of contamination with soil. The concentrations of these elements for the Control Farm silages were typical of those generally obtained for Irish silages.

Mineral analyses of the hay samples fell within the typical Irish ranges. Aluminium, iron and titanium were elevated indicating soil contamination. Silages made in 1996/1997 on the Somers and Ryan farms were, on average, of better quality than they had been in 1995, i.e. mean DMD was 670 and 698 compared to 630 and 635 g/kg, respectively, for the Somers and Ryan farms. Preservation quality was poor in both 1995 and 1996.

In summary, the nutritive value of silage from the Somers and Ryan farms was similar to the mean values reported for Limerick silages but was low when compared to national values. Silage had a higher nutritive value in 1997 than in 1995, with mean dry matter digestibility (DMDs) of approximately 680g/kg compared to 630g/kg. As with grazed herbage, herbage from fields closed for silage gave no indication of having suffered pollution from heavy metals.

Analysis For Longitudinal Study

These analyses formed part of the Longitudinal and Retrospective studies conducted by the VLS (see Chapter Two). Farms LS1, LS2, LS3 and LS5 in the Longitudinal Study were designated RS05, RS06, RS07 and RS09, respectively, in the Retrospective Study.

Soils were sampled to a depth of 100 mm on two grazed and two silage paddocks on each farm. Some of the paddocks clearly had a requirement for phosphorus and potassium. A number of paddocks especially on Farm LS3 appeared to be low in available copper. Trace element (zinc, cadmium, nickel, lead) values for soils from Farm LS2 tended to be slightly elevated and this was attributed to mild geochemical (i.*e.* natural) pollution.

There was an indication of sulphur deficiency in some of the herbages (high nitrogen, low sulphur). Sulphur deficiency in herbage is most common in mid-summer herbage (the time of the second silage cut), especially on free draining soils, and is nowadays regarded as quite prevalent. Selenium levels were low and molybdenum levels were moderately elevated in herbage. Herbage manganese concentrations at 8 and 20.0 mg/kg were very low in two of the four herbage samples from LS3.

The sampling programme for soil and herbage was repeated in November 1997 with Farm LS1 (two paddocks) being included on this occasion. The incidence of some low soil nutrient values was confirmed. Herbage sulphur was elevated on one paddock on Farm LS 5 in both July and in November. Herbage selenium and copper was higher in November when, in addition, molybdenum was moderately raised in some herbage samples. Since Farm LS1 was not included in the July sampling, additional soil analyses were performed on the November soil samples from this farm. Cadmium values were slightly elevated but parameter values were otherwise normal. Manganese values were satisfactory for all herbage samples in November.

Silages were collected in November 1996 from all farms. Preservation quality was erratic and nutritive values (DMD) were poor on some farms. Low values for manganese on Farm LS3 was again noted.

In general, analysis of soil herbage and silage from the four farms that participated in the Longitudinal Study indicated that soil phosphorus levels were low at a number of locations. Mild geochemical pollution by cadmium and molybdenum was noted. Nutritive value of silage from two farms was poor.

Analysis For Retrospective Survey

Nature of the Investigation

This investigation was conducted in order to complement the veterinary Retrospective Study that was initiated in December 1995 and which was designed to cover a maximum of 25 farms with self-attributed problems (*see* Chapter Two). Samples of soil and herbage were taken in July 1997 and again in November 1997. On the first occasion silage samples were also taken.

Soils were sampled to a depth of 100 mm on 2 ha plots from one or two grazing and silage areas on each farm. In July 1997, 47 paddocks on 21 farms were sampled and in November 48 paddocks on 22 farms. Herbage was taken from each area sampled for soil. Silages (20) and a hay sample were taken from each farm where available. Analyses were conducted for a wide range of relevant parameters.

Soil

Variations in soil properties displayed by Retrospective Study farms were considerably greater than those found for the Somers, Ryan and Control farms, which is not surprising, as soil variability is known to increase with area. Values for soil pH, and for extractable phosphorus, potassium, magnesium, copper, zinc and manganese (not shown in Table 3.18 below) were not unusual, varying from moderately deficient to moderately enriched.

Soil pHs in particular were generally on the high side, reflecting the limestone parent material. The metals, copper, manganese and cobalt were general present at normal concentrations. Fluorine levels were higher than those found in most other parts of Ireland. They were similar to those recorded for the Ryan and Control farms in the 1995 investigation but were lower than those on the Somers Farm. Nickel values were on the high side and chromium (with which nickel is generally positively associated) tended to be low. Selenium and lead levels were perhaps slightly elevated on average (Table 3.18).

Table 3.18

Mean, minimum and maximum concentrations (mg/kg) for cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), fluorine (F), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn) concentrations with standard deviations (SD) in 47 soil samples, taken in July 1997, from farms participating in the Retrospective Study.

	Concentration			
Component	**Mean**	**SD**	**Minimum**	**Maximum**
Cd	1.06	0.73	0.20	4.04
Co	10.3	2.8	3.4	15.6
Cr	25.1	6.7	10.8	47.4
Cu	21.6	10.6	11.6	58.6
F	674	164	330	1070
Ni	35.9	10.4	10.9	59.1
Pb	73.8	112.5	17.1	789.0
Se	1.06	2.06	0.40	14.50
Zn	117.9	49.1	46.4	376.7

Elevated cadmium values were attributed to the proximity of the Clare shale out-crop which runs generally in a north-south direction and crosses the Shannon near Foynes. Cadmium is now viewed as a negative component of soils and levels in excess of 1 mg/kg are generally taken as constituting contamination. The level of cadmium pollution, generally 1-2 mg/kg, was mild but widespread, extending to more than half of the soils analysed.

Three soils differed considerably from the norm. One soil had a relatively high level of selenium which could be considered dangerous to grazing animals: very high levels of this element are associated with the peaty phase of alluvial soils occurring in small pockets in a number of areas including south-west Limerick. A second soil had a particularly high level of lead, approaching 800 mg/kg. Such a level, while exceeding normal background by a factor of about 30, would not normally have a measurable impact on plant or animal when confined to a small area but could do so under exceptional circumstances (e.g. major dust blow or access to flooded areas by young animals). Zinc, at nearly 400 mg/kg, was particularly high in a third soil. At such a level the possibility of inhibition of plant growth arises. From existing information it seems likely that these three instances of elevated selenium, lead and zinc had a geochemical origin.

Herbage

Analyses for herbage nitrogen, phosphorus, potassium magnesium, sodium, calcium and sulphur (Table 3.19) indicated fairly normal ranges with the occasional high value. While some high values for sulphur were recorded, there were others of less than 2.0 mg/kg, which raise the possibility of sulphur deficiency. With respect to trace components, selenium levels, although within the normal range, included some very low values (viz. 0.03 mg /kg). Herbage from the area of high soil selenium also had elevated selenium (4.90 mg/kg). Two of the manganese values at 8 and 20 mg/ kg were exceptionally low for an Irish herbage. These samples came from soils of high pH (7.4). High pH is a feature in the production of manganese deficient herbage. As noted above, soils in the area have generally normal, and arguably even slightly elevated, levels of manganese.

Table 3.19

Mean, minimum and maximum concentrations for nitrogen (N), sulphur (S), cadmium (Cd), chromium (Cr), copper (Cu), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) and manganese (Mn) and standard deviation (SD) for 47 herbage samples, taken in July 1997, from farms participating in the Retrospective Study.

Component	Mean	SD	Minimum	Maximum
N (g/kg)	32.0	10.1	12.6	48.8
S (g/kg)	3.0	0.6	1.0	4.7
Cd (mg/kg)	0.16	0.25	0.02	1.66
Cr (mg/kg)	0.37	0.26	0.04	1.10
Cu (mg/kg)	10.1	2.3	5.9	15.2
Mo (mg/kg)	2.2	2.7	0.3	17.0
Ni (mg/kg)	2.27	1.19	0.47	5.74
Pb (mg/kg)	0.64	0.75	0.10	4.00
Se (mg/kg)	0.20	0.71	0.03	4.90
Zn (mg/kg)	40.3	30.3	20.0	236.2
Mn (mg/kg)	146	105	8.0	517

Zinc and copper levels were unexceptional. However, a number of samples had elevated molybdenum. This was not unexpected since the area covered overlaps considerably that delineated in 1966 as having elevated environmental levels of this element (Thornton *et al.*, 1966). This suggests the possibility of a more marked elevation of molybdenum later in the year, since its uptake by plants is strongly influenced by soil moisture. Values for herbage in November were similar to those found for the July sampling. Calcium was considerably reduced in November samples, a feature that has been encountered previously at this time of year.

Most nitrogen, phosphorus, potassium, magnesium, sodium and sulphur values were greater in November than in July samples. However, the high July selenium value (4.90 mg/kg) was reduced to 0.54 mg/kg in November. Manganese, zinc and copper values were similar on both sampling dates. However, molybdenum was on average twice as high in November compared to July and averaged 4.3 mg/kg. Three paddocks had herbage molybdenum values exceeding10 mg/kg whereas an additional 17 had values of 3.0 mg/kg or higher. This is the level at which interference with copper metabolism in the ruminant can be considered to arise.

Fodder

Two samples were excluded from the statistical analysis. The first was a hay sample. The second sample though nominally a silage had a dry matter of 629 mg/kg and a pH of 6.5. The remaining silage samples were generally adequately preserved (Table 3.20). The DMD of many of the samples, however, was clearly less than adequate. Mean DMD for the group was low (633g/kg) but normal for the area. The concentrations in the samples of major elements and trace elements included values that were less than those found in fresh herbage for some components, notably nitrogen, sulphur and phosphorus (Table 3.20). Instances of high selenium, cadmium, zinc and lead that were recorded for herbage from silage ground were not reflected in the silage samples. Three silages had manganese values below 40 mg/kg.

In summary, soils on farms participating in the Retrospective Study had values for pH and for extractable phosphorus, potassium, magnesium, copper, zinc and manganese that were not unusual - varying from moderately deficient to moderately enriched. Total copper, manganese and cobalt were generally present at normal concentrations. Heavy metal levels on the farms were within the expected range except that three soils differed markedly from this pattern. One soil had a relatively high content of selenium, a second of lead and a third of zinc. Half the soils had mildly elevated cadmium. It is highly likely that these instances are of geochemical (i.e. natural) origin. Major element content of herbage was unexceptional. Of the trace elements, molybdenum was seriously elevated in some herbages and selenium in another. Manganese was extremely low in

Table 3.20

Mean, minimum and maximum concentrations for DMD, pH, nitrogen (N), sulphur (S), cadmium (Cd), chromium (Cr), copper (Cu), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) and manganese (Mn) and the standard deviation (SD), for 20 silages and one hay, taken in July 1997 from farms participating in the Retrospective Study.

Component	Mean	SD	Minimum	Maximum
DMD	633	67	495	717
pH	4.2	0.4	3.7	4.9
N (g/ kg)	17.2	3.5	10.6	24.4
S (g/ kg)	1.7	0.3	1.2	2.4
Cd (mg/ kg)	0.15	0.08	0.04	0.33
Cr (mg/ kg	1.11	0.82	0.28	3.29
Cu (mg/kg)	7.1	2.2	2.9	10.8
Mo (mg/kg)	1.30	0.85	0.50	4.20
Ni (mg/ kg)	2.26	1.10	0.47	4.76
Pb (mg/ kg)	0.68	0.59	0.13	2.14
Se (mg/ kg)	0.08	0.05	0.04	0.23
Zn (mg/ kg)	30.4	5.9	19.5	40.5
Mn (mg/ kg)	148	97	35	313

some herbage samples from one farm. However, it is considered unlikely that any of the above contributed significantly to the animal health problem as indicated to the investigators.

Follow-up Investigation of Three Instances of Severe Geochemical Contamination

Selenium
The silage area on Farm RS15 in the Retrospective Study was re-sampled in June of 1998. The sampled area comprised a single low-lying field, marshy and suited mainly to the production of hay in most years. The field excluding border areas was divided into eight approximately equal plots of 0.20 ha each. Samples of soils (0-100 mm) and herbage (mature grass for silage) were taken from each plot. The selenium content of soil ranged from 13.5 - 22.5 mg/ kg (mean 17.6: SD 3.8) and of herbage ranged from 1.20 to 5.40 mg/kg (mean 2.72: SD 1.4). These values confirmed the belief that selenium toxicity to animals was a real possibility where conditions favoured plant uptake of the element.

Zinc
Soil samples were taken from 11 sub-plots within the area of elevated zinc on Farm RS24. The soil had been tilled in the period since the previously sampling. Analysis of samples confirmed the presence of high soil zinc (221 – 1596 mg/kg; mean 479, SD 405) and lead (93 – 1234 mg/ kg; mean 256, SD 329). The area with the highest values was characterised by the presence of darker soil compared to its surrounds. Soil with highest zinc value had a higher than normal proportion of the element in plant-available form (364 mg/l EDTA-extractable) suggesting that it would be phytotoxic especially to newly established plant species.

Foliage samples with different degrees of chlorosis were taken from potato plants on Farm RS24. Analysis showed that zinc content increased (up to 314 mg/kg) in parallel with injury observed in plant. More significant perhaps was the elevated cadmium (3.2-4.2 mg/kg) in all three foliage samples. Lead was also elevated in one potato plant sample (24.9 mg/ kg), which also exhibited severe growth retardation.

Lead
Soil was obtained from Farm RS31, grazing area, sub-divided into seven sections each of ca 0.15 ha. Soil lead ranged from 176 - 1653 mg/kg (mean 613, SD 507). It is now known that the site overlaid a disused lead mine. Whereas grass or other plants would not be expected to suffer growth reduction or to assimilate high quantities of lead, nevertheless the presence of very high amounts in soil could be dangerous to livestock by direct ingestion.

In summary, an excess of zinc, that was sufficient to inhibit plant growth, was measured in soil on one farm.

Levels of lead on this farm, and also on another, were sufficiently high to suggest the possibility of lead toxicity to grazing animals under adverse conditions at the sampled sites. Selenium was found at toxic concentrations in herbage on a third farm. Molybdenum content of herbage was seriously elevated in half of the samples taken on one occasion. All these features are considered to result from natural causes.

Botanical Survey

The Somers, Ryan and Control farms were visited initially in March and again in May 1995. On both occasions observations were made in the field on the botanical composition of the pastures. Herbage samples taken in May were examined in detail at the laboratory for species composition.

First Survey - March and May 1995

Somers farm

The farm appears to have been originally in nine fields. A few field boundaries have been removed entirely, a farm road has been built and some of the bigger fields have been sub-divided into paddocks with electric fences. The farm is all in grass. A few paddocks, have been reseeded in the last ten years. At the time of inspection in March, the farm had been heavily grazed. Some young cattle were out wintered on silage on the highest part of the farm.

There were clear signs of grazing of hedgerows and hedge banks on the farm. The ground was often totally poached in a narrow strip running along the base of a hedgerow or field boundary. Grasses, herbs, ivy and briars around the edges of five paddocks showed signs of having been grazed in recent months. Poaching in March had damaged the surfaces of most paddocks. Degree of poaching was estimated to vary mainly from slight to moderate and was severe on two paddocks where cows were being outwintered.

All of the normal grassland paddocks are of the (more productive) *Lolio-Cynosuretum* type and include significant levels of higher quality grasses including ryegrasses. This would account for about three quarters of the farm. The remaining section consists of the Marsh area. These had a mean cover of ryegrass (perennial and Italian combined) in late March of 0.28. This had risen to 0.50 by the middle of May. This compares with a mean of 0.62 from a detailed survey of ten intensive dairy farms in 1982 in the Cork/Waterford area. High ryegrass content in the swards is generally associated with successful dairy farming in Western Europe.

A separate herbage sampling of the farm was conducted for chemical analysis in May. The botanical composition of these fresh herbage samples was determined at Johnstown Castle allowing the contribution to the yield of the different grass species present to be assessed. There was a mean contribution to the yield by the ryegrass of 0.42 which is close to that of 0.50 obtained by qualitative examination of the paddocks.

As noted above, when the farm was first visited in March it had all been severely grazed in previous months. The mean grass height on all paddocks was 50 mm or less. There was a dramatic improvement observed when visited again in May. The paddocks that were closed for silage had a dense, lush, grass growth about 450 mm tall. Even the paddocks, which were being grazed, were showing good grass recovery. Most paddocks had cover of 0.40 or more of ryegrass. The only area still showing poor growth was the wet area in the north east of the farm. It had a very low ryegrass content and was dominated instead by slow-growing marsh species.

There was virtually no sign of poisonous weeds on the farm. Ragwort (*Senecio jacobea*) was virtually absent.

In summary, the proportion of desirable grass species in the pastures on the Somers farm was lower than would be expected on intensive dairy farms.

Investigation of Purple Coloration of Grass on the Somers Farm

The owners sought advice from Teagasc on two occasions regarding a purple colour on the leaves of the grass in silage or grazed grass.

1) Purple veins in grasses in the 1994 silage were observed and reported. The grass was examined and found to be Yorkshire fog (*Holcus lanatus*). Purple veins are a characteristic of the leaf sheaths of Yorkshire fog.

2) Purpling of grass leaves in the pasture was observed in June 1995. The affected pastures were examined on

June 21. Plots that had been recently grazed had little herbage remaining. At the time of the visit there was no grass with purple leaves in these plots. One of the ungrazed plots, with purple coloured leaves visible, was selected and examined.

The pasture had the general appearance of nitrogen deficiency, *i.e.* pale green colour and relatively poor grass growth. It had a large number of dung and urine patches where more vigorous growth, with dark green grass, was observed. There were no purple tinted leaves observed in the grasses growing in the dung and urine patches.

The pasture had grasses with purple tinted leaves. Visual examination revealed that the tinges were confined to *Lolium multiflorum* (Italian ryegrass). This species of grass is unusual in grazed pastures and is used primarily for the production of silage. It was present only in small amounts. The purpling was more pronounced on the upper sides of the leaves. It was not observed on *Lolium perenne* (perennial ryegrass).

A pink/purple colour is commonly found in *Lolium* species on the leaf sheaths. The colour is more pronounced when the plants are exposed to bright light *e.g.* in a sparse or weak sward. The purple leaf tinges on the *Lolium multiflorum* on the Somers farm were distinct from the normal colours associated with healthy *Lolium* species.

A total of three grass samples were taken from one field for analysis. The first sample was *Lolium multiflorum* with purple tinted leaves from the grazing area. The second sample was *Lolium multiflorum*, without purple tinted leaves, from dung and urine patches. The third sample was *Lolium perenne*, without purple tinted leaves, from dung and urine patches. Two other *Lolium multiflorum* samples (from west Cork) with similar purple tints to those observed on the Somers farm were secured and included in the analysis. The samples were analysed as whole plants, leaves only and stem only. The chemical analysis included nitrogen, phosphorus, potassium, magnesium, sodium, calcium, sulphur and manganese. There were no major differences between the analysis results on similar plant parts, except for nitrogen which was low (21 g/kg or less) in leaves from all purple plants compared to greater than 35 g/kg in green leaves.

The symptoms observed in the *Lolium multiflorum* are typical of that grass when it is suffering from nutrient deficiency, especially nitrogen and phosphorus. Purpling of the leaves is not as common in the slower growing *Lolium perenne* and other grasses compared to *Lolium multiflorum*. The higher growth rate of *Lolium multiflorum* requires a greater nitrogen supply than its slower growing counterparts.

It is concluded, therefore, that a reduced nitrogen supply was responsible for the purple coloration observed on the leaves of *Lolium multiflorum* on the Somers Farm in June 1995.

Ryan Farm

The farm was composed of eight fields some of which had been sub-divided for management purposes by electric fences to give 12 paddocks. A botanical examination of the farm was carried out in March and again in May. The grassland area of the farm had been grazed during the winter. There was little standing crop of grass on the fields in March. Poaching had damaged the surface of most paddocks. Damage ranged from slight to severe with two paddocks in the latter category. When visited again in May grass growth was poor and the height of the standing crop had only increased slightly. There were no fields closed for hay or silage at the time of the May visit.

Only three of the 12 paddocks were of the (less productive) *Centaureo – Cynosuretum* type. All the paddocks, except one, which was reseeded in 1988, were in old permanent pasture. Ryegrass cover in late March was 0.18 and had risen to only 0.24 by the middle of May.

There were intermittent hedges along the lines of the field boundary walls. The hedges were typically dominated by hawthorn (*Crataegus monogyna*) and blackberry (*Rubus spp*) (O'Sullivan, 1995). There were signs of localised grazing of hedgerows, particularly in paddocks where cows had been out wintered.

Two poisonous weeds were noted on the farm, viz cuckoo pint (*Arum maculatum*) and ragwort (*Senecio jacobea*). The cuckoo pint grew along the base of the hedges, especially in two paddocks. Ragwort was present in six paddocks but the infestation rate was low in all cases.

In summary, the grassland on the Ryan farm was of medium to poor quality, in terms of species composition, for an intensive dairy farm with only one paddock having more than 0.50 ryegrass cover in May 1995 and many

having less than 0.30.

Investigation of White Encrustations on Grassland Plants on the Ryan Farm
During a Teagasc visit to the farm in late August 1995, attention was drawn to a whitish encrustation on some of the grassland plants. Two samples were taken, (1) leaves of dandelion with whitish material on both sides of leaves and (2) leaves of mainly perennial ryegrass with dusty, whitish deposit on them.

The samples were examined microscopically the next day at Johnstown Castle. The whitish, dusty material on the samples was provisionally identified as a powdery mildew. The two samples were sent on the same day to the Plant Pathology and Entomology Department at Teagasc Oak Park, Carlow. A third sample was included, namely sow-thistle growing near the laboratories at Johnstown, which also had a powdery white material on the leaf surfaces.

The white material on the surfaces of the dandelion and sow-thistle leaves was confirmed as powdery mildew by Oak Park. There were powdery mildew lesions on the grass leaves also. Powdery mildew is favoured by dry warm weather and was very prevalent in 1995.

Control Farm
The farm is in permanent grassland. The paddock separated from the main farm is mainly used for silage. The grassland had been grazed up to December 1994. On the March visit most fields had a sward cover of at least 0.75 and the general grass height at that time varied between 50 and 100 mm. Poaching damage from grazing animals was minimal in all paddocks.

A botanical examination of the farm was carried out on March 22 and again on May 15. All the swards were of the *Lolio-Cynosuretum* type. They were all dominated by perennial ryegrass (*Lolium perenne*). The main accompanying grasses were meadow grass (*Poa trivialis* and *Poa annua*), Yorkshire fog (*Holcus lanatus*) and common bentgrass (*Agrostis tenuis*). All the swards were at least 20 years old. Broad-leaved weeds were generally scarce. Broad-leaved dock (*Rumex obtusifolius*) was common in a number of paddocks when visited in March.

The paddocks were typically surrounded by hawthorn (*Crataegus*) hedges. There were occasional trees, generally of ash (*Fraxinus*).

There was no sign of any grazing by livestock of either the hedgerows or the vegetation on the walls and banks. No poisonous species were noted, either in the fields or along the boundaries except for a trace occurrence of cuckoo pint (*Arum maculatum*) at the edge of one paddock. Ragwort (*Senecio jacobea*) was scarce or absent from most paddocks.

In summary, the species composition of the grassland on the Control farm was typically of those associated with intensive dairy farms.

Additional Botanical Investigations – Trees and Shrubs

Somers and Ryan Farms August 1995
The Somers farm was visited on August 23, 1995. A brief visual assessment of the trees on the farm was undertaken. The farm is moderately exposed to the prevailing southwest and west winds, being situated close to the Shannon estuary. It should be borne in mind that the survey was carried out after a prolonged and very sunny dry spell, which had placed trees all over the country under stress.

Conifer Trees Several conifer trees (cypress species), of approximately 5-8 m in height, situated near the Somers farm entrance were dead. Lawson's cypress is hardy to spring frosts but is not suitable for use on exposed sites. Unlike many conifers it withstands atmospheric pollution well. Some cypress species are known to be intolerant of exposure and salt pollution. One tree still had a portion of live material with a live crown and one live side branch on the sheltered side. There was no sign of any physical damage or disease on the live portion of the tree, which looked healthy. It was not possible to make any definite assessment of the cause of death of these trees. A possible cause of death is exposure. A nearby Monterey cypress, which is tolerant of both sea coast conditions, salt spray and exposure was showing no obvious sign of damage. Another row of cypress of a different variety along the driveway into the farm were healthy but showing signs of dieback on the

lower branches, which is typical for this variety. Other conifers in the immediate area were mostly healthy but showed signs of climatic exposure.

Broadleaved trees The hawthorn hedgerow shrubs showed some signs of twig die back, particularly on the exposed side, but this is typical for this species in exposed areas. Similar defoliation of very small twigs was noted at the Teagasc Research Centre in Kinsealy, Co. Dublin at the time. The ash in the hedgerows looked healthy.

At the Ryan farm, sycamore trees at the entrance, which were pointed out, were suffering from Tar Spot and Leaf Blister and some aphids were present. All of these, pest and diseases, are common on sycamore. There was also some browning of the leaf edges, which has been observed elsewhere in the country. It may be attributed to sun scorch or drought. Some of the trees on the driveway showed crown thinning with some shoot die-back. These were mature trees some of which may have been disturbed by widening of the driveway to the house, which if it caused damage to the roots, would lead to some crown death.

A decorative willow on the site was showing a stem infecting form of *Melampsora* rust, which is becoming a virulent pathogen on willow. Such infections lead to cankers, shoot-die-back and wind snap of affected branches.

Recently planted trees and shrubs were showing signs of drought, which may have been aggravated by grass competition. The grass had been mown which would tend to exacerbate the competition for moisture and nutrients.

Observations in1999
In early June 1999 Farm D was visited at the request of the owner to inspect hedgerows and pastures. Farms RS05, RS17, RS24, RS28, Somers farm and an additional farm, where damage to vegetation was claimed, were also visited on the same day. The following observations were made:

Farm RS05 A spotted laurel shrub (*Aucuba japonica*) about 2.5 m high and about 1.5m wide was located near the dwelling house, on the south west side of a low stone wall. Most of the leaves on the northwestern side of the shrub were completely black and dead. The blackness was uniform on one main branch and there was no effect on adjoining branches. There was no gradation of the effect towards the edge of the affected area. The farmer reported that he noticed the damage about 1st April immediately after getting an ammonia-like smell in the atmosphere on the previous night. Some leaf burn and bare twig tips were noted on the north western side of a hawthorn (*Crataegus monogyna*) hedge. The effects were greater towards the top of the plants and near gaps in the hedge. Only minor effects were noticed on the sheltered southeastern side of the hedge. A holly (*Ilex aquifolium*) shrub showed signs of physical damage and disease. The top leaf canopy of the shrub was thinned out considerably.

Farm RS1 A young beech (*Fagus sylvatica*) tree showed leaves with brown sections on all sides of the plant. In a wooded rockery area hawthorn leaf-burn was present. In a new plantation of ash (*Fraxinus excelsior*) and oak (*Quercus robur*) there were brown areas on leaves of oak on the western side of the plantation. There were also a large number of oak galls on the young oak trees. Some young ash leaves were withered and black while others were blackened along the leaf edges.

Farm RS24 Similar type damage to hawthorns as seen in the other farms was noted. The affected hawthorns were on the edge of an uncut silage field. The crop in the field was 100 ryegrass and in perfect condition. The leaves were broad and dark green and there was no sign of discoloration in any leaf.

Farm RS28 A horse chestnut (*Aesculus hippocastanum*) tree showed many leaves with brown margins or large brown areas on the northwestern side of the tree: There was a distinct gradation from very damaged on the northwestern facing side to virtually none on the southeastern side. A nearby macrocarpa (*Cupressus macrocarpa*) tree showed burning effect on the northwestern side also.

Somers Farm Similar effects were seen on ornamental shrubs and hawthorns as noted for the preceding farms. The farmer explained about the presence of a purple colour on the leaves of grasses during April and in his silage crops. The silage had been harvested and examples of the purple colour were therefore less plentiful. The presence of a pink or purple pigment in ryegrass is very common. It is associated with low supplies of nutrients, especially nitrogen, that are essential for chlorophyll development. The samples found on the farm were typical

of the condition. The occurrence of the purple colour in the leaves of grasses was more noticeable than usual in 1999. A potato crop near the dwelling house sown in mid March was well advanced and in good healthy condition – not showing any damage. Large parts of the electric fence that was installed 2–3 years ago were badly rusted. Other parts of the fence did not show any signs of rusting.

Farm - Additional Similar damage to horse chestnut to that seen at Farm RS28 and some damage to hazel (*Corylus avellana*) shrubs on northwestern side was noted.

Trees and Shrubs at Johnstown Castle (Co. Wexford), Tipperary and east County Limerick Also in June 1999, samples of similarly damaged hawthorn leaves and shoots were collected at Johnstown Castle and from locations between Limerick City and Tipperary. These locations were: 1) Beside the Limerick - Tipperary road about 12 km east of Limerick. (N 52.37. 208 W 08.28 .992) and 2) Two sites on a hillside near Cappamore (N 52.35.816 W 08.27.665). The damage was the same as seen in the Askeaton area. The damage to leaves and shoots in all cases occurred on the side of the hedges exposed to the prevailing winds. About 0.4 km away near a signpost, 'Boher 1 km', there was a large horse chestnut tree exhibiting a lot of leaf damage on its western side. The damage was of a similar nature to that seen at Askeaton but was much more severe.

In summary, damage to hedges, trees and shrubs was considered more likely to be a result of exposure to prevailing weather conditions than environmental pollution.

CONCLUSIONS

The Teagasc investigation was conducted to determine the concentrations of a wide range of elements in soils, herbage (grass/fodder) and water and to evaluate these in terms of the reported animal health and performance problems on farms in the Askeaton area. To achieve this a programme of soil, herbage, conserved fodder, concentrates and water sampling and analysis was undertaken between March 1995 and December 1999. In addition soil and botanical surveys of three farms were undertaken in 1995 and a number of incidences of plant damage was investigated during the period of the investigation.

The following are the main conclusions of the investigation:

The soils on the Somers, Ryan and Control farms were typical of those in north County Limerick and as such represented nothing unusual in terms of providing an explanation of the animal health and production problems reported in the area.

- The mineral and trace element concentrations (*i.e.* those considered to be required for healthy crop and animal production) of both soil and herbage samples on the Somers, Ryan, Control farms and on 23 farms participating in the Retrospective study, were generally within expected national ranges. The results from all the soil and herbage analysis cannot account for either the range or severity of animal health and production problems displayed in the Askeaton area.

- Much of the Askeaton area is naturally molybdeniferous. Molybdenum uptake by herbage on nearly half the farms was high and under certain circumstances this could cause reduced absorption of copper by animals.

- There were discrete areas, though relatively small in extent, in which elevated soil concentrations of some elements (e.g. lead, zinc, selenium) were found. These can have serious implications for the growth and nutritive composition of plants and may even result in toxicity to plant and animal.

- Relatively high levels of soil fluorine were found during the investigation but subsequently it was established that these were a natural characteristic of the Askeaton area.

- No evidence was found to suggest contamination of soil and herbage by potential pollutants from the local industries (e.g. sulphur, aluminium). There was no consistent evidence of elevated sulphur in herbage.

- Analysis of soil samples from the three farms for persistent organic compounds (potentially toxic to animal) found the values obtained were typical for Irish soils.

- The nutritive value of the silage samples taken from all farms investigated was normal for County Limerick, but low in national terms. In general, with this quality of silage, supplementation with concentrates would

be necessary to meet animal nutritional requirements.

- The quality of the pastures on the Somers and Ryan farms was lower than considered optimal for intensive dairy production.
- There was no evidence of heavy metal contamination of fodder, water, feed concentrate or mineral mixes on the Somers, Ryan and Control farms.
- Visual discoloration of grass in some Askeaton pastures was considered to reflect nitrogen deficiency – a not unusual phenomenon that occurs in pastures at certain times of the year.
- Damage to hedges, trees and shrubs were considered more likely a result of exposure to prevailing weather conditions than environmental pollution.

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Chapter Four

HUMAN HEALTH

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BACKGROUND

Sporadic concerns about the occurrence of animal health problems in the Askeaton area of County Limerick have been voiced since the late 1980's and were often perceived locally to be related to the concentration of heavy industry in the Shannon Estuary. These issues came to the fore in late 1994 and early 1995. On 6th January 1995 Mr Donagh O'Grady, a farmer in the Askeaton area, wrote to Mr Martin Duffy, Programme Manager, Mid-Western Health Board. He argued that as the animal problems being experienced in the area were the result of environmental pollution, then the health of people living in the area must also be at risk. At a public meeting on the 10th January 1995, which was attended by Dr Mary O'Mahony, MWHB, widespread concern was raised concerning adverse human health in the local area. The local community expressed concern about the numbers of miscarriages and foetal abnormalities ("Every woman who has one miscarriage has a second"), and the rate of cancer in the local area ("Young people, less than five, dying of cancer"). There were widespread reports of episodes of upper respiratory tract and eye irritation, with some burning of exposed skin. Until the letter mentioned above and this first public meeting on the issue, the MWHB had not been aware of any adverse episodes of human ill health in the area. However local people related that these concerns had existed for the last seven to eight years.

Following this public meeting Dr O'Mahony responded swiftly by contacting six general practitioners (GPs) in the Askeaton/ Ballysteen area requesting a review of the patterns of illness in their practices. The type of adverse health effects which may result from exposure to an environmental hazard could include skin rashes, mucosal irritation, i.e. eye, nose and throat irritation, respiratory problems, abnormal outcome of pregnancy, change in the pattern or incidence of cancer and neurological problems. No cluster of adverse health effects that might be attributable to an environmental hazard was reported by any general practitioner, although isolated reports of health problems of the type described had been received. Later one GP wrote concerning cancer, while others contacted the board when the health status survey was being conducted to offer support. At this point Dr O'Mahony also conducted a literature review of the possible health effects of the known pollutants, as well as holding discussions with local industry and the Senior Environmental Engineer in Limerick County Council.

Following the Ministerial request to the EPA to co-ordinate investigations into the animal health problems in the area, the MWHB was charged with investigating human health and illness patterns and this work commenced in 1995.

A further public meeting on the issue was held on 11th April 1995, following which Dr O'Mahony met Mr Liam Somers and Mr Justin Ryan on 2nd May 1995. At this meeting both Mr Ryan and Mr Somers reported how concerned they were regarding adverse upper respiratory symptoms they and others in the area had experienced. The MWHB continued to meet both a local action group (the Askeaton/Ballysteen Animal Health Committee) and individuals on a regular basis over the period of the investigation. These meetings proved to be essential as they facilitated communication between the local population and the MWHB. At such meetings local people were encouraged to put their questions, concerns, criticisms and comments to the investigating team. The health board was able to feedback results and keep local people updated on the progress of the investigation and the problems encountered. Communication is an essential element in an investigation into suspected environmental pollution and both the MWHB and the local community made good use of such meetings. The MWHB also offered individuals further investigation of health issues by expert clinicians. Some of these offers were accepted, while others were declined.

The Board asked the Department of Epidemiology and Public Health Medicine at UCD to work with it on the project. The two organisations set up a joint Steering Group to oversee the project. Over the summer months and early autumn of 1995 the two organisations developed the scope of the study and detailed protocols for each element of the proposed investigation. In November 1995 the MWHB wrote to the Department of Health detailing the protocols for the proposed investigation and seeking funding. The Department of Health responded

by approving funding for *1996*. At this point in time the Department of Public Health was created in the MWHB and assumed responsibility for the MWHB's investigation. The newly appointed Director of Public Health, Dr Kevin Kelleher, hired a team of personnel specifically to examine human health in the Askeaton area.

Given the relative scarcity of experience of prior pollution investigations in the Republic of Ireland, as the investigation progressed there was extensive consultation nationally and internationally with environmental pollution experts and epidemiologists. A number of individuals experienced in pollution investigations were invited to the Mid-West and their comments and advice sought. These experts included Prof. Tim Aldrich, Environmental Epidemiologist in South Carolina Department of Health & Environmental Control, Dr Nichol Black, Consultant in Communicable Disease Control in Newcastle, England, and Dr Patrick Wall of the Public Health Laboratory Service in Colindale in the UK. Two of these external consultants also attended meetings between the Department of Public Health and members of the local community action group. Such meetings provided a valuable opportunity for local people to ask their own questions, and maintain confidence in the investigation process.

Following the initial contact with GPs in the area, the attention of the investigating team of the MWHB turned to examining in more detail both the health concerns reported by the local population and the relevant health information systems which might be of use in investigating these concerns. Four clear features of this investigation emerged very quickly, which largely defined the nature of the ensuing investigation:

- The first feature was the absence of reports of one specific adverse health effect. Concern among the local population was not limited to just evidence of upper-respiratory tract, eye and skin problems. Other issues such as cancer and congenital abnormalities were repeatedly mentioned. This meant that there was no one clear line of inquiry to investigate. The investigation process was therefore largely a trawl of health data.
- The second feature of the investigation that emerged was that no one pollutant was specifically mentioned. Concern ranged over a number of possible pollutants including aluminium, fluoride, SO_2, NO_2, and particulate matter (PM_{10}). The absence of an explicit pollutant with a known adverse health effect hindered the choice of clear routes of investigation.
- The third defining feature was the almost complete absence of adequate health information systems, particularly computerised health information systems. This deficiency in particular proved to be an enormous impediment to the swift execution of the investigation. The investigators found that where computerised health information systems existed, they were not geographically coded below County level, and therefore expensive and time-consuming effort had to be expended to extract relevant information. Similarly where only paper based health information systems existed, a mammoth task was undertaken by the investigators to access the information. The investigators also found that no useful health information system detailing either miscarriage rates or low-level morbidity existed in the region. This meant that investigators had no alternative but to embark on an expensive and time-consuming effort to assess health in the region through the use of a survey of human health.
- Fourthly, the investigation was hampered by the absence of established Irish, and more particularly rural, norms for many of the health measures. This meant that as well as undertaking an examination of health in the suspected high and medium risk areas of Askeaton and the surrounding area, it was necessary to undertake the same investigation in a number of control areas throughout the MWHB region to facilitate a comparison. This once again slowed the pace of the investigation and involved an extensive investment of time and resources. The absence of reliable health information systems was particularly noticeable in relation to child health, where other proxy health measures had to be sought and used.

The poor state of the health information systems in existence meant that with the exception of some of the small preliminary studies, there was a significant delay in the ability of the MWHB to respond to the concerns of the local community. This delay left a void in which community concern over possible environmental pollution effects grew unabated. Concerns over differing adverse health effects were given time to develop, which in turn necessitated an increasingly large scale and wide-ranging investigation to evaluate those concerns. By the time of its completion the investigating team had attempted a total of fourteen separate studies, twelve of which were deemed viable and were pursued until conclusion.

RESEARCH QUESTIONS

In the absence of more specific information, this investigation began with three basic questions:

1. What is the health experience of people living in the Askeaton area?

2. Is the health experience of people living in the Askeaton area significantly different from that of people living in similar areas in the MWHB region?

3. Can any observed differences in the health experience of people living in the Askeaton area reasonably be thought to be the result of environmental pollution?

THE STUDY AREAS

Although the Counties of Clare and Limerick are predominantly rural, a significant amount of industry has developed there in recent years, putting 'rural' Askeaton close to a relatively high concentration of industry by Irish standards. The majority of this industry is based around the edge of the Shannon estuary. The most visible industrial developments are probably Aughinish Alumina near Askeaton, the Roche-Syntex plant in Clarecastle across the estuary and the two ESB power stations of Moneypoint and Tarbert to the west of Askeaton. Although not having a reputation for heavy industry, the scale of the industries along the Shannon Estuary should not be underestimated. Industry along the Shannon Estuary now produces over 50 per cent of Ireland's sulphur dioxide emissions (*see* Chapter Five). In addition to the industries already mentioned above, the presence across the estuary of Shannon Airport and Shannon Aerospace should be noted, as should other industries in Shannon Industrial Estate such as De Beers Industrial Diamonds, SIFA Ltd., and PGP Industries (Ireland) Ltd. Askeaton, itself, has two small industrial premises making expanded polystyrene (Southern Chemicals) and baby food (Wyeth Nutritionals Ireland).

The areas to be examined were chosen in the very early days of the investigation.

Previous studies of health effects associated with airborne pollution have identified the geographical area of concern on the basis of:

- available meteorological data on wind direction and strength;
- the local topography's influence on plume transport;
- the results of environmental tests for specific pollutants;
- the basis of nuisance complaints received;
- or a combination of the above.

The EPA and the Technical Group considered the possibility of using similar data to delineate the areas of concern in the Askeaton area. However given the presence of a number of emission sources interspersed through the greater area and the absence of an identifiable contaminant as sufficient cause for the observed animal health problems, the group assessment was that such an approach would be of questionable value. The technical feasibility of adopting such an approach was also questioned. Thus it was agreed that the presence of animal health problems was the best indicator of potential exposure to an environmental hazard for humans. The prime area of concern was the area (area 1, Fig. 4.1) in and around Askeaton where cases of severe animal ill health had been reported. This area encompasses a population of approximately 4000 people in eight DEDs (Askeaton East, Askeaton West, Iveruss, Craggs, Aughinish, Lisnakeery, Nantenan and Riddlestown).

In the majority of the studies in this investigation, the comparison areas were five other areas (Fig. 4.1) throughout the MWHB's area chosen for their similarity to the Askeaton area. However some studies make use of norms for Limerick County or the State as a whole for comparison purposes. The medium risk area (area 2) encompasses the rest of Rathkeale rural district and Rathkeale Urban district. This area effectively forms a rough concentric ring around the Askeaton area. Two further comparison areas were chosen in County Clare. One is situated across the estuary comprising Killadysert rural district (area 3), while another in the north of the County encompasses all of Ennistymon rural district (area 4). The final comparison area chosen is in Tipperary North Riding and encompasses Moyne & Litteleton dispensary districts (area 5). As a result of emerging environmental concerns in Clarecastle, County Clare, this area was included in the study as area 6. Area 6 consists of the DEDs of Clareabbey and Doora as well as the southern half of Ennis Rural DED (made up of the townlands of Coor, Cahircalla More, Cahircalla Beg, Shantulla, Ballymacaulla, Keelty, Kilnacally, Ballylinnidy, Shanvogh, Clonroad More, Bunnow, Gaurus, Drumbiggil).

OUTLINE OF THE STUDIES

The majority of studies that took place in the Askeaton investigation are examined in more depth in the Human Health Volume. This chapter is an overview of the main findings and characteristics of each study. However the chapter will also fully detail a small number of studies which were either very compact or unfeasible. The

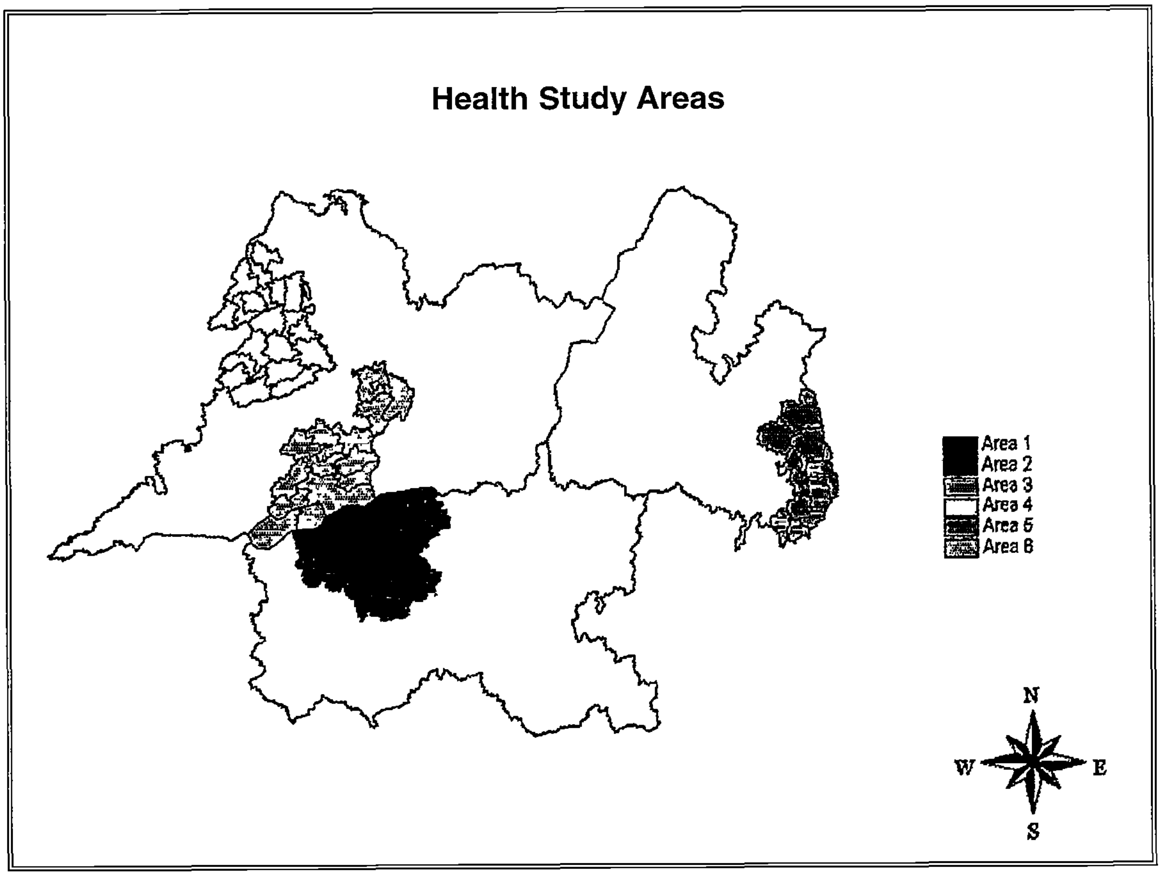


Fig. 4.1 Delineation of Study areas. See text for details.

studies were all ecological in design, comparing the health experience of the Askeaton area with other similar areas within the MWHB region. What follows is a short description of each of the studies.

Literature Review of the Effects of Common Atmospheric Pollutants on Human Health*

Comment on the effects of pollution on mortality has been traced back to Graunt's Bills of Mortality in 1662. Since the industrial revolution the volume of pollutants has increased. The rapid industrialisation seen in Western Europe and North America in the last century led inevitably to air pollution disasters. These were characterised by short-term episodes of overload of the local atmospheric pollutants, notably in the Meuse Valley in Belgium in 1930, in Donora in Pennsylvania in 1948 and in London in 1952. Following the well known episode in London in 1952, which was associated with approximately 4,000 more deaths than would have been expected in a similar, normal time-period, the Clean Air Act, 1956 was passed in the United Kingdom and was followed in 1963 by its equivalent in the United States of America. The first pollutant to be identified as damaging was black smoke and following the 1952 smog episode in London black smoke and sulphur dioxide were the parameters

* Details of the scientific literature consulted in writing this section are given in the Human Health volume.

adopted for monitoring. Since then several other pollutants have been identified and different categories of size of particulate matter have been established. Over the last twenty years the Environmental Protection Agency in the United States of America, the World Health Organisation and the European Union have all developed their own standards or guidelines as to the permissible level of these substances.

Research has shown that health effects due to air pollution tend to be acute. Less information is available on possible long-term effects upon health. Those with respiratory disease are most likely to demonstrate ill effects due to airborne pollution. Other research has indicated that the effects of air pollution may magnify or add to the effects of other risks to respiratory or cardiovascular health. Cigarette smoking is the cardinal cause of this condition but there is evidence that atmospheric pollution may also contribute. Environmental studies have shown that these diseases are more commonly found in urban areas particularly those with heavier atmospheric pollution. Evidence exists that chronic bronchitis and emphysema are aggravated by smoke, sulphur dioxide and other pollutants, and that patients with these conditions do less well during these episodes.

It should be noted that childhood asthma has increased by about 50 per cent in the last 30 years in the United Kingdom against a background of diminishing emissions of coal, smoke and sulphur dioxide but increasing levels of nitrogen dioxide and volatile organic compounds. Although atmospheric pollution may exacerbate asthma, there is no evidence to suggest that it causes the condition.

The evidence of the health effects of atmospheric pollutants appears stronger in relation to day to day variations rather than chronic exposure to long term average concentrations. Some studies have led to the assertion that there is no safe level of exposure to particles. This remains unproven. The effects on cardiovascular disease remain unquantified. It is possible that exposure to air pollutants may precipitate deaths which would have in any case occurred very soon. This would not affect the number of deaths brought about by air pollution but would affect the public health importance of such pollutants. The time scale involved is unknown - were it only a few days, perhaps, it may not be so important but were lives to be considerably shortened then it would obviously become a more important public health issue.

Air pollutants and ill health are undoubtedly linked. The only dispute in the last 50 years has been about the relative contribution of constituent pollutants and the ambient levels at which such pollutants are likely to produce their effects. Many of the contradictory conclusions arising from the literature over the years have been resolved by the use of advanced statistical techniques to overcome the many sources of confounding factors in studies into the health effects of atmospheric pollutants.

Atmospheric pollution has not been demonstrated *per se* to cause disease but it can exacerbate pre-existing conditions.

The effects of smoke and particulate matter on mortality and morbidity are well documented and while airborne particles appear to have the most profound influence, sulphur dioxide is increasingly recognised as being associated with increased mortality and morbidity, independent of the effect of particle. The adverse short-term effects of sulphur dioxide on the airways of asthmatics, mortality and the admission patterns of elderly subjects and children have been extensively documented. Long-term exposure has recently been recognised as having an adverse effect on survival in the general population.

The standards currently in place in the US and Europe are dramatically lower than was the case even 15 years ago, but health effects in response to atmospheric pollutants, are being demonstrated at levels at and below these standards. If this is the case, then are the statutory guidelines sufficiently stringent, particularly given the changing nature of the pollution to which we in the West are subjected, to protect the public from harm?

Recent data from the APHEA European Cities Pollution Study has suggested that smaller rises in ambient pollution levels in western Europe are required to produce the same mortality effects as seen in central European cities, suggesting a greater sensitivity to pollution effects amongst the population of western Europe. A subsequent study has shown that sulphur dioxide concentration and mortality for cardiovascular and respiratory conditions as more strongly associated in western Europe than in central Europe and that this effect is more pronounced for sulphur dioxide than for particulate matter. These results suggest that populations who enjoy the cleanest air may be more likely to react adversely to even modest levels of air pollutants and if this trend continues that health effects may continue to be seen at levels below what are considered "safe".

The Births and Congenital Abnormalities Study

Background
At the public meeting in early 1995, concern was expressed about the level of congenital abnormalities among new-born children and the number of miscarriages suffered by women in the area. One particular concern was the rate of multiple miscarriage in individual women. However in assessing the rate of congenital abnormalities it is important to note the 'normal' rate, which one would expect to find in any area. Internationally, the rate of congenital abnormality is approximately 2.2 per cent of all births. However it should be noted that minor physical abnormalities which have no surgical or cosmetic significance could occur in up to a further 4 per cent of births. It is thought that environmental causes are responsible for about 10 per cent of human birth defects, while genetic causes are estimated to account for 20-25 per cent of such defects. However, over 60 per cent of birth defects are of unknown aetiology.

Unusually in a case of suspected industrial pollution, the Department of Public Health was given no clear picture of specific abnormalities to investigate in the target area. No reports of clusters of specific abnormalities were reported. Alternatively, in the absence of such case reports, it is often normal for investigators to be made aware of a specific environmental pollutant, with a known effect. This in turn would allow investigators to focus their attention in a specific direction. However no clear contaminant was identified and concern ranged over a number of known pollutants.

Aim and Method
The aim of this study was to determine if the rates of congenital birth defects in Askeaton were normal, or indicative of possible environmental pollution. For the purpose of this study Askeaton was designated the "high risk area", the area around Askeaton was designated as the "medium risk area", while the remainder of Limerick Community Care Area was used as a control area. The study time frame covered the period from 1987 until 1994, as this was the period of concern.

Cases were defined as all malformed live and stillbirths to mothers resident in the defined geographical areas. These included structural malformations, chromosomal abnormalities, metabolic disorders and hereditary diseases. Malformations were classified into subgroups indicating their mutagenic (e.g. Downs syndrome) or teratogenic origin and known association with environmental exposures. The form in which the information was available did not allow for the identification of all abnormalities where more than one major congenital abnormality was present. This report as a consequence does not differentiate between individual types of abnormalities. A case is a baby or stillbirth not an abnormality. The EUROCAT system of coding includes metabolic and genetic diseases such as Phenylketonuria (PKU) and Cystic Fibrosis. Whilst these cases have been identified, they are kept apart from the rest of the study as their cause is known to be genetic and not environmental.

This study necessitated the perusal of over 14,000 manual records, due to the absence of any form of more advanced recording system. Supplementary sources of potential information on congenital abnormalities were also examined. These were Special Care Baby Unit records, Public Health Nurse records, Counselling Nurse records, Long Term Illness records, domiciliary care allowances and official birth notices. All still birth records were examined ın the Limerick, Cork and Tralee hospitals in order to ascertain whether a congenital abnormality was present.

Results
Of the total number of 14,906 births in Limerick Community Care Area during the study time frame, just 443 (2.97 per cent) were from area 1, while 1078 (7.23 per cent) were from area 2 and 13,385 (89.79 per cent) infants were born to women resident in area 3. There were 98 still births during the eight years giving a still birth rate of 6.6 per 1,000 live and still births. This rate is the same as the most recent national rates (1986-1992).

Between 1st January 1987 and 31st December 1994, 191 cases of congenital abnormality were identified in Limerick community care area. Of the total number 95 per cent (n =183) were liveborn and just 5 per cent (n =4) were stillborn. More males (52.3 per cent) than females (47.7 per cent) were born with a congenital abnormality. This includes 12 cases of Cystic Fibrosis and 7 cases of PKU. For the purposes of the analysis these cases have been excluded as they have a genetic basis and therefore are not considered to be congenital abnormalities. Thus, the total number of cases in the study was 172 of which four came from the high-risk area, 14 from the medium risk area and 154 from the control area (area 3). The total prevalence rate of congenital abnormalities in Area 3 during this period was 115/10,000 births. The annual prevalence rates in areas I and 2 fluctuated during this

period, which probably reflects the uneven and incomplete nature of data, and the small numbers involved available in this study (Table 4.1) Overall rates in area 3 are relatively stable which reflects the larger sample size. The prevalence rate per 10,000 was highest in area 2 (129/10,000) and lowest in area 1 (90/10,000). When area 1 and 2 are combined the rate is 118/10,000. Comparing area 1+ 2 with area 3 there is no statistically significant difference between the two areas.

Table 4.1
Prevalence Rate /10,000 births per year of cases of congenital anomalies in Limerick and other registries

Area	**Year**								
	1987	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*Mean*
Area 3	136	85	132	138	144	73	92	117	115
Area 2	64	0	73	125	280	300	170	86	129
Area 1	160	170	170	0	0	0	217	0	90
Area 1+2	92	46	103	92	188	222	185	57	118
Dublin*	283	274	209	227	227	227			
Galway*	229	171	144	223	295	295			
Eurocat*	231	216	220	210	203	203			213

* prevalence rates only available to 1992 EUROCAT

Discussion

Overall the rate of congenital abnormality is lower than in other European registries but within the norms accepted internationally (1-2 per cent births). The results show rates for the eight-year period which are lower than the control area for the high-risk area and very slightly higher for the medium risk area. Neither of these rates is statistically significantly different from the rate for the control area.

The main problem affecting this study is the whole issue of small numbers. The number of cases and the number of births in both areas 1 and 2 were small, especially in area 1. This can lead to a number of difficulties in interpreting the data. There is likely to be much greater year on year fluctuation and one extra case could result in a 20 per cent or even 100 per cent increase. Unfortunately the study has been affected by the poor quality, accessibility and structure of the base data. An investigation, which involved the perusal of 14,000 manual records, was by necessity prolonged beyond its anticipated finish date. Data collection for this study was severely hampered by a number of factors. These included the absence of computerised records, limited information on still births, missing records, imprecise diagnosis and missing information on both medical records and birth notification forms. In addition information on births occurring outside the Mid-Western Health Board to unmarried mothers resident in Limerick who were not keeping their baby was missed.

Early warning systems of surveillance can be effective for the detection of large increases in rare and well-defined anomalies, which are easily diagnosed at birth. For the detection of smaller increases in prevalence in common anomalies a well validated data set is needed as well as longer duration of surveillance. It is desirable to conduct enhanced surveillance of public health in the Shannon Estuary Area so as to enable the timely detection of outbreaks or clusters of adverse health events and to determine trends in the overall number of cases. Baseline health status could be determined and in time the pattern of incidence rates according to gender, age, socio-economic status and other variables could be described. Such information would offer substance for testable hypotheses in the event of public health concerns arising in the future. This study was costly, time consuming, arduous and suffered from poor data quality. It is recommended that a structured and systematic surveillance system should be put in place to allow routine analysis of trends in congenital abnormalities in the region. This should be the EUROCAT system to allow comparison with other parts of Ireland and Europe.

The Sex Ratio Study

Background

Normally male births exceed female births. The sex ratio refers to the ratio of male births to female births. However alterations in the usual sex ratio pattern have been associated with airborne pollution from steel foundries and from incinerators. It has been suggested that as male infants and foetuses are weaker than females, unborn males may be more susceptible to the adverse effects of environmental pollution. Environmental and

other occupational health research suggest that change in the sex ratio in births in favour of girls may be an early indicator of environmental hazards of importance to public health.

Aim and Method
The aim of this study was to examine if the sex ratio of births in Askeaton was normal, or indicative of possible environmental pollution. For the purpose of this study Askeaton was designated the "high risk area", the area around Askeaton was designated as the "medium risk area", while the remainder of Limerick Community Care Area was used as a control area. The study time frame covered the period from 1987 until 1994. To examine the sex ratio for births, gender details on births in the areas were obtained from the community care birth lists compiled from the midwife and official birth notifications. A check with the public health nurse birth registers in the areas 1 and 2 was also undertaken to confirm geographic coding. Data on birth notifications without information on gender were obtained by a further check with the public health nurse.

Results
The sex ratio overall was 1.08:1 males to females which is similar to national norms (Table 4.2) There was a slight increase of males in areas 1 and 2 compared with area 3, but no more than would be expected by chance (This is what is meant by the term non-significant). If an abnormal sex ratio was present, one would expect fewer males rather than more males, which was the case here.

Table 4.2

Birth Sex Ratios 1987-1994

	Area 1+2 Study area	***Area 3 control area***	***Total***
Males Births	800	6,919	*7,719*
Female Births	719	6,438	*7,157*
Totals[1]	1521	13365	*14,884*
Male sex ratio	1.11	1.07	1.08

[1] Sex was not given for some birth records

Discussion
Overall the ratio of male to female births is actually higher rather than lower than national norms, the opposite of what might be expected in an area of environmental pollution. However, as in all three of the birth studies which formed part of this investigation, one major difficulty is the small number of births involved. Of the total number of 14,906 births in Limerick Community Care Area during the study time frame, just 443 (2.9 per cent) were from area 1 while 1078 (7.2 per cent) were from area 2 and 13,385 (89.7 per cent) infants were born to women resident in area 3.

The Twin Rates Study

Background
Media reports alleged that an increase in twin births among farm animals, especially dairy cows, had been seen in the area around Askeaton. Some years ago a study carried out in Scotland looked at the geographical distribution of twinning during the period 1975 to 1983 in defined geographic areas which were considered by some health authorities to be most at risk from air pollution from incinerators. An increased frequency of human twinning was found in these and was accompanied by a dramatic increase in twinning among dairy cattle about the same time. While there was no concern expressed by the community of an increase in human twinning in the Askeaton area, an examination of twinning rates was carried out to see if a similar relationship existed.

Aim and Method
The aim of this study was to determine if the rates of twin births in Askeaton were normal, or indicative of possible environmental pollution. The definition of a twinning rate is the number of twin births per thousand births. For the purpose of this study Askeaton was designated the "high risk area", the area around Askeaton was designated as the "medium risk area", while the remainder of Limerick Community Care Area was used as a

control area. The study time frame covered the period from 1987 until 1994. To examine the twinning rate details on births in the areas were obtained from the community care birth lists compiled from the midwife and official birth notifications. A check with the public health nurse area birth registers in the areas 1 and 2 was also undertaken to confirm geographic coding.

Results
The twinning rate overall was 12/1000 which is similar to national norms (Table 4.3) There is no increase in the twinning rate in area 1 which had a rate of 9.1/1000. Although area 2 has a higher rate (14.1/1000) compared with the remainder of Limerick community care area (12/1000), this difference is not greater than would be expected due to chance variation.

Table 4.3

Twin Birth Rate January 1 1987 – December 31 1994

	Area 1	*Area 2*	*Area 3*	*Total*
Births[1]	439	1,063	13,222	*14,724*
Twins	4	15	159	*178*
Total	**9.1/1000**	**14.1/1000**	**12/1000**	***12/1000***

[1]Twin birth counted as a single event here

Discussion
The twin rate observed in Askeaton is actually slightly lower, although not significantly, than the County and State norms. The reverse would have been predicted in an area of environmental pollution. However as in all three birth studies which formed part of this investigation one major difficulty is the small number of births involved. Of the total number of 14,906 births in Limerick Community Care Area during the study time frame, just 443 (2.9 per cent) were from area 1 while 1078 (7.2 per cent) were from area 2 and 13,385 (89.7 per cent) infants were born to women resident in area 3.

The Survey of General Practitioners' Perceptions of Health Problems in their Practices

Background
Preliminary investigations were carried out of six General Practitioners in the Askeaton area in 1995. GPs in this area were requested to review the pattern of illness encountered in their practice. The type of adverse health effects which may result from exposure to an environmental hazard could include skin rashes, mucosal irritation, i.e. eye, nose and throat irritation, respiratory problems, abnormal outcome of pregnancy, change in the pattern or incidence of cancer and neurological problems. No cluster of adverse health effects that might be attributable to an environmental hazard was reported by any general practitioner, although isolated reports of health problems of the type described had been received.

However despite this result it was felt that as GPs are the main health contact for most individuals, a more systematic analysis of GP experiences should be undertaken. General practice is relatively underdeveloped in Ireland compared to Britain. Approximately one third of the population are entitled to free medical care at the primary level (General Medical Service entitlement - the medical card). Entitlement is based on income assessment and is highest in deprived urban areas, rural areas and to those who are self-employed, have serious illness or are elderly. The remainder of the population, not covered by a GMS card, are private patients who may attend more than one GP. Most general practices therefore do not have defined private practice populations with age/sex registers of all their patients. Therefore for research purposes they are of reduced value. In addition few practices are computerised throughout the country. It should be noted that not all GPs record each patient contact either on paper or on computer. The Department of Public Health therefore decided to conduct a postal survey of GPs using questions with a similar format to that used in the main health status study.

Aim and Method
The main aim of the study was to describe the perceptions of GPs regarding patient morbidity and environmental hazards in six geographically defined areas in the MWHB region and to see if there were significant differences

between them. The specific objectives were to assess whether GPs in Askeaton and Rathkeale compared with other areas had noted an increase in number of patient consultations for respiratory symptoms, sinus and skin irritations, cancers and serious illness over the past one year and, for fertility problems, cancer and serious conditions, over the past ten years.

A questionnaire was sent to all GPs registered with the MWHB as being in either private or public practice in one of the six defined areas during the month of November 1996 (Each area was based on the population sampled for the human health study and included Askeaton, Rathkeale, Killadysart, Clarecastle, Ennistymon and Littleton/Moyne.) GPs in towns adjacent to the six areas were also included for practical reasons. GPs were asked if they had concerns about respiratory, skin and sinus/throat diseases within the past year. Details of the age group of patients most affected were requested and other additional relevant information. GPs were also asked if they had concerns about fertility problems or unusual numbers of cases of miscarriages in their practice population within the past 10 years, or if they had specific concerns about health problems in the practice population. In addition they were asked about unusual numbers of patients with serious illnesses within the past one to ten years. Serious illness was not defined, but examples were given such as cancer, leukaemia and neurological problems. Finally GPs were asked to give their views on environmental hazards in their area. In light of the small numbers involved for the purpose of analysis, the Askeaton and Rathkeale areas were combined. All other areas were treated as controls. GP perceptions were examined by county of residence.

<u>Results</u>

A total of 50 general practitioners was contacted. A response rate of 68 per cent was achieved.

- Fewer doctors in the exposed area had concerns about sinusitis/rhinitis than GPs in non-exposed areas. (15.3 per cent compared with 23.8 per cent).
- Four doctors indicated that they had noticed an unusual number of miscarriages in the past 10 years. Amongst comments received were that miscarriages were clustered in areas. The number of doctors concerned about miscarriages in the exposed area was three (23 per cent) compared with one (4.8per cent) in the non-exposed area (a ratio of 4.85 but the confidence level did not reach statistical significance).
- Seven GPs (20.5 per cent) said that they had experienced an unusual number of cases of serious illness in their practice in the past year. These included brain tumour, leukaemia, pancreatic and oesophageal cancers. Proportionally fewer doctors replied that they were concerned about serious illness in the exposed area than in the non-exposed area (ratio 0.69). Six doctors (17.6 per cent) were concerned about the rate of serious illness over the past ten years (examples given included childhood cancers, health problems in older people, depression, deaths in young men).
- In contrast proportionally more doctors in the exposed area were concerned about illness over the past ten years. However this was not statistically significant (ratio 1.76 CI .42-7.3).
- About one in three general practitioners said they had more than usual concerns about specific health problems in their practice, 38 per cent in Askeaton/Rathkeale compared with 25 per cent of the remainder.
- The health problems cited at least twice were asthma and chest diseases, smoking and cancer in young people. Other health problems mentioned once were obesity, hypothyroidism in women, childhood autism, air pollution, public worries about health and numbers of patients with skin rashes.

A recurring theme throughout several commentaries was the lack of information or accurate statistics to answer these queries: "patients express concerns about miscarriage but I don't have specific knowledge" and "this has been queried but there are no hard facts" were some of the replies.

The results indicate that general practitioners have a variety of concerns about their patients' health. GPs in Askeaton/Rathkeale were more likely to be concerned about rates of miscarriages, incidence of serious illness and specific health problems in their practice compare with those in "non exposed areas". However, doctors in the latter areas had proportionally more concerns about other illnesses including respiratory problems, sinusitis and incidence of serious illness within the past ten years. Over a third of doctors in Askeaton/Rathkeale compared to a quarter of GPs elsewhere were concerned about environmental hazards in their area.

<u>Discussion</u>

Overall the 34 general practitioners who responded to the questionnaire did not indicate undue concern over their patients health. There was a trend throughout all areas of a perception of an increase in respiratory problems especially asthma in younger patients. General practitioners in all areas were also concerned about specific health

problems in their practice which were mainly related to smoking, air pollution, chest diseases and patient perceived worry. Overall just under one third of doctors had concerns about the environment and these related mainly to air pollution, food and water pollution and road traffic accidents. There was no consistent variation in the perceptions of general practitioners regarding patient morbidity in their practice, although GPs from the exposed area did express proportionally more worries about rates of miscarriage and serious illness over five years and had more health concerns about their patients. This may reflect the level of anxiety conveyed to general practitioners by their patients and their own proximity to major industry. Overall, there was no statistically significant difference in perception among general practitioners between exposed and non-exposed areas and between counties Clare, Limerick and Tipperary.

It must be stated that GPs in the Mid Western Health Board area do not have accessible information on patient morbidity in their practices and that the study was unable to answer questions about patient morbidity because of lack of routinely recorded or computerised records. The renewed introduction and support of a widespread system of GP sentinel practices and the whole-scale introduction of computerised GP patient information systems are highly recommended. Given the reality that only an estimated five per cent of GP consultations are referred on for further consultation, the potential of both quality sentinel systems and more accessible computerised GP information systems cannot be ignored.

The Health Status Survey

Background

In the light of the poor human health information systems that existed at the time of the Askeaton investigation, the decision was made to conduct a survey of human health in the risk and comparison areas. In order to respond to community concerns a number of different areas still required investigation. These included illnesses such as upper respiratory tract problems, eye and skin irritation. Another focus of this research was an examination of pregnancy outcomes, particularly given community concerns over miscarriage rates. In the light of the importance of this issue, the size of the target sample of women of child bearing age (15-44) was doubled compared to all other groups.

A key task of this study was to examine 'low level' morbidity. None of the data sets examined elsewhere, when this study was designed, could measure low levels of illness that might not even require presentation to a GP. Such an analysis was important given the likely low-level effect of environmental pollution. This study was felt to be vitally important because many of the other elements to the Askeaton investigation were retrospective analysis of existing routine data sets, not designed for such an environmental pollution investigation. This survey was however designed solely to answer these concerns. One obvious concern in undertaking an investigation into self-reported health of this type is the effect that community concerns can have on people's evaluation and memory of their health. People may focus very attentively on and remember every symptom and episode when alerted by concern over environmental health. In areas where there is no such concern however such instances may be ignored and quickly forgotten.

There was consultation between the Department of Public Health and the local community group on the study design. The local group reviewed the questionnaire and made recommendations on changing the order of some sections of the questionnaire. Such comments were welcomed and the suggested changes were implemented.

Aim and Method

The main objective of the human health study was to examine geographical patterns in human health to see if there was any association with the reported pattern of animal ill health. The study was an interviewer administered questionnaire on self-reported health and ill-health. There were six study areas, viz Askeaton, from where animal health problems had been reported, Rathkeale, adjacent to Askeaton, and four comparison areas - Ennistymon, Killadysert, Moyne and Littleton and Clarecastle.

The questionnaire was comprised of nine separate sections:

Section 1 - The Short Form-36 The largest single piece of the questionnaire is the Short-Form 36 questionnaire (a very well validated questionnaire), usually just called the SF-36. This is a set of 36 questions, developed and evaluated by the Medical Outcomes Trust in the USA. Their purpose is to provide a general measure of health, the SF-36 score, and a set of more specific measures of health and well being. The SF-36 is not appropriate for children, and was asked only of those aged 15 and over.

Sections 2,3 and 4 - The Symptom questionnaires These three sections focus on specific symptoms. The first of these was a set of questions on chest symptoms, such as coughing, wheezing, treatment for asthma, and hay fever. The next was a set of questions about skin disease. These include questions on itching, flaking skin, dry skin and so on. Finally, there was a set of questions about general health, including questions on tiredness, on aches and pains, dizzy spells, ear problems, sickness, and allergies.

Section 5 - Pregnancy, fertility and childbirth This section inquires about pregnancies, babies, and difficulties in getting pregnant. Every pregnancy mentioned by the women interviewed is recorded, and basic details of the outcome are documented. Only women aged between 15 and 44 were asked these questions.

Section 6 – Lifestyle This section was a series of questions about diet, changes in diet, smoking and drinking, exercise and use of televisions, computers and video games. Only people aged 15 and over were asked these questions.

Section 7 - Social details This section asked about social and demographic factors such as housing, work, education, farm or land ownership, as well as asking for self-reported weight and height. Everyone was included.

Section 8 - Concerns about the environment This section examined how worried respondents were about the environment, and what action they had taken about this worry. It also investigated which aspects of the environment concerned participants most. Only people aged 15 and over were included.

Section 9 - Animal health This was a set of questions for people who lived on farms where cattle are kept. This section was included to facilitate the research being conducted by DAFRD and was not examined by the Department of Public Health.

Ireland has no population register and given the limitations of the electoral register the Economic and Social Research Institute (ESRI) was commissioned to identify participants for the survey. Given the strict stratified sampling frame used in this research project the ESRI worked from the electoral register to identify demographic (age and sex) details of household occupants prepared to take part in the sample. From respondents who agreed to take part in the research, a random sample of people, ranging in age from 1 year old to 69 years old was chosen. The target sample size for each area was 450 people. This was comprised of 50 people of each sex in each of four age groups (1-4, 5-14, 15-44, 45-69), with the exception that the female 15-44 year age group had a sample size of 100.

The questionnaire was interviewer administered, and in light of the sensitivity of the questions, all of the interviewers were nurses, the majority of whom worked as public health nurses. Ten per cent of respondents who completed interviews were contacted either by telephone or in person to verify that the interview had in fact taken place. The ESRI achieved a participant rate of 77 per cent in valid households. The nurse-interviewers completed 2480 interviews from 2697 people, giving an overall response rate of 71 per cent.

<u>Results</u>

Study areas were compared with and without statistical adjustment for other factors, such as age and socio-economic status. Results were similar irrespective of this adjustment. It is important to note that the overall finding of this study is the low level of reported illness and ill health in any of the study areas. The median score on many of the measures used was zero, indicating no health problems were reported. However examining the different areas in more detail, a clear pattern of similarities and differences emerges (Figs 4.2 – 4.4).

The SF-36 total and sub-scale scores indicate that Askeaton residents report worse health than the other areas. That worse health experience is equivalent to the difference between men and women or to the health experience of somebody who is five years older. However residents of the Moyne & Littleton region of Tipperary North Riding reported a similar health experience. On the asthma measure Askeaton and Clarecastle both had high scores, well in excess of those found in Killadysert and Ennistymon. The respiratory disease measure revealed that Askeaton, Clarecastle and Moyne and Littleton had the worst health experience in this domain. Similarly on the general health measure Askeaton, Moyne and Littleton and Clarecastle report the worst health. The skin disease measure again shows this pattern, with Moyne and Littleton reporting the worst health in this area, followed by Askeaton. The pregnancy and birth outcomes information section found no statistically significant differences between the six areas.

<u>Discussion</u>

Some statistically significant differences in self-reported health were detected among the six study areas. The actual impact of many of these differences is debatable, as many are of little or no clinical significance. However

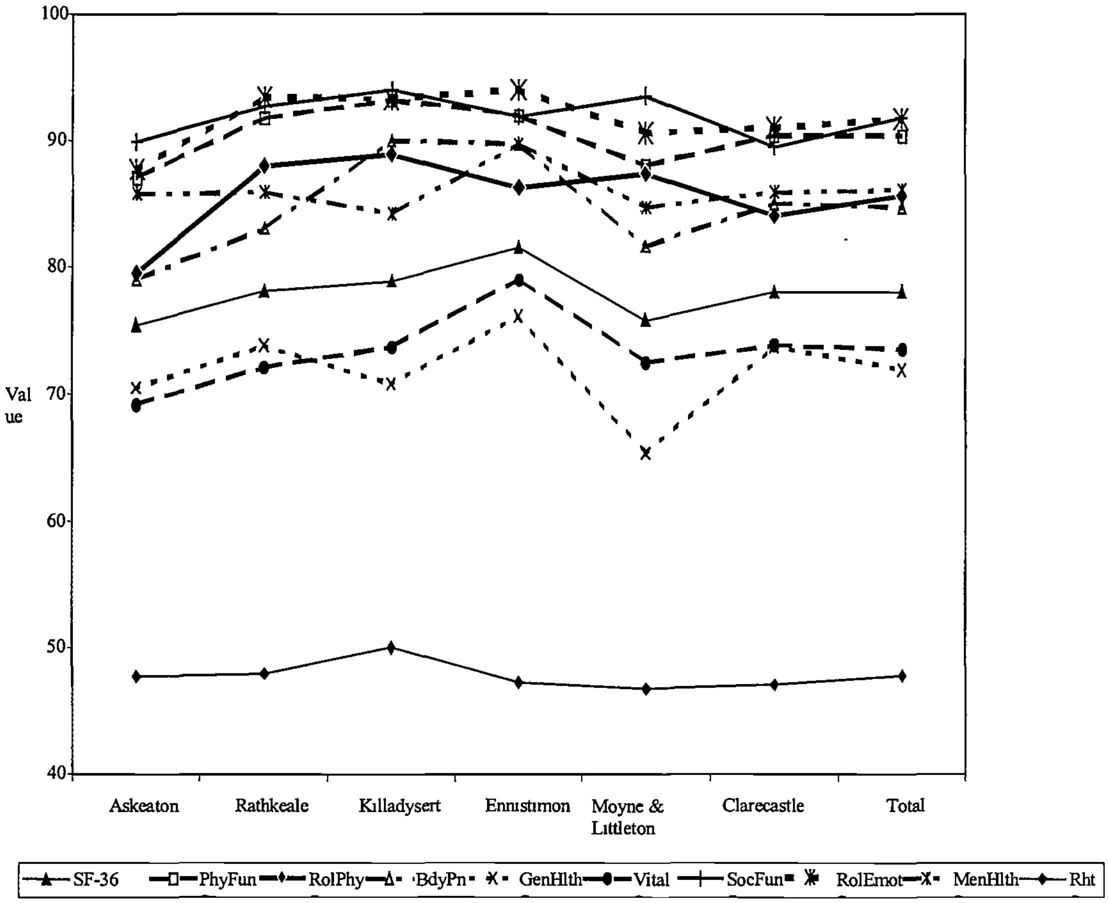


Fig. 4.2 Sf-36 scores by area (PhyFun: physical functioning; RolPhy: role limitations due to physical problems; BdyPn: bodily pain; GenHlth: general health; Vital: energy/vitality; SocFun: social functioning; RolEmot: role limitations due to emotional problems; MenHlth: mental health; Rht: health over past year).

a general pattern emerged in that Askeaton, Clarecastle and Moyne and Littleton tended to have a similar level of self-reported health, that was somewhat poorer than that observed in Rathkeale, Ennistymon and Kılladysert. This pattern is not consistent with any known pollution source.

The Acute Health Effects/Diary Study

Background

Given the reports of extreme animal ill health on a number of farms in the Askeaton area, and reports of human ill health, it was decided to examine the health of individuals on farms in the affected area in more detail.

Aim and Methodology

The study had five aims:

- To identify acute health problems recorded prospectively by family members in a one-year period.
- To determine the prevalence rates of symptoms of the upper respiratory tract, eye and skin irritation.

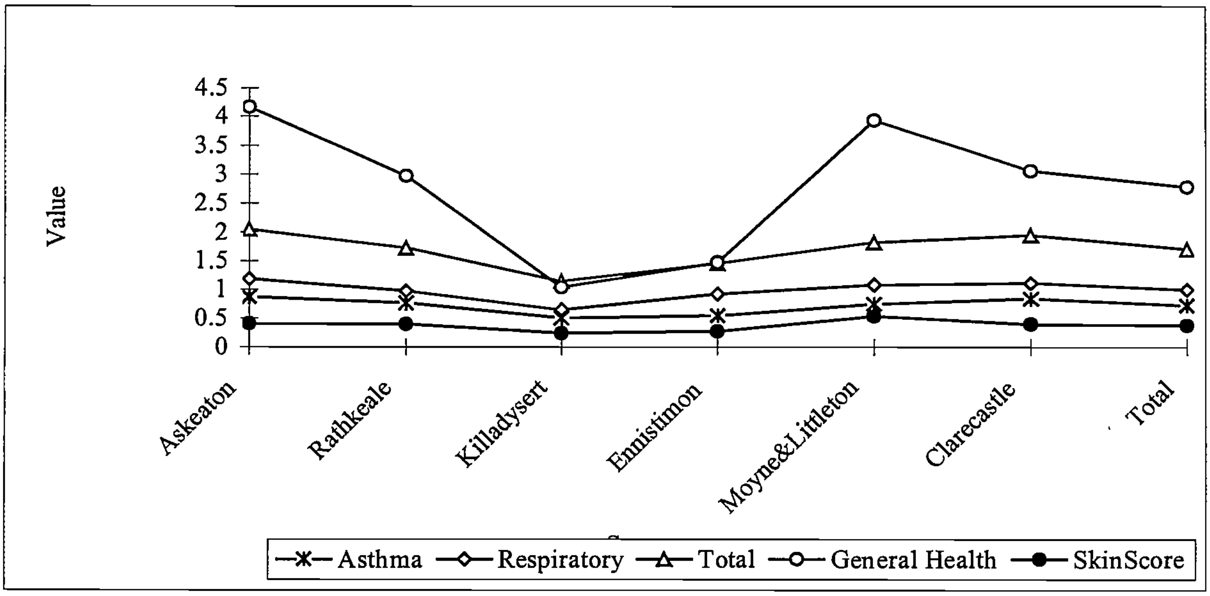


Fig. 4.3 Mean Health Scores by area

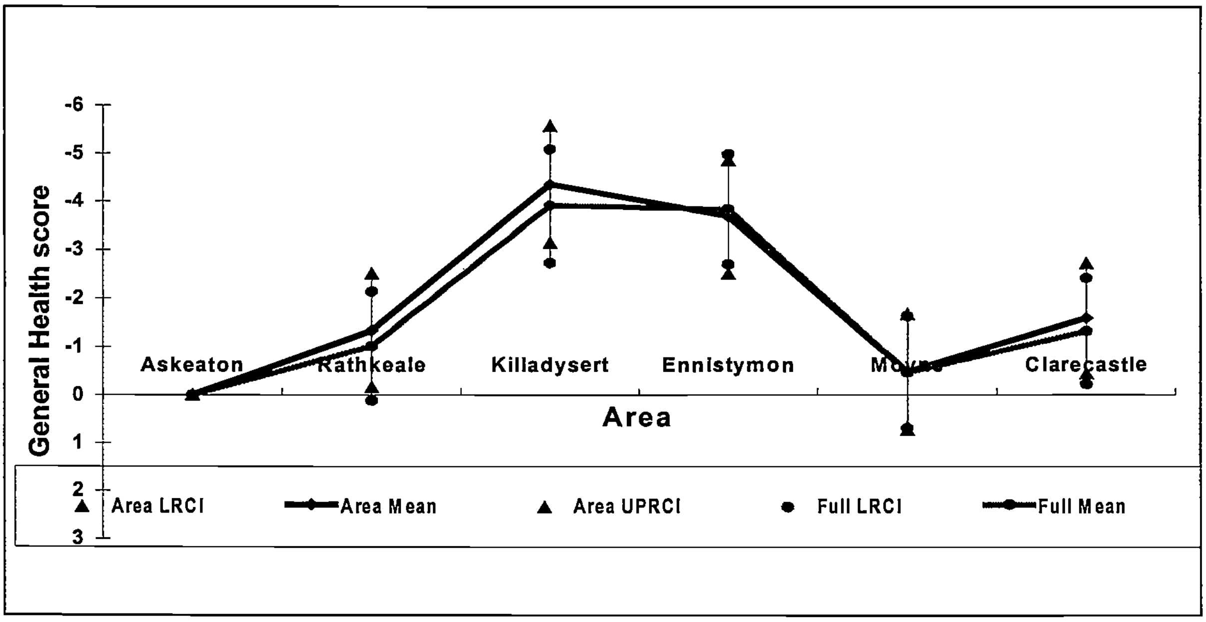


Fig 4.4 General Health Scores by area.

- To investigate if some family members experienced more health problems than others.
- To investigate seasonal differences in the health status of family members.
- To investigate possible causes of health problems.

All of the farms that participated in this study had experienced unexplained animal death or animal ill health. The method of inquiry was a diary study conducted over a 13-month period. A total of 26 families agreed to take part in the study, although by the end of the study only 19 were still involved. For the purpose of the analysis only 18 were included, due to incomplete data in one instance. Despite this drop in the numbers, the adherence rate was much higher than would have been anticipated from the literature, where it is noted most diary studies usually only last short periods, such as one or two weeks. Each family taking part in the study appointed a family co-ordinator for the project. Each day the family co-ordinator would record the presence of health problems on a dedicated form for all members of the family. Each month the survey co-ordinator visited the farms, collected the previous month's diary and gave participants a new set of forms. Demographic information on each individual was collected, as well as the number of family members reporting symptoms and the number of symptoms recorded by each family member. Information was collected on the number of recurring days each symptom persisted, the mean severity of each symptom, action taken to alleviate symptoms, as well as the perceived cause of the symptoms. Symptoms recorded by each family were re-coded into the following categories: Respiratory, Eye, Skin, ENT, Mental Health, Skeletal-muscular, Gastrointestinal, Fatigue and Other.

Results
The 76 individuals (18 families) recorded a total of 1353 symptoms. In total, 11,827 days were reported as ill days by respondents. Respiratory symptoms were the most commonly reported symptoms (19.5 per cent), followed by ENT symptoms (16.4 per cent), skin symptoms (13 per cent) and fatigue (12.6 per cent). Reported symptoms peaked in the winter months (Fig. 4.5) and the rate for children was in all months slightly lower than that for adults (Fig 4.6).

Five individuals reported high levels of morbidity throughout the study. These five individuals accounted for 550 symptom episodes and 6475 ill days. In addition they accounted for almost half of all fatigue symptom days. The results clearly show a pattern of two farm households with extremely poor health, three farm households with moderate health and the remainder with good health. In the absence of a control population, it is not known if this finding is of any significance.

Discussion
The problems inherent in this type of self-reporting study are significant. This type of study is obviously highly subjective. Given the long duration of the study (13 months) it is possible to influence health behaviours as well as sensitising individuals to focus on their health status. Five individuals suffered an excess of low-level morbidity over a protracted period. However, most of this ill health did not require consultation with a GP or any other health professional.

The Cancer Incidence Study

Background
The local population expressed concern about the incidence of cancer in the Askeaton area at a series of public meetings. In assessing cancer, it is important to note that in Ireland 1 in 10 hospital admissions and 1 in 4 deaths are due to cancer. Cancer death rates in men and women are relatively low during early life and rise rapidly beyond the age of 60. The overall death rate from cancer has remained unchanged since the early 1970s and Irish figures are comparable to those for other western European countries. Variations do occur however. Within Ireland death rates and incidence for cancer show geographical variation; for example, lung cancer is commoner in the more heavily industrialised parts of eastern Ireland, in keeping with the known epidemiology of lung cancer.

Much of the evidence linking human cancer and air borne noxious substances has come from studies of occupational cancer. From the 1930's onward a steady rise in lung cancer incidences was noted in the industrialised world and this was initially attributed to fumes, in particular from diesel engines. The definitive work of Doll and Hill in examining the lung cancer experience of British doctors demonstrated that cigarette

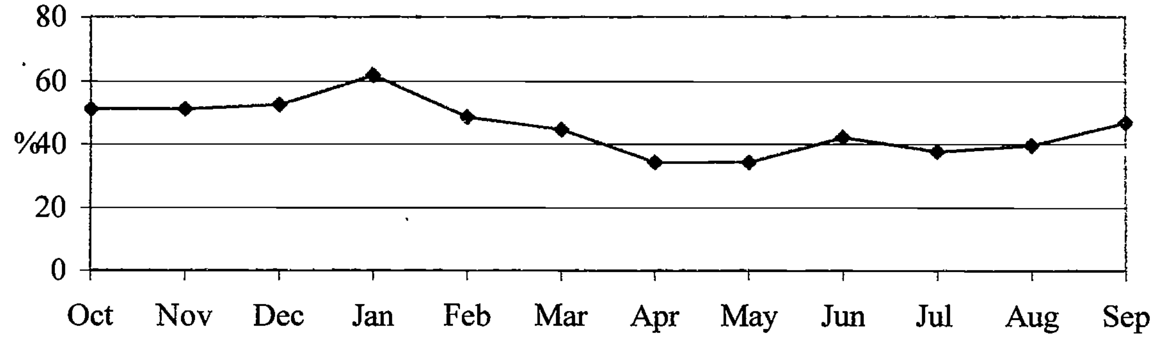


Fig. 4.5 Percentage of respondents who reported a health symptom throughout the year of investigation.

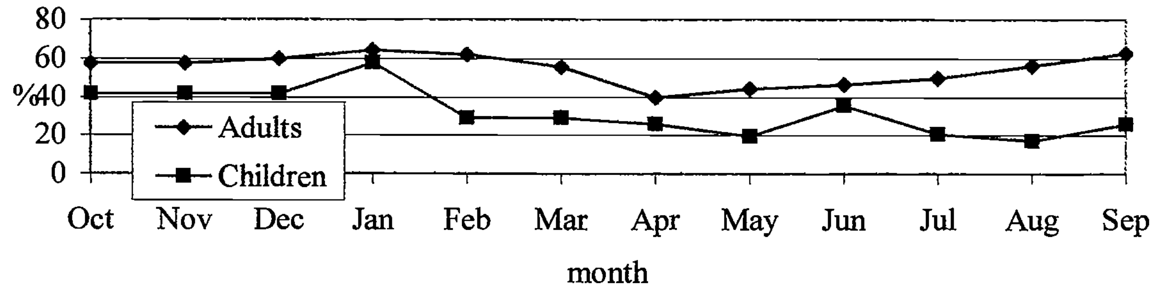


Fig. 4.6 Percentage of adults and children who reported a health symptom throughout the year of investigation

smoking and lung cancer were closely linked. The confounding effects of cigarette smoking therefore have dogged studies into the possible carcinogenic effects of atmospheric pollution.

Epidemiological studies over the past 40 years have suggested rather consistently, that general ambient pollution, chiefly due to incomplete combustion of fossil fuels, may be responsible for increased rates of lung cancer. The highest number of potentially carcinogenic chemicals are emitted by combustion sources (i.e. tobacco smoke, car exhausts and coal combustion). Polycyclic organic materials that are produced by the incomplete combustion from the above sources make up the largest single contribution to human cancer risk. From these combustion sources motor vehicle emissions account for the greatest cancer risk in outdoor air. Environmental tobacco smoke and radon are the major sources of cancer risk from indoor exposures. While the evidence may not favour a link between point source emissions and cancers due to airborne pollution, urban/rural differences in cancer experience are well documented.

Aim and Methodology
The aim of the study was to determine if people living in the Askeaton area had a greater likelihood of developing cancer than those living outside the Askeaton area. To this end, the study used the same six areas as the other studies. The study time frame consisted of cancer incidence returns for 1994 and 1995, the first two years of operation of the National Cancer Registry. These data only became available in late 1997.

Cancer incidence data provided by the National Cancer Registry were geocoded manually from tables of addresses provided by Local Government Computer Services. Incident ratios were calculated for each of the study areas and compared with the regional Mid-West cancer incidence rates that were used as a reference. Rates of cancer incidence for those years were then determined for each sex and age group in each of the areas. Age specific rates per 100,000 population were calculated and compared with regional Mid-Western Health Board standards and with national standards to give standardised incidence ratios (SIRs). The results were further analysed in terms of total rates of cancer, including skin cancers and total rates of cancer excluding non-melanomatous skin cancers, in order to allow more detailed evaluation of data without the diluting effects that large numbers of cases of skin cancer produce.

Results
When cancer incidence in 1994 - 1995 is examined with the Mid-Western Health Board as a standard population (Tables 4.4 and 4.5) there is no increased risk of cancer in Askeaton regardless of whether skin cancers are included or not. Results from the analysis of cancer incidence (including skin cancer) indicate that males in Askeaton have an SIR of 86.02 meaning they have approximately 15 per cent less risk of developing cancer than the average population of the Mid-Western Health Board. The figure is roughly similar for Rathkeale (SIR of 86.48) and the control area interestingly reports an excess of cases (SIR of 140.98). In the case of females this pattern is even more pronounced. In Askeaton the SIR for females is 35.59 meaning that their risk of developing cancer is approximately one-third that of the standard Mid-Western Health Board population. Rathkeale rate was 64.06 but is still below what would be expected and again the control area demonstrates an excess of cases (SIR of 185.65).

Results from the analysis of cancer incidence (with data on skin cancer excluded) show that this pattern is maintained. In the case of men the reduction in risk in Askeaton was not as marked (SIR of 99.50). However in the case of women the reduction was even more marked down to one-quarter of what would be expected in the standard Mid-Western Health Board population (SIR of 25.27).

When compared against the standard Irish population the pattern seen in the three areas are maintained and if anything slightly accentuated (Tables 4.6 and 4.7). This is not unexpected given the favourable cancer mortality experience of the Mid-Western Health Board population as compared with the national population. An analysis of all cancer incidence, demonstrates that for males in Askeaton the SIR is 70.18 indicating a decreased risk of cancer in that area by about 30 per cent. The control area shows a slight excess, with an SIR of 104.55. In the statistical analysis of these figures, however, these merely indicate trends as the confidence intervals indicate that these results were not statistically significant. Looking at females the patterns of reduced incidence are maintained and enhanced. Females in Askeaton have an even lower SIR when compared with Ireland with a

Table 4.4

Standardised Incidence Ratios for cancer in Males and Females in each of the 3 Study Areas compared to the Mid-Western Health Board Population including skin cancer data.

	Observed Cases	Expected Cases	SIR	95per cent CI
Males				
High Risk Area	16	18.6	**86.02**	72.69, 99.35
Medium Risk Area	43	49.72	**86.48**	78.31, 94.66
Control Area	166	117.75	**140.98**	134.20, 147.76
Females				
High Risk Area	6	16.86	**35.59**	26.58, 44.59
Medium Risk Area	29	45.27	**64.06**	56.68, 71.43
Control Area	156	84.03	**185.65**	176.44, 194.86

Table 4.5

Standardised Incidence Ratios for cancer in Males and Females in each of the 3 Study Areas compared to the Mid-Western
Health Board Population excluding skin cancer data.

	Observed Cases	Expected Cases	SIR	95per cent CI
Males				
High Risk Area	12	12.06	**99.50**	81.70, 117.31
Medium Risk Area	23	32.24	**71.34**	62.12, 80.56
Control Area	92	76.36	**120.48**	112.70, 128.27
Females				
High Risk Area	3	11.87	**25.27**	16.23, 34,32
Medium Risk Area	20	31.86	**62.77**	54.07, 71.48
Control Area	86	59.15	**145.39**	135.68, 155.11

Table 4.6

Standardised Incidence Ratios for cancer in Males and Females in each of the 3 Study Areas compared to the National Population including skin cancer data.

	Observed Cases	Expected Cases	SIR	95per cent CI
Males				
High Risk Area	16	22.80	**70.18**	43.79, 112.57
Medium Risk Area	43	56.91	**75.56**	52.98, 98.14
Control Area	166	158.78	**104.55**	88.65, 120.45
Females				
High Risk Area	6	22.11	**27.13**	5.42, 48.84
Medium Risk Area	29	55.07	**52.66**	33.49, 71.83
Control Area	156	109.55	**142.40**	120.05, 164.75

Table 4.7

Standardised Incidence Ratios for Males and Females in each of the 3 Study Areas compared to the National Population excluding skin cancer data.

	Observed Cases	Expected Cases	SIR	95per cent CI
Males				
High Risk Area	12	14.21	**84.45**	36.67, 132.23
Medium Risk Area	23	35.56	**64.68**	38.25, 91.11
Control Area	92	98.83	**93.03**	74.07, 112.11
Females				
High Risk Area	3	14.19	**21.14**	-2.78, 45.06
Medium Risk Area	20	35.78	**55.90**	31.40, 80.40
Control Area	86	70.16	**122.58**	96.67, 148.49

value of 27.13. This indicates that the risk was approximating close to one-quarter the risk of the Irish standard population. The control area showed a significant excess over what would be expected (SIR of 142.40). These results were statistically significant.

The analysis of the study data compared to Irish norms with skin cancer data excluded, demonstrated that the pattern is maintained with diminished risk for males and females in Askeaton. This was particularly marked for females with an SIR of 21.14, while males have a SIR of 84.45.

Discussion

These figures indicate that there was no increased incidence of cancers in the high risk Askeaton area in 1994 and 1995. If anything, these figures indicate that there are fewer cancers in the Askeaton area in that period than would otherwise be expected. This pattern is maintained whether or not Askeaton is compared with the Mid-West in general, or with the Irish population as a whole. This pattern is also maintained whenever skin cancers are excluded from the picture as the large numbers of such cancers will tend to have a dilutional effect on the less common and more serious cancers.

The Askeaton Mortality Study

Background

An analysis of all cause mortality and respiratory mortality between 1991 and 1996 in the Mid-Western Health Board region was undertaken. Routinely produced mortality information in the Republic of Ireland is only detailed to County level. Even County Boroughs such as Limerick City are not separated out. However it was felt this level of analysis was insufficient to examine possible excess mortality in small areas, such as those currently under investigation. The decision was made therefore to invest a significant amount of time and resources to extract this information.

Aim and Methodology

This investigation set out to answer the following three questions:

- did people living in the Askeaton area have a higher mortality rate than people living in the lower risk or control areas?
- if they did suffer a higher incidence of mortality was this increase to be found in any particular sub-groups of the population?
- was there an association between mortality and distance from nearby pollution sources?

The areas chosen were the same six as for the other studies.

All deaths in the Mid-Western Health Board region between 1991 and 1996 were geocoded by hand and analysed. Deaths which could not be considered due to the effects of environmental pollution were excluded, namely those due to accidents and suicide. Death rates for each of the district electoral divisions (DEDs) in the Mid-West region were calculated as standardised mortality ratios using the Mid-Western region as a standard. A form of analysis known as Bayesian analysis was used to analyse the data, to ensure greater validity. In addition analysis were conducted both with and without an adjustment for deprivation levels in the areas being examined.

Results

The results (Tables 4.8 and 4.9) for each of the analysis are detailed below by cause, age, and gender:

All cause mortality, all ages (Males and Females)

When the SMRs for this category are considered without adjustment for deprivation the results show that there is no evidence of difference between any of the areas. There is a non-significant rise from a SMR in Askeaton of 83 to a SMR of 102 in Clarecastle indicating that Askeaton and Rathkeale have a more favourable mortality experience than the other areas. When adjustment is made for deprivation there is little change in the outcome.

All cause mortality, all ages (Females)

When the SMRs in the six areas are considered under this heading there is a rise from Askeaton with an SMR of 57 to an SMR of 99 in Clarecastle. These levels are at or below the expected levels of mortality for the region and again indicate a favourable mortality experience for those living in the Askeaton area. When adjustment is made for deprivation Askeaton has a more favourable mortality experience than the control areas.

Table 4.8

All Cause Mortality (A without and B with adjustment for deprivation level)

Outcome	**No. (per cent) DEDs with SMRs significantly a) > 100 b) > 150**	**Evidence of association with distance**	**Evidence of difference by Area**	**Area SMRs (median)**
1A. All Cause all age (Male & Female)	75 (18) 58 (14)	No	No	1. 83 2. 91 3. 54 4. 85 5. 105 6. 102
1B. All Cause all age (Male & Female)	76 (18) 53 (14)	No	No	1. 84 2. 90 3. 54 4. 85 5. 106 6. 91
2A. All Cause all age (Female)	51 (12) 48 (11)	No	No	1. 57 2. 54 3. 61 4. 100 5. 89 6. 99
2B. All Cause all age (Female)	52 (12) 48 (11)	No	Yes 1 vs 4,5 2 vs 4,5	1. 56 2. 54 3. 61 4. 100 5. 87 6. 91
3A. All Cause all age (Male)	48 (11) 41 (10)	No	No	1. 87 2. 85 3. 64 4. 73 5. 99 6. 91
3B. All Cause all age (Male)	50 (12) 42 (10)	No	No	1. 88 2. 83 3. 64 4. 73 5. 104 6. 78
4A. All Cause age 1-64 (Male & Female)	8 (2) 6 (1)	No	Yes 1 vs 3,4 2 vs 3,4,5	1. 101 2. 89 3. 58 4. 79 5. 110 6. 85

Contd.

Table 4.8 contd.

Outcome	No. (per cent) DEDs with SMRs significantly a) > 100 b) > 150	Evidence of association with distance	Evidence of difference by Area	Area SMRs (median)
4B. All Cause age 1-64 (Male & Female)	18 (4) 14 (3)	Yes RR increases with distance.	Yes 1 vs 3,4,6 2 vs 3,4,6	1. 97 2. 91 3. 65 4. 81 5. 108 6. 74
5A. All Cause age 0-14 (Male & Female)	None	No	Yes 1 vs 3,4,5,6 2 vs 3,4,5,6	1. 125 2. 112 3. 55 4. 80 5. 172 6. 85
5B. All Cause age 0-14 (Male & Female)	1 (< 1) 1 (<1)	Not determined	Yes 1 vs 3,4,5,6 2 vs 3,4,5,6	1. 109 2. 100 3. 44 4. 66 5. 135 6. 73
6A. All Cause age 15-64 (Male & Female)	28 (7) 27 (6)	Yes RR increases with distance.	Yes 1 vs 3,4 2 vs 3	1. 93 2. 71 3. 50 4. 78 5. 104 6. 75
6B. All Cause age 15-64 (Male & Female)	32 (8) 31 (7)	Yes RR increases with distance.	Yes 1 vs 3,4 2 vs 3,4,5	1. 88 2. 72 3. 53 4. 72 5. 104 6. 72
7A. All Cause age 65-84 (Male & Female)	55 (13) 46 (11)	No	No	1. 77 2. 90 3. 60 4. 93 5. 103 6. 108.
7B. All Cause age 65-84 (Male & Female)	55 (13) 46 (11)	No	No	1. 77 2. 90 3. 61 4. 93 5. 103 6. 108

Table 4.9

Respiratory Mortality (A without and B with adjustment for deprivation level)

Outcome	No. (per cent) DEDs with SMRs significantly a) > 100 b) > 150	Evidence of association with distance	Evidence of difference by Area	Area SMRs (median)
8A. Respiratory all age (Male & Female)	26 (6) 26 (6)	No	No	1. 98 2. 108 3. 73 4. 88 5. 71 6. 77
8B. Respiratory all age (Male & Female)	29 (7) 29 (7)	No	Yes 2 vs 5	1. 94 2. 106 3. 76 4. 88 5. 68 6. 62
9A. Respiratory all age (Female)	13 (3) 13 (3)	No	Yes 1 vs 3,4,6 2 vs 3,4,6	1. 58 2. 58 3. 78 4. 100 5. 55 6. 109
9B. Respiratory all age (Female)	13 (3) 13 (3)	No	Yes 1 vs 3,4,6 2 vs 3,4,6	1. 58 2. 57 3. 85 4. 100 5. 57 6. 95
10A. Respiratory all age (Male)	7 (1) 7 (1)	No	Yes 1 vs 3,4,5,6 2 vs 3,4,5,6	1. 129 2. 111 3. 78 4. 82 5. 74 6. 67
10B. Respiratory all age (Male)	11 (2) 11 (2)	No - marginally	Yes 1 vs 3,4,5,6 2 vs 3,4,5,6	1. 128 2. 104 3. 83 4. 81 5. 78 6. 52
11A. Respiratory age 1-64 (Male & Female)	none	No	Yes 1 vs 3,4,6 2 vs 3,4,6	1. 96 2. 92 3. 86 4. 101 5. 94 6. 71

Contd.

Table 4.9 contd.

Outcome	**No. (per cent) DEDs with SMRs significantly a) > 100 b) > 150**	**Evidence of association with distance**	**Evidence of difference by Area**	**Area SMRs (median)**
11B. Respiratory age 1-64 (Male & Female)	12 (3) 12 (3)	No - marginally	Yes 1 vs 6 2 vs 6	1. 83 2. 79 3. 79 4. 93 5. 86 6. 56
12A. Respiratory age 0-14 (Male & Female)	Nos. too small	-	-	-
12B. Respiratory age 0-14 (Male & Female)	Nos. too small	-	-	-
13A. Respiratory age 15-64 (Male & Female)	2 (< 1)) 2 (< 1)	-	Yes 1 vs 4,5 2 vs 4,5,6	1. 81 2. 78 3. 81 4. 105 5. 94 6. 68
13B. Respiratory age 15-64 (Male & Female)	18 (4) 18 (4)	Yes RR increases with distance.	Yes 1 vs 4 2 vs 4	1. 74 2. 67 3. 77 4. 95 5. 83 6. 55
14A. Respiratory age 65-84 (Male & Female)	14 (3) 14 (3)	No - marginally	Yes 2 vs 5	1. 103 2. 105 3. 75 4. 87 5. 74 6. 102
14B. Respiratory age 65-84 (Male & Female)	12 (3) 12 (3)	No - marginally	Yes 1 vs 6 2 vs 6	1. 83 2. 79 3. 79 4. 93 5. 86 6. 56

All cause mortality, all ages (Males)
There was no evidence of statistical differences between the areas. This picture did not change after adjusting for deprivation.

All cause mortality, ages 1-64 (Male and Female)
Examining all cause mortality among people aged 1 to 64 revealed that Askeaton has an SMR of 101 indicating that the population in Askeaton in this category have a mortality experience which is approximately that of the rest of the Mid-West. However SMRs are lower for areas 2, 3, 4 and 6 and there is evidence of statistical difference between areas 1 and 3 and 4. This picture is maintained whenever deprivation is taken into account and the first time a relationship is seen with distance in that the risk of mortality increases the farther away the area from the point source.

All cause mortality, ages 0-14 (Male and Female)
Analysis of the SMRs between different areas show area 1 varying from other areas, although still close to the average, with the highest SMR being found in area 5. The differences between area 1 and areas 3, 4, 5 and 6 are statistically significant and indicate that those aged 0 to 14 in the Askeaton area and in one of the control areas have a higher mortality experience than would be expected for the rest of the region. This relationship remains but is weakened whenever deprivation is taken into account. The actual numbers of children involved however are very small. The total number of deaths of children in the Askeaton area, during the study period, was three. Although the difference between the number of deaths that would be expected and the number seen is statistically significant, the actual difference is very small.

All cause mortality, ages 15-64 (Male and Female)
The low SMR of 93 for Askeaton indicates it had a favourable mortality experience in relation the Mid-West. After adjustment for deprivation this pattern is maintained.

All cause mortality, ages 65-84 (Male and Female)
Askeaton had a favourable mortality experience (SMR of 77) compared to the control areas and the Mid-Western region and this relationship is maintained following adjustment for deprivation.

Respiratory mortality, all ages (Male and Female)
There is no statistically significant difference between the areas.

Respiratory Mortality, all ages (Female)
There is a gradual rise across the areas from an SMR of 58 in Askeaton to 109 in Clarecastle. The differences between are statistically significant and this relationship is maintained following adjustment for deprivation.

Respiratory mortality, all ages (Male)
This group shows a statistically significant drop in SMRs from the Askeaton area (SMR of 129) to the control areas (e.g. Clarecastle has an SMR of 67) and this relationship is maintained following correction for deprivation.

Respiratory mortality, ages 1-64, (Male and Female)
Results indicated statistically significant differences between Askeaton and other areas. There is an overall downward trend in SMRs from Askeaton (96) to other areas indicating that Askeaton has a slightly worse mortality experience in this age group than in the control areas. This pattern is maintained following correction for deprivation. However, it must be noted that the Askeaton experience is no worse than the region as a whole.

Respiratory mortality, ages 0-14 (Male and Female)
The numbers here were too small to analyse.

Respiratory mortality, ages 15-64 (Male and Female)
Results here indicated a picture of better mortality experience than the Mid West for all areas.

Respiratory mortality, ages 65-84 (Male and Female)
The SMR for Askeaton was 103, slightly worse mortality experience than three of the four control areas. This relationship is largely maintained following correction for deprivation.

Conclusions
Generally, the mortality picture for Askeaton was better than the overall regional position. However some exceptions are apparent in relation to the Area controls. All cause mortality among young people (aged 0-14) of both sexes showed a significantly higher rate in Askeaton. In addition the rate of respiratory mortality among men of all ages was significantly higher in Askeaton. On the basis of this analysis of deaths from all cause and respiratory mortality, there is no consistent pattern of elevated risk associated with Askeaton compared to the control areas or the Mid West as a whole. Based on a distance from site model, is there no consistent evidence for an increased risk closer to the alumina plant – if anything, the risk increases as distance increases away the plant.

The investment of resources in this study was significant and intensely time-consuming. The current level of geocoding mortality data to County level in the Republic of Ireland is no longer acceptable. More precise information, to DED, townland, enumerator district, or ideally to individual household level is an essential and overdue development.

The Adolescent Health Study

Background
The Askeaton investigation quickly identified the limits of existing health information systems. These deficiencies were particularly apparent in relation to child health. It was felt that a specific child health status measure should be used. Up to the 1990's, health-related outcomes in children and adolescents were still being defined in predominantly clinical terms of morbidity and mortality. The field lacked a well-validated and comprehensive self-report tool measuring perceived health and well being of children. After considerable research, a newly developed questionnaire from the USA was adopted. The Child Health Questionnaire (CHQ) was constructed to measure the physical and psychosocial well being of children five years of age and older. Concepts measured in the CHQ-CF87 (Child Form, 87 items) include physical functioning, role/social limitations - physical, role/social limitations - emotional and behavioural, general health perceptions, bodily pain, self-esteem, mental health, general behaviour, family activities, family cohesion, and change in health.

Aim and Methodology
The aim of this study was to determine if the physical health experience of teenagers living in the Askeaton/Rathkeale area of County Limerick was worse than that of teenagers in three comparison areas in County Clare (Killadysert, Ennistymon and Clarecastle). Secondary schools were located within the study areas with the assistance of the local School Inspectorate and were invited to participate. Nine of the ten schools identified agreed to take part, the tenth stating that at the time they were too busy. The study consisted of a respondent completed survey comprised of the CHQ-CF87 plus a short section recording demographic details being administered to an opportunistic sample of second year and pre-Leaving Certificate year pupils at schools in the risk and control areas. (It should be noted that the Moyne & Littleton comparison area in Tipperary North Riding is excluded from this study as there is no secondary school within the area.) Due to the small number of participating schools in Askeaton and Rathkeale (one secondary school in each), results from these areas are combined for the purpose of the analysis. The seven schools in the comparison areas of Killadysert, Ennistymon and Clarecastle were combined and used as controls. A total of 750 pupils took part in this study, approximately one-third from Askeaton and Rathkeale and the remainder from Killadysert, Ennistymon and Clarecastle.

Results
From the present study (Table 4.10), it was evident that the physical health experience (as measured by physical and general health subscales of the CHQ-CF87) of teenagers living in the Askeaton/Rathkeale area is not significantly different to that of teenagers living in comparison areas in Co. Clare. Askeaton/Rathkeale students did not:

- experience more problems doing physical activities due to health problems,
- experience more bodily pain or discomfort,
- have role or social limitations due to physical health problems
- and they perceived their general health in the same way as control area students.

The "change in health" item which asked respondents to rate their health now compared to one year ago did produce a significant difference between areas. Respondents in the risk area scored significantly higher on this item than respondents in the comparison area. On average, however, both risk and comparison area students rated their health as between "about the same now as one year ago" and "somewhat better than one year ago". Care

Table 4.10

Results of Adolescent Health Study

Subscales	**Area**	
	Risk	**Comparison**
Bodily Pain**	69.32 (103)	70.65 (479)
Role/Social Limitations - Physical**	91.27 (98)	91.89 (471)
Physical Functioning**	92.94 (96)	93.51 (442)
Global Health**	69.71 (103)	71.56 (473)
General Health Perceptions**	62.08 (89)	62.98 (412)
Change in Health*	3.46 (101)	3.28 (475)
Mental Health**	70.02 (86)	69.25 (427)
Self-Esteem**	69.66 (85)	69.10 (445)
Role/Social Limitations - Emotional**	83.88 (102)	82.05 (476)
Global Behaviour**	68.89 (104)	67.48 (475)
Behaviour**	72.14 (95)	71.11 (431)
Role/Social Limitations - Behavioural**	90.12 (99)	86.46 (476)
Family Cohesion**	69.31 (101)	66.18 (467)
Family Activities**	72.96 (98)	75.46 (456)

*$p<0.05$; **NS

must be taken when evaluating data from single global items, especially in the absence of other significant effects. Students from the risk area had significantly higher mental health, self-esteem and behaviour scores than students in the control area.

Discussion

Retrospective health assessment can be problematic. In view of this fact, health status measures generally adopt recent time frames within which respondents report their health experience. For example, in the CHQ-CF87 used in the present study, the physical health questions refer to the "past four weeks". Self-reports of physical health would be unreliable beyond this time frame. While anecdotal concerns in the risk area about young people's health may have spanned a number of years, it is not possible using a self-report measure to examine physical health for that time period. However, at the time of this study (mid-1997) the physical health of teenagers living in the risk area of Askeaton/Rathkeale was not significantly different to the physical health of teenagers living in three comparison areas in Co. Clare.

The Child Absenteeism Study

Background

This study following consultation with and recommendations from the local residents group (Askeaton/Ballysteen Animal Health Committee) and Dr Pat Wall, Consultant Environmental Epidemiologist. The study was a response to the absence of child health information systems and the problems encountered in examining child health through questionnaire-based methodologies.

The use of routinely collected data to try and assess the impact on health of pollution is not a new phenomenon. Fairbairn and Reid (1959) used routinely available archival data on sickness absence among civil servants and postmen to try and evaluate the negative health effects of fog pollution. Their pioneering study found a significant link between pollution and sickness absence in different parts of Great Britain. A significant volume of research has linked pollution with negative health effects among both children and adults. Many of these effects would logically seem to be of a nature whereby they could impact adversely on school attendance among

children. Landgraf *et al.* (1996) note that 'historically, restricted school attendance (i.e., disability days) has been the most frequently used proxy item for assessing role limitations in children'. However, only a small number of studies have specifically examined the relationship between pollution and school absenteeism.

Aim and Methodology

The aim of this study was to determine if school absenteeism in the risk areas was different from that in the comparison areas. As with previous studies the same six areas were used.

There were no centralised records of pupil absenteeism in a format amenable to this type of investigation. Fifty-two National Schools were identified in the six study areas. All 52 schools agreed to take part and data were collected from 50 of these. The study time frame for this ecological study was the ten years covering the school year 1985-1986 to the school year 1994-1995. The data were generally collected from the "clárleabhar", which provides a summary of total days attended for pupils over their stay in each school year. As well as attendance data, date of birth and gender were collected. However, the "clárleabhar" register was incomplete in approximately one-half of schools and data were collected in part or entirely from the day to day roll-book. Information on the number of days each school was open for each of the ten years included in the study was also collected and an attendance rate for each pupil was calculated. In the light of age differences reported in the research literature on school absenteeism and pollution, results were also analysed by age group. Analysis of attendance by area and age was undertaken. Data were collected on 10,723 pupils in total; of these, 4,531 came from Askeaton/Rathkeale, while 6,192 came from the comparison areas.

Results

Attendance in Askeaton/Rathkeale and the comparison areas over the ten years studied showed a very similar pattern of peaks and troughs (Fig. 4.7). The Askeaton area had lower attendance in each of the ten years examined and in nine of the ten years examined this difference was statistically significant. The year in which no statistical difference was found was 1988.

Discussion

Children from the Askeaton area had significantly higher rates of absenteeism in nine of the ten years examined (1986-1995) than children from the comparison areas. The difference in rates was not statistically significant for 1988. It is however important to put the present study's findings in context. The statistically

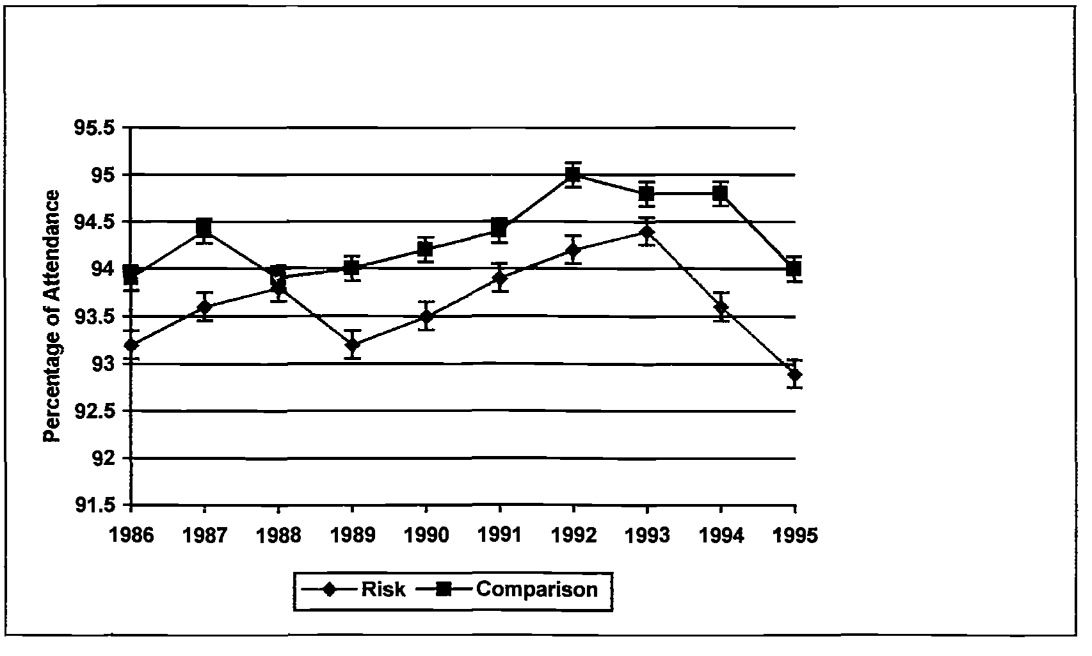


Fig. 4.7 Percentage of attendance at school in the risk and comparison areas (2-6) 1986-1995

significant differences in school absenteeism reported above equate to a difference, on average, of between 0.5 days and 1.25 days a year. To help put this difference in perspective, asthma sufferers have on average three more days absent from school per year than non-sufferers. It is important to differentiate between statistical and clinical significance. The very large sample sizes involved mean that even very small differences may be statistically significant. It should be noted that this retrospective study has limitations and care should be taken when evaluating the results. School absenteeism is only a proxy measure of ill health. Other studies examining school absenteeism have tended to include only sickness-related absenteeism or were only focused on respiratory-related absenteeism. This study had no such detailed information, only a crude absenteeism score. Additionally, the study does not include information on the social class of the children involved. This factor has been shown to influence school attendance.

In conclusion, statistically significant differences in absenteeism were found between Askeaton and the other areas. These differences may not be clinically significant. The absenteeism rates cited are only a proxy measure of ill health and it is not possible to state that they are ill health absences let alone respiratory ill health absences. It is not possible to link the absenteeism to pollution as no measure is available. This study was exploratory in nature and no causal links can be drawn from the results.

Report on the Sampling of Horticultural Produce

Background

The Environmental Health Department of the Mid-Western Health Board at the request of the EPA undertook a sampling programme for horticultural products from the Ballysteen area. The programme was instigated on foot of fears expressed by some market gardeners in the area. They feared that their livelihoods would be adversely affected by a public perception of an environmental problem in the area (Ballysteen) in which their vegetables were sourced.

Method and Objectives

The objective of the survey was to establish whether vegetables grown in the Ballysteen area showed evidence of being contaminated or unfit for human consumption and to this end establish:

- Whether certain elements were present in the vegetables.
- Whether these elements, if present, were present in levels that might be considered above normal.

Following consultation with the Public Analysts Laboratory, University College Hospital, Galway, it was decided that samples would be analysed for aluminium, fluoride, lead, cadmium, arsenic, chromium and vanadium. A total of 40 samples was submitted. This figure included samples of vegetables produced in the Ballysteen area as well as control samples from outside the area. The vegetables sampled were predominantly loose-leaf vegetables such as cabbage and spring greens with a very limited number of cauliflower, turnips, leak and potatoes also included. The sampling programme extended from March to December 1996, with the majority of the samples being submitted on a fortnightly basis between March and May of that year. Samples were transported to the Public Analysts Laboratory on the day on which they were procured. Samples were identified by reference number only.

Results

The results are listed below for each of the elements investigated and the comparison with control areas.

Lead

A total of 18 samples was analysed for lead content. Statutory admissible levels for lead in food are set out in the Health (Arsenic and Lead in Food) Regulations 1972 (S.I. No. 44 of 1972). These Regulations prohibit the sale of food which contains lead in a proportion exceeding two parts per million. All samples submitted were found to be well within the acceptable range.

Cadmium

Of the 18 samples analysed for cadmium, twelve contained levels below that which can be detected in the laboratory (<0.05mg/kg). The highest reading for vegetables sourced in the Ballysteen area was 0.08mg/kg. There is no national legislation in respect of admissible levels of cadmium in food in this country. Daily intakes

of cadmium in food in Europe, New Zealand and the USA are usually about 10-25 µg. Estimatmg average green vegetable consumption to be 0.043 kg/person per day (MAFF Report on Aluminium in Food, 1993) intake of cadmium from this source based on highest level detected would amount to 3 µg/day.

Aluminium

Since aluminium is the third most abundant element in the earth's crust, as expected aluminium levels in samples submitted were higher than other monitored elements. A total of 22 samples was analysed for aluminium. In analysing four samples submitted on 04.12.96 particular care was taken to exclude soil particles. Quantifiable levels of aluminium were not found in any of these samples. In the case of the remaining 18 samples aluminium levels of less than 10 mg/kg were detected in16 (89per cent). The remaining two samples had levels of 11.6 mg/kg and 14.7 mg/kg respectively.

The average aluminium content of vegetables sourced in the Ballysteen area from which soil had not been excluded was 6.20 mg/kg, while the average content of control samples was 5.97 mg/kg. Allowing an average aluminium dietary intake of 3.9 mg/day (MAFF Report on Aluminium in Food, 1993) consumption of vegetables from the Ballysteen area would represent 6.8 per cent of the daily dietary intake of the element in the UK. The median of aluminium values for Ballysteen grown vegetables was 5.0 mg/kg. This figure would represent 5.5 per cent of the average daily intake.

Chromium

Thirteen samples were analysed for chromium, and all were shown on analysis to contain less than the detection limit of 0.25 mg/kg.

Vanadium

Five of the samples submitted were analysed for vanadium. All samples analysed were found to contain less than the detectable level of 1 mg/kg..

Arsenic

All five of the samples analysed for arsenic were found to have levels of less than 1mg/kg. The Health (Arsenic and Lead in Food) Regulations, 1972 (S.I. No. 44 of 1972) prohibits the sale of any food which contains arsenic in a proportion exceeding one part per million.

Fluoride

Five samples were analysed for fluoride, and all were found to contain levels less than the detection limit of 1mg/kg.

Control Samples

Out of a total of 40 samples submitted, 17 were control samples. In the case of lead, chromium, vanadium, arsenic and fluoride no difference was detected in levels between control samples and samples from the Ballysteen area. A very slight difference in aluminium and cadmium levels was noted between the vegetables from the two locations. The mean level of aluminium detected was 6.2 mg/kg in Ballysteen, while in the control samples it was slightly lower at 5.9 mg/kg. The mean level of cadmium detected was 0.056 mg/kg in Ballysteen, while in the control samples it was higher at 0.090 mg/kg.

Conclusion
The survey gave no indication that any of the elements measured in the Ballysteen sourced vegetables were present at levels which might be considered above normal when compared with levels measured in the control samples.

The Chloracne Study

At the beginning of the Askeaton investigation there were speculative press reports of cases of chloracne in the Askeaton area. Chloracne is a 'particularly refractory form of acne caused by halogenated aromatic chemicals, which may also cause systemic toxicity' (Oxford Textbook of Medicine. 3rd Edition. Eds: Weatherall, Ledingham

& Warrell. OUP. 1996: 1165). Chloracne is perhaps best known as a result of contamination following the leakage of 2,3,7,8-tetrachlorodibenzodioxin around Seveso in Italy.

In response to the local concerns, the Department of Public Health, MWHB, wrote to every known Consultant Dermatologist in the State asking them about their pattern of referrals suffering from chloracne. Responses from the Consultant Dermatologists indicated that none had ever encountered a case of chloracne in Ireland. In those instances where Consultants had encountered chloracne, it was while previously working in the UK and elsewhere and related to cases of occupational exposure. It was therefore possible to indicate that no such hazard existed in the Askeaton area.

The General Medical Script (Abnormal Prescribing Patterns) Study

Given the absence of health information systems that could facilitate an in-depth analysis of morbidity and mortality in the study areas, attention focused on other information systems that might be of some use to the investigation. The computerised General Medical Services (GMS) prescription record system was examined as a potential proxy measure of human health in the study areas. It was initially felt that it might prove feasible to detect abnormal patterns of morbidity in the Askeaton area through abnormal prescribing patterns. However following exploratory talks with the agency responsible for maintaining the database, and careful local review, the GMS system was rejected as a potential tool in this investigation. A number of key factors influenced this decision:

- the GMS scheme covers less than half of the population (approximately 35 percent) and therefore such a measure can at best yield an incomplete picture.
- the data held in the system are coded by General Practitioner. Therefore it cannot clearly be stated where an individual GMS patient resides. Only the location of their GP could be coded.
- the amount of information involved made the task a practical impossibility, particularly given the absence of any clear health effect or environmental contaminant.
- it is well known that at the level of individual GPs their own prescribing preferences are the main determinant of prescribing not local morbidity
- the measure was only a proxy method of examining health.

The HIPE Study

A number of studies have been done internationally linking environmental pollution with increased hospital admissions for certain diseases. The feasibility of using the equivalent in Ireland, the Hospital In-Patient Enquiry (HIPE) system, was examined. This system records information on each in-patient discharged from hospital including sex, age, date of admission and discharge, as well diagnosis and procedures undergone. Diagnosis is assessed using the standard International Classification of Diseases system (ICD-9). When HIPE records are matched with records from the Patient Administration System (PAS) which records a patient's home address it is theoretically possible to geographically code patterns of illness that resulted in hospital admission. However further investigation revealed that the patient address recorded in the PAS system is input simply as a string of characters. The only geographical level at which the HIPE/PAS systems define patient residence is a separate question in which residence at County and County Borough level is coded. Therefore, although it was simple to differentiate between HIPE/PAS records for Limerick County, as opposed to Limerick County Borough, more refined spatial analysis proved impossible.

The Eastern Health Board had developed address matching software which can geo-code the vast majority of addresses in its area to ward/ district electoral division (DED) level. Outside of this, the only commercially available software was designed to geo-code addresses to the nearest town. For the purpose of this investigation neither methodology was felt to be adequate or precise. Quality address matching software capable of working at DED level, or preferably sub-DED level (townland, enumerator district, or household level), would have been essential to investigate morbidity using the HIPE/PAS system. The tens of thousands of records involved made the possibility of geo-coding records by hand unfeasible, particularly in the absence of a clearly identifiable health effect or environmental contaminant in Askeaton.

CONCLUSIONS

An assessment of the findings of the investigation suggests the following conclusions:

- The review of the literature on the effects of atmospheric pollutants states that recent evidence is emerging of adverse reactions to environmental pollution at levels well below present national and international standards.

- The Chloracne study as discussed above can be discounted as little more than a media red herring.

- It is equally reassuring that the three birthing studies did not find any evidence of abnormal ill health in the area. The rate of congenital anomalies was as expected, as was the twinning rate. The possible change in the sex ratio among births in favour of females, as might have been expected in an area of pollution, was absent.

- The GP study, an admittedly imprecise instrument, but a key one given GPs importance in being solely responsible for dealing with 95 per cent of patient health queries, found proportionally more worries about rates of miscarriage, serious illness, and patient health in Askeaton.

- The Human Health Survey reported a mild excess of self-reported ill health for Askeaton on many of the measures used. However similar results were found in Moyne & Litteleton and Clarecastle. It is, however, hard to evaluate these results, given the high degree of environmental awareness and concern in Askeaton, and the effect this might have on this self-report measure. However the results indicate a pattern in which the areas examined fall into two groups, that mentioned above experiencing worse health, and the other group consisting of Killadysert, Ennistimon and Rathkeale experiencing better health. This pattern is not consistent with any known pollutant.

- The diary study conducted for over one year on farms in the affected area found an excess of mild ill-health on two farms in particular, and poor health on another three. Again the health diary is obviously a self-report measure and care must be taken in its interpretation.

- The cancer investigation found no evidence of an excess of cancer incidence in the risk area. The study actually revealed a significantly lower level of cancer in the risk area compared with the comparison areas, the MWHB and the State.

- The mortality study recorded generally a better than expected pattern of mortality. However, the significant excess results for all cause mortality among young people (aged 0-14) of both sexes and the rate of respiratory mortality among men of all ages in Askeaton goes against that pattern.

- The adolescent health measure (the CHQ-CF87) examining health over the month previous to the study found no evidence of worse health in the Askeaton.

- The study using school absenteeism as a proxy health measure did record significantly lower attendance in Askeaton in nine of the ten years studied.

- Given the shortage of routinely available data highlighted in this investigation, systems must be put in place which will allow routine surveillance of health status in circumstances such as those in Askeaton.

On balance it would appear that there is an excess of self-reported mild ill health in the Askeaton area that does not lead onto health service intervention. The clinical or practical significance of some of the findings is questionable, despite their statistical significance. It is impossible to be certain of the validity of the findings given the self-reported nature of much of the evidence. Environmental concern may have been high enough to raise peoples concerns about their health in the Askeaton area. The results from the Human Health Survey do not support a link to any form of local environmental pollution. The Human Health Survey demonstrated a clustering of the reported health experience of the six areas examined into two spatially scattered groups. The areas experiencing worst health included Askeaton, Moyne & Littleton and Clarecastle. Ennistymon, Killadysert and

Rathkeale reported better health status. This pattern of health experience is not consistent with any known pollutant or pollution source.

In summary, this study has not found a significant degree of excessive ill health in the Askeaton area.

Chapter Five

ENVIRONMENTAL QUALITY

P. Toner, J. Bowman, C. O'Donnell, M. McGettigan and C. Concannon

INTRODUCTION

It was clear at the start of the investigations that there were strong suspicions on the part of the farmers directly concerned and of many others in the farming and non-farming communities in the Askeaton area that the animal health problems and possible human health problems were caused by environmental pollutants. Emissions from the alumina production plant at Aughinish Island, located some 8 km west of the affected farms, were a particular focus of these suspicions. In view of the strong feeling on the matter locally, it was considered necessary that, whether or not the suspicions were justified, a full assessment of the pollution risks and the environmental quality position in the area be undertaken.

Prior to the investigations, Limerick County Council, as the statutory pollution control authority in the area, commenced measurements of air and precipitation quality on one of the two problem farms (Somers) in 1993. In addition, air quality monitoring networks had been operating around both the Aughinish Alumina Ltd. (AAL) and the Electricity Supply Board (ESB) plants at Moneypoint and Tarbert since the commencement of their operations in the mid 1980s and some of these, particularly those operated by Forbairt (now Enterprise Ireland) for AAL, are near to the locations of the affected farms. These monitoring operations constituted the only relevant measurements of environmental quality available in the area for the period when the animal health problems were at their most severe (late 1980s to mid 1990s).

PROTOCOL FOR INVESTIGATION

The investigation was designed to assess the possibility that environmental pollution was occurring in the area at a level which might cause or contribute to the animal health problems and which might also be responsible for reported human ailments. In addition, the overall approach adopted was based on a consideration that, if environmental pollution was a factor, this was most likely to be of an atmospheric nature, resulting in poor air quality and/or harmful levels of pollutant deposition on farm land.

In order to achieve this objective, it was considered necessary to undertake the following tasks.

a) Determine the potential for emissions of atmospheric pollutants from all important industrial sources and power stations likely to affect the area under investigation and the risks associated with such pollutants

b) Estimate the quantities of relevant air pollutants emitted from all such sources.

c) Assess the areas of greatest impact of these emissions and whether these include the problem farms.

d) Determine the short-term variations of the potential gaseous pollutant concentrations on the affected farms and compare with a control farm.

e) Estimate the deposition of potential pollutants on the farms and compare with a control site

f) Investigate the level and potential impact of a number of organic compounds, including dioxins, and other substances which are not likely to be emitted in significant quantities in the Askeaton area but regarding which public concern had been expressed.

As a general strategy, it was also decided to concentrate the bulk of the environmental measurements on the farms originally reporting problems (Somers and Ryan). The problems on these two farms were generally acknowledged to be severe so that if environmental pollution was involved, it was reasonable to expect that measurements at those locations alone should be able to confirm this hypothesis. This approach paralleled that

adopted for the veterinary and soils and herbage investigations which were also concentrated on the Somers and Ryan farms.

POLLUTANTS EMITTED AND POTENTIAL IMPACTS

Industrial Activity

The main industrial activity in the area giving rise to atmospheric emission of pollutants is the burning of oil and coal to generate heat and power. In the immediate area of Askeaton, the bulk of this activity takes place in the AAL bauxite processing plant at Aughinish, Co. Limerick (see Fig. 5.1). However, the two ESB electricity generating stations further to the west at Moneypoint, Co. Clare and Tarbert, Co. Kerry are larger emission sources. The other main sources of atmospheric emissions in the immediate area are the production processes, particularly calcining, at AAL. Smaller activities in the local area include the manufacture of milk-based baby foods at Wyeth Nutritionals Ltd and polystyrene products at Southern Chemicals Ltd. A variety of activities takes place in the Shannon Industrial Estate to the north-east across the Shannon estuary while, further afield in that direction, the Roche (formally Syntex) pharmaceutical plant is located at Clarecastle, Co. Clare. A full account of the industrial activities in the area is given in the environmental quality volume.

Sulphur Dioxide and Nitrogen Oxides

Sulphur dioxide (SO_2), arising from the oxidation of sulphur in the coal and oil, and nitrogen oxides (NO_x), (sum of nitric oxide (NO) and nitrogen dioxide (NO_2)), formed by the oxidation of atmospheric nitrogen in the high temperatures generated, are the main gaseous pollutants emitted by the combustion of oil and coal in the area. Both SO_2 and NO_2 are potential irritants of the respiratory system in man, asthmatics being particularly vulnerable, and they may also cause aggravation of cardiovascular disease. However, there is little information in the literature on the direct effects of the pollutants on farm livestock although experimental work with a variety of laboratory test animals showed similar effects to those observed in man. In addition, high concentrations of SO_2 and NO_x in air can directly damage vegetation especially in combination with other stresses such as cold.

SO_2 and NO_x contribute to the "acid rain" phenomenon due to their conversion in the upper atmosphere to sulphur and nitric acids; this process is relatively slow and the main impacts are likely to occur well away from the emission sources. However, some deposition of sulphur may occur locally due to absorption on particulate matter and washout in rain. A substantial increase of soil sulphur levels resulting from such deposition could interfere with the uptake of minerals into herbage thereby creating a risk of ill health in livestock.

Estimates were made of the emissions of SO_2 and NO_x (Figs 5.2 and 5.3) as these were clearly the pollutants with by far the greatest potential to cause environmental problems in the area. For SO_2, the estimates were based mainly on information on the quantities of fuel used and the sulphur content of the fuel. The emissions of NO_x were estimated using emission factors applicable to the combustion conditions in the different plants, as determined from direct measurements. These estimates are subject to considerably more uncertainty than in the case of SO_2. Records of emission monitoring data were also examined to further clarify the situation.

It is clear that the two ESB stations account for the bulk of the emissions of the gases in the general area. Over the 12 year period shown in the figures, the combined emissions from Moneypoint and Tarbert accounted for, on average, 82 and 92 percent, respectively, of the total emissions of SO_2 and NO_x. Of particular note is the large increase of the emissions from the Tarbert plant over the period; this is due to the recommissioning of several previously idle generating units in order to meet rising national demand.

The AAL plant, being nearest to the area of the affected problem farms, is, however, of greatest interest in relation to possible pollution in the Askeaton area. Annual emissions of SO_2 there varied from a minimum of 11,310 tonnes in 1988 to a maximum of 19,475 tonnes in 1994. In several months in 1994, SO_2 emissions exceeded the limits set in planning permission due to deliveries of oil to the plant, which were above specification (3%) for sulphur content. Apart from those in 1994, the annual emissions of SO_2 from the plant showed relatively little variation between 1990 and 1999.

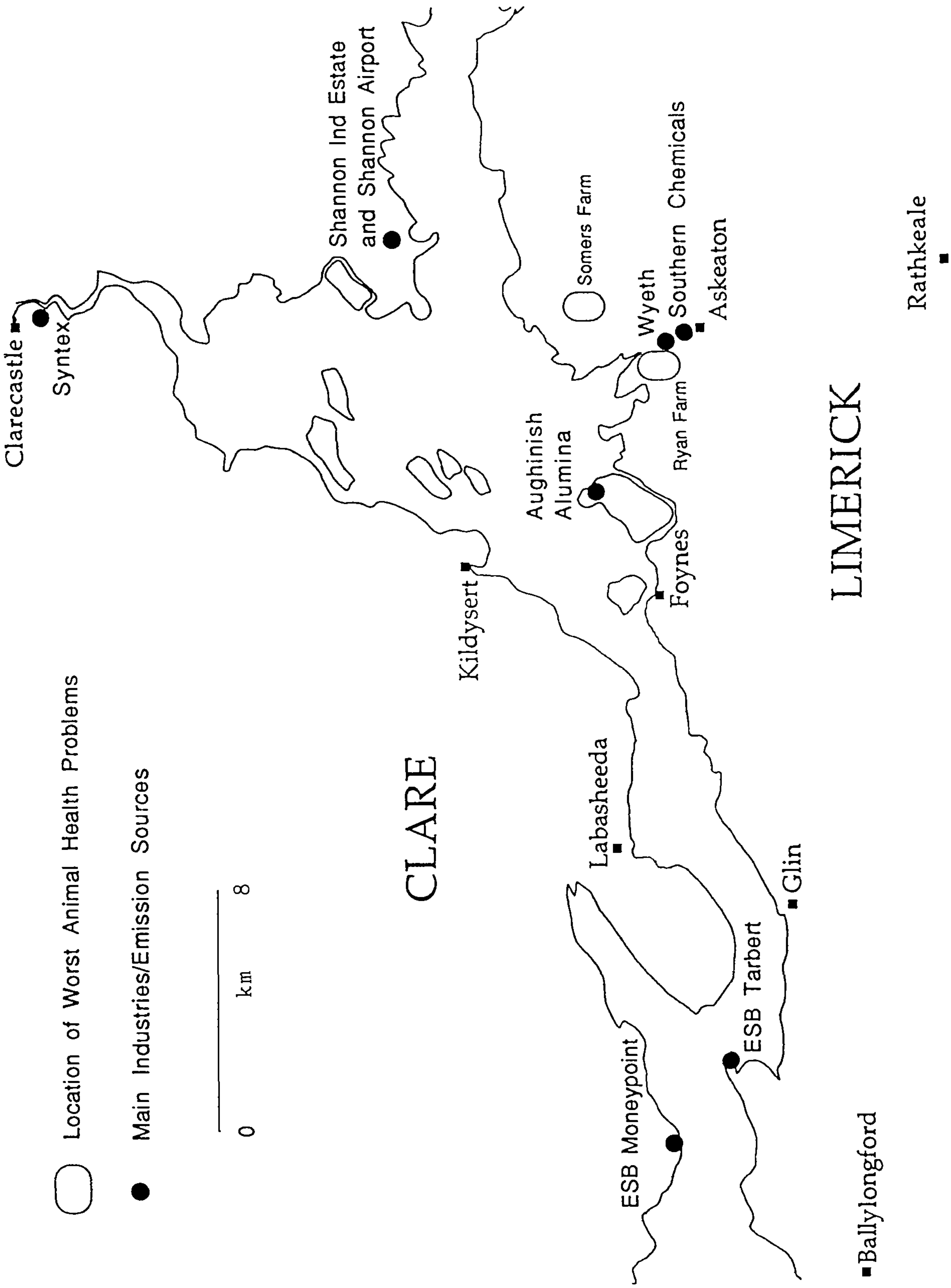


Fig 5.1 Locations of main industrial activities in the Shannon Estuary region

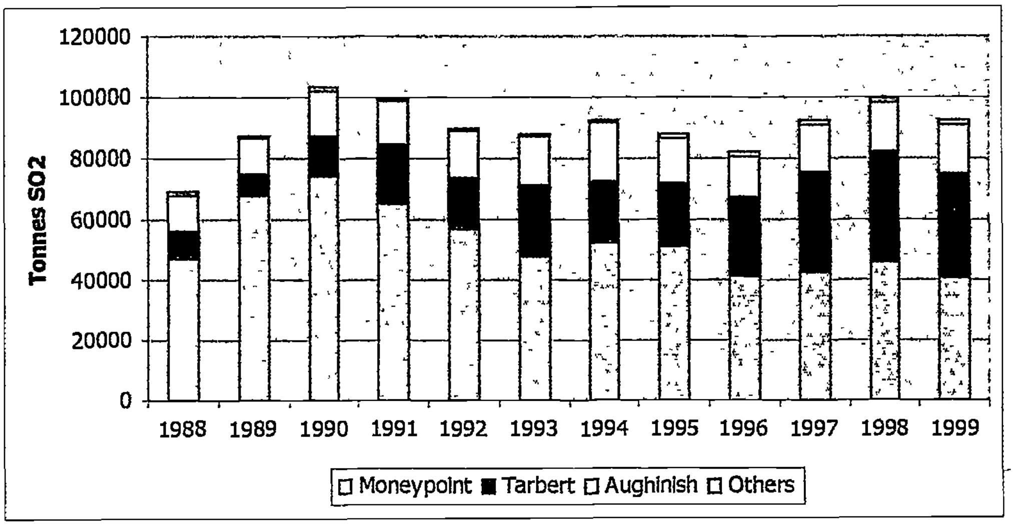


Fig 5.2 Estimated emissions of SO_2 from the main and combined minor sources in the period 1988-1999.

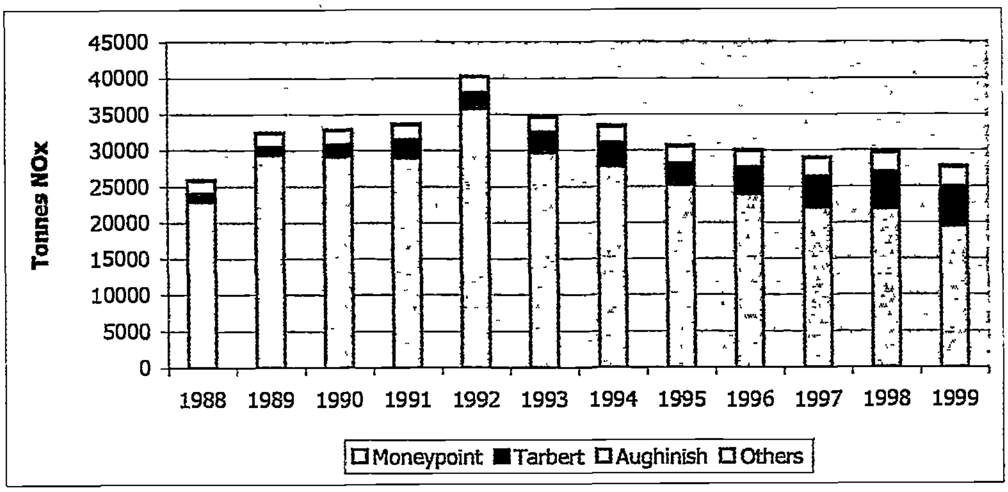


Fig. 5.3 Estimated emissions of NO_x from the main and combined minor sources in the period 1988-1999.

An IPC licence granted to AAL in 1998 sets a limit of just over 23,000 tonnes per annum for the total annual emission of SO_2 from the plant. This is an increase on the limit of some 17,000 tonnes set under the local authority planning permission, which prevailed before the introduction of the IPC licence. However, the actual emissions were within both limits in the years after 1995. The emissions of NO_x from AAL, while showing a gradual increase over the period, are much smaller (13-16 per cent) than those of SO_2.

Compared to the emissions from AAL, those from the other activities in the immediate area are of minor dimensions, and are estimated to be of the order of 1000 t SO_2 and 150 t of NO_x per annum.

Particulate Matter

Combustion of fuel, as in the ESB and AAL plants, gives rise to the emission of particulate matter (PM), of mainly carbonaceous origin; PM may be formed also by reactions between other pollutants, such as SO_2, NO_2,

volatile organic compounds and ammonia. Particulate matter is also emitted from the calciner and other process vents at AAL and may be swept into the air from the surface of the waste lagoons there. Epidemiological studies in cities have shown a relationship between the concentrations of such matter in the air and the incidence of various respiratory ailments, especially in the case of the smaller size fractions of less than 10 micrometres (PM_{10}).

Particulate matter in general may have organic compounds adsorbed and thus introduce such substances to the respiratory system when inhaled.

Metals

There are releases to the local environment of metals and metallic compounds such as vanadium from the fuel oil and alumina (aluminium oxide) from the calcining operations at AAL. There is also a potential for dust, containing metallic compounds, to be blown on to adjoining land from the waste lagoons at AAL, these compounds mainly consisting of oxides of iron and titanium. Metals and their compounds are potentially toxic to plants and livestock but it should be noted that those aforementioned are of relatively low toxicity and are present naturally in soils at substantial concentrations (*see* Chapter Three). There are no significant releases of the more toxic metals, such as cadmium, to the local environment.

At the start of the investigations, suggestions were made locally that aluminium contamination could be involved in the animal health problem in view of the proximity of the AAL plant. Aluminium salts are known to affect livestock through interference with phosphorus uptake from the gut leading to a variety of physiological dysfunctions. The risk of this effect in the Askeaton area is lessened by the fact that the form of aluminium released from AAL is the oxide which is relatively non-reactive and, thus, of low toxicity. As mentioned above, however, aluminium was measured in precipitation in order to determine if above normal levels were being deposited in the area. In addition, livestock have been checked for symptoms of aluminium poisoning (see Chapter Two).

Organic Compounds

There are no major sources of synthetic organic compounds in the Askeaton area but small amounts of such substances are emitted from a number of plants. Methyl ethyl ketone, a solvent emitted from the Wyeth milk processing plant, where it originates in lacquers, is the most notable organic compound emitted. Styrene (vinylbenzene) is released in the cutting of polystyrene blocks in the Southern Chemicals plant but there is no specific venting of this to the atmosphere. Concentrations in the plant resulting from fugitive emissions have been measured at less than 10 ppm, which can be compared to an occupational hygiene exposure limit of 50 ppm. Further afield, several organic solvents such as acetone and toluene are released from the Roche (formerly Syntex) pharmaceutical plant near Clarecastle in Co. Clare. However, there has been a large reduction in these emissions recently due to the introduction of an incineration facility for the disposal of waste solvent. In addition, various organic compounds are emitted by smaller industries in the Shannon Industrial Estate.
Exposure to high concentrations of these substances can have adverse effects such as dizziness, drowsiness, headache and nausea. However, the amounts emitted indicate that ambient concentrations in the Askeaton area would be insignificant and would not constitute a risk to human health. Measurement of volatile organic compounds was undertaken to confirm this assessment and the results are given later in the report.

The industrial processes in the area are not among those generally recognised as significant sources of dioxins and related compounds. However, the emissions from the ESB plants and from AAL have been tested for the presence of these substances. Levels found were generally well below the EU limit of $0.1 ng/m^3$.

Fluorine

Fluorine was also mentioned as a possible pollutant in the area. This substance is known to have specific effects on livestock, including mottling of teeth. However, the main potential for fluorine pollution in aluminium production is associated with the smelting industry in which a fluorine-containing compound is used as a catalyst. The AAL facility is concerned solely with the extraction of alumina from bauxite, the product being shipped to smelters in the UK and further afield. It is known that due to local geological characteristics, soils in some parts of the Askeaton area have relatively high levels of fluorides (*see* Chapter Three).

MEASUREMENT PROGRAMME

Following the assessment of the industrial activities and their waste emissions in the area it was concluded that the main risk of pollution arose from SO_2 and NO_X gases in air and from the deposition of sulphur and nitrogen

compounds in precipitation. The former pose a direct threat, in particular to human health, while the latter could lead to interferences with the uptake of minerals into herbage used for grazing livestock or for the making of silage. Thus, the bulk of the environmental measurements made during the investigations were concerned with the levels of SO_2 in air and the amounts of sulphur and of nitrogen compounds being deposited in precipitation. It was considered that monitoring of SO_2 levels in air would also serve to determine whether there were harmful amounts of NO_x gases present as the emissions of the latter were much smaller than those of SO_2.
It has been mentioned at the start of the chapter that monitoring of SO_2, by both the ESB and AAL, was already in place for some years before the start of the investigations,. These monitoring programmes employ conventional 8-day samplers which yield daily mean concentrations of the gas. It was decided, therefore, that, in addition to considering data arising from the latter programmes, further information should be gathered by deploying continuously measuring instruments on the two problem farms. This would allow an assessment as to whether there were any short-term episodes of very high concentrations of SO_2 which might be masked by the daily means produced by the existing networks. Thus SO_2 monitors were installed on the Somers and Ryan farms between April and May 1995 and operated there for the duration of the investigations.

Precipitation sampling on the Somers farm had been undertaken by Limerick County Council before the start of these investigations. It was decided, however, that the scope of this work should be increased by more frequent sampling and the measurement of a greater range of parameters. Following a preliminary investigation between March and September 1995, based on weekly sampling, daily sampling of precipitation on both the Somers and Ryan farms commenced in November 1995 and continued until November 1998. Daily sampling was also carried out in 1998 at a site near to the Askeaton Water Works (AWW) where studies on vole enzymes had suggested anomalies possibly linked to pollution (see Chapter Two). In addition, in order to extend the scope of the measurements, weekly sampling was carried out on two further farms in the area (White and Hannon) in 1997-1998. For comparative purposes, weekly sampling, in addition to daily, was carried out on the Somers farm in the same period. As a separate exercise, the possibility of excessive deposition of heavy metals in the area was assessed by monthly sampling and analysis of precipitation on the Somers and Ryan farms. Monthly sampling was employed in this case as the results were being compared with data from remote sites in Cos. Kerry and Wicklow where this sampling frequency was used. As the collecting devices were continuously exposed, all samples taken in these programmes were of total precipitation, that is including both rain and dry matter.

In 1995, measurements were made of a number of other substances which had been suggested locally as possible causes of the problems. While the examination of the industrial activities in the area did not indicate that there was a risk from such substances, it was considered desirable to back up this assessment with environmental data to allay local concerns. Measurements were made, *inter alia*, of dioxins in soils, volatile organic compounds in air and aluminium and fluorine in milk.

RESULTS OF MEASUREMENTS

SO_2 Concentrations

Modelling of the dispersal of the emissions from the ESB plants and from AAL had shown that the increases of SO_2 concentrations above background due to these emissions would not constitute any risk of breaching the national limits (Table 5.1) in the Askeaton area. Selected statistical predictions for the AAL emissions are shown in Fig. 5.4. The highest predicted value for the 98 percentile value of the daily mean concentrations is around 75 $\mu g/m^3$ compared to the national limit of 350 $\mu g/m^3$.

These predictions are borne out by the monitoring results from the ESB and AAL networks (Fig 5.5) which show that the daily concentrations are well within the various national limits at all of the sites operated. Data for three of the sites in the AAL network are shown in Fig 5.6. As the stations in this network are nearest to the area of interest, they are of greater relevance than those in the ESB network which generally lie further west. It is clear that the 98 percentile of daily mean concentrations at these sites are much lower than the national limit.

Table 5.1

Air Quality Standards for SO_2 and smoke set by National Regulations (DoE, 1988) ($\mu g/m^3$)

Statistic	**Limit value for SO_2**	**Associated Smoke Concentration**	**Limit value for Smoke**
Annual median of daily mean values	80 120	>40 = or <40	80
Winter median of daily mean values	130 180	>60 = or < 60	130
98-percentile of daily mean values	250 350	>150 = or < 150	250
Not more than three consecutive days	250 350	>150 = or < 150	250

Table 5.2

Selected statistics for hourly concentrations of SO_2 on the Somers and Ryan farms

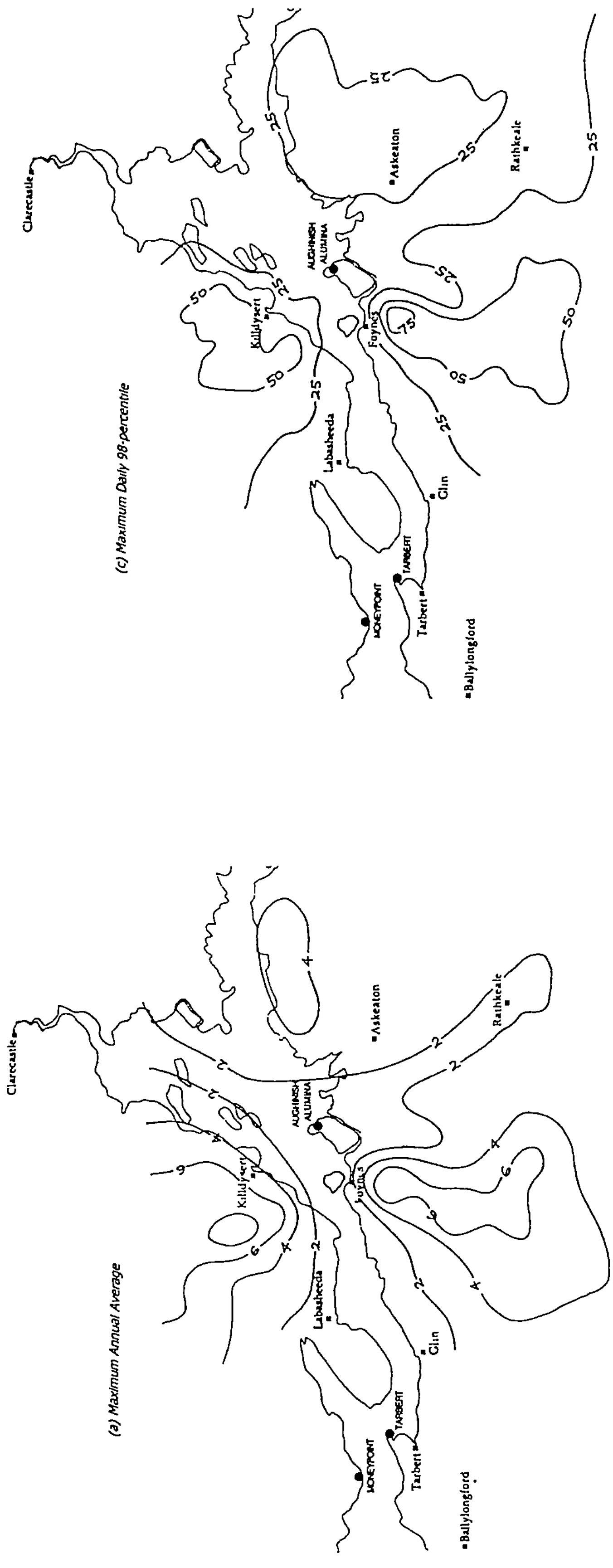
	1995	1996	1997	1998
Somers				
Total hrs of record	4925[1]	5296[2]	7692	7691
Maximum $\mu g/m^3$	250	270	298	348
Hours > 350 $\mu g/m^3$	Nil	Nil	Nil	Nil
Hours > 80 $\mu g/m^3$	65	73	105	176
Ryan				
Total hrs of record	3833[1]	8307	8113	7701
Maximum $\mu g/m^3$	385	350	270	207
Hours > 350 $\mu g/m^3$	1	Nil	Nil	Nil
Hours > 80 $\mu g/m^3$	33	52	16	97

[1] Measurements do not cover the full year [2] Monitor out of commission in three months

It is also noted that the concentrations measured are within the revised EU daily limit of 125 $\mu g/m^3$ which must be achieved in member States by 2005. The directive (CEC, 1999) giving effect to this more stringent requirement, allows for three exceedances of the limit over the year, effectively a 99 percentile limit. It should be further noted here, that the limits are met over all the years from 1988 to 1999 which encompasses the period when the animal health problems were manifest.

The 1999 EU directive also sets a limit of 350 $\mu g/m^3$ for the mean hourly concentration of SO_2, which may not be exceeded more than 24 times in a calendar year. The data from the monitors operated on the Somers and Ryan farms shows that this limit is respected in both cases. Table 5.2 shows that there were no records of hourly concentrations greater than the limit value on the Somers farm and only one instance of this on the Ryan farm. The bulk of the hourly concentrations were less than 25 $\mu g/m^3$ but there were occasional peaks well over background on both farms. Table 5.2 also shows the number of hours in each year when the concentrations exceeded 80 $\mu g/m^3$. Although less than 25 per cent of the EU hourly limit of 350 $\mu g/m^3$, this concentration would indicate a considerable anthropogenic enhancement of the background levels of the gas. A very small proportion (2 per cent or less) of the hourly values recorded on the farms were over 80 $\mu g/m^3$.

Of particular note in relation to the SO_2 data is the fact that an annual limit of 20 $\mu g/m^3$ set by the 1999 EU directive for the protection of ecosystems was complied with in all cases. Annual concentrations on the two farms, based on the data from the continuous monitors, ranged from 5-11 $\mu g/m^3$ in the 1997-1998 period (it



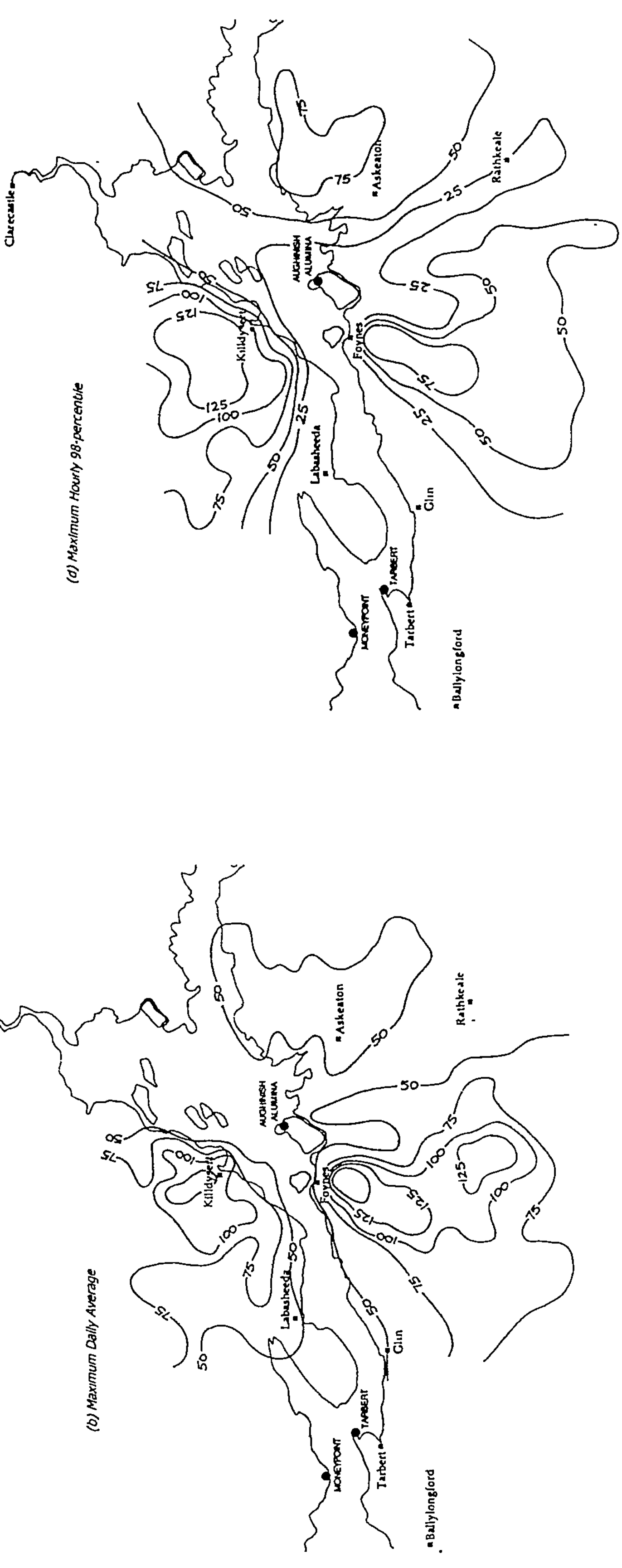


Fig. 5.4 Model predictions – AAL emissions of SO_2 ($\mu g/m^3$)

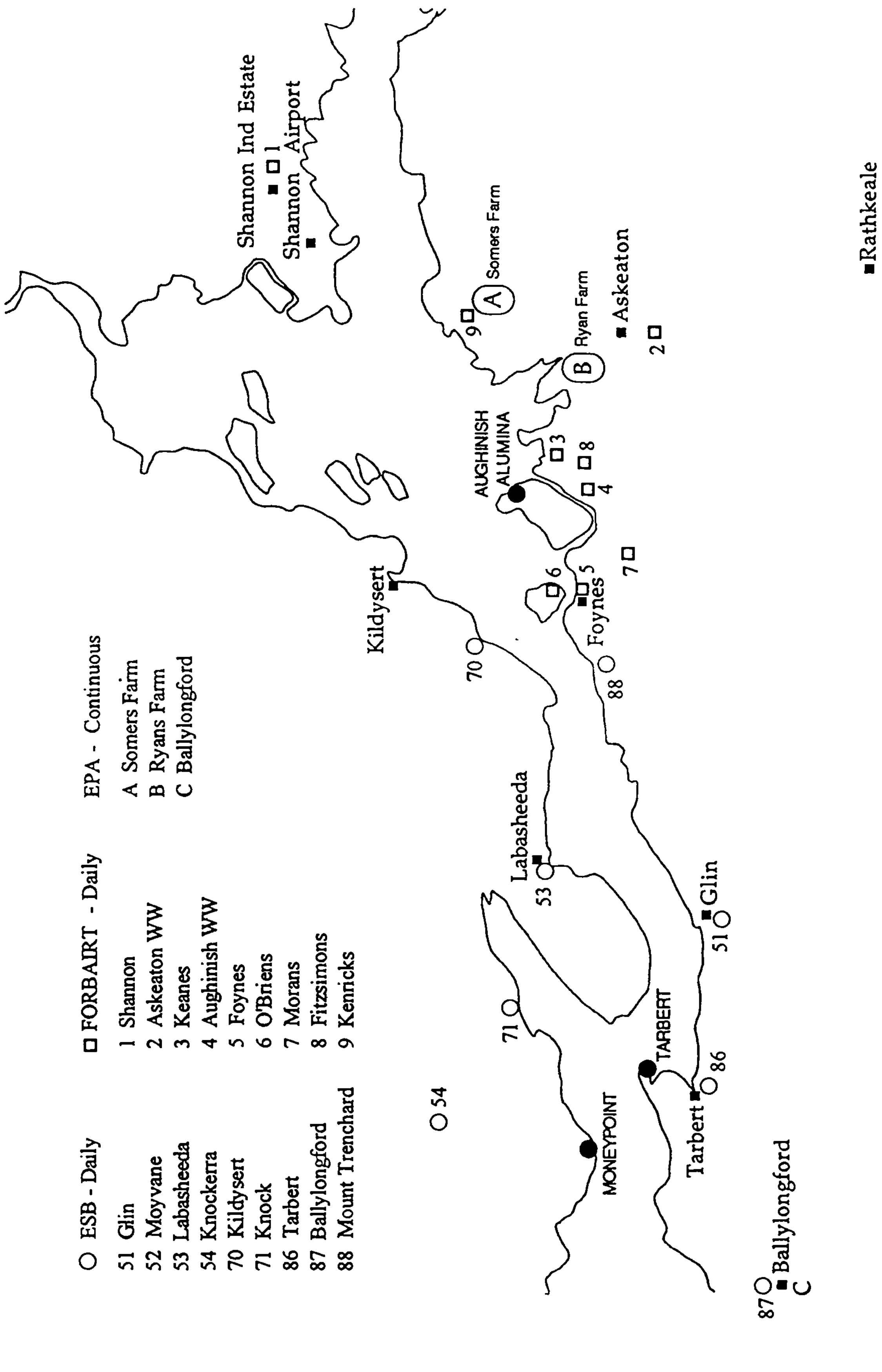
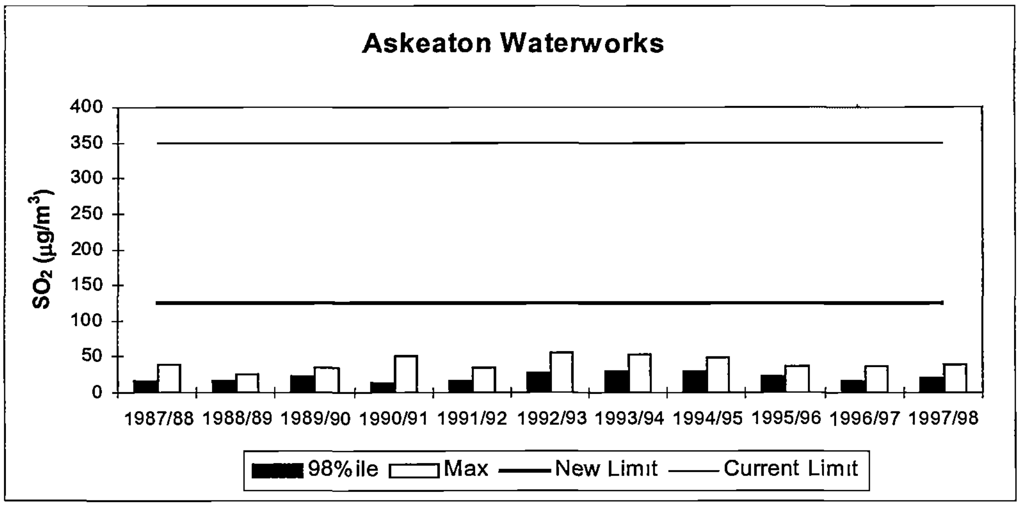
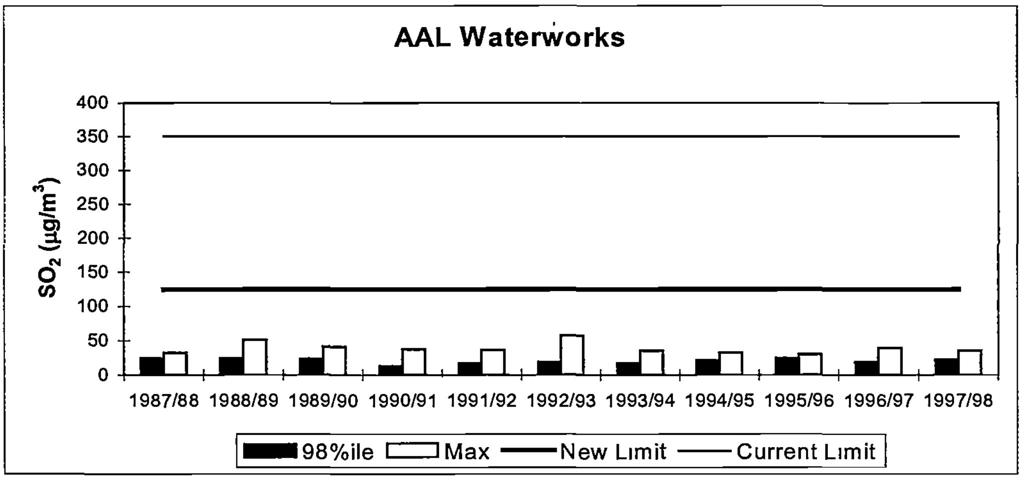


Fig. 5.5 Air quality monitoring stations





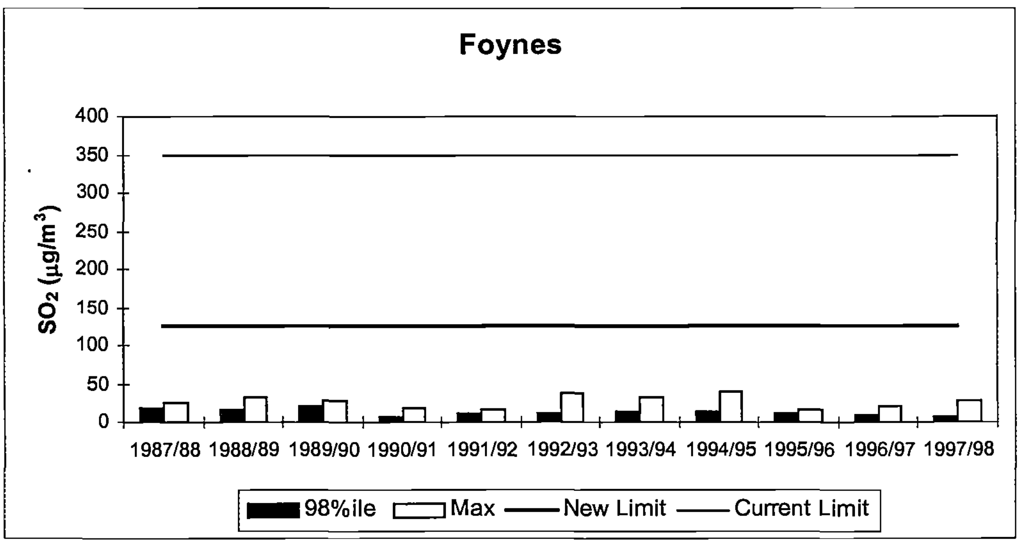


Fig. 5.6 Annual 98 percentile and maximum values of the daily average concentrations of SO_2 at selected stations in the AAL air quality monitoring network compared to current (98 percentile) and new (99 percentile) EU limits.

was not possible to extract this statistic from the records for the earlier years). In the AAL daily sampling network, the annual means between 1987 and 1998 were mostly less than 10 $\mu g/m^3$ while those in the ESB network were somewhat higher, ranging up to 18 $\mu g/m^3$. Compliance with this limit suggest that the levels of SO_2 in the area are unlikely to have any adverse implications for the growth of vegetation, including grasses.

Analysis of the hourly SO_2 data suggested that the hours when mean concentrations exceeded the arbitrary value of 80 $\mu g/m^3$ were mostly associated with winds on the farms which were blowing from the direction of the AAL plant, i.e. a generally western direction. This sector would also correspond broadly with the positions of the ESB plants. However, such hourly occurrences accounted for only a minor proportion of all of the hours when winds were blowing from that sector. These observations are generally inline with the model predictions which indicate that significant increases above background are likely to occur on occasion in the area of the farms depending on dispersal conditions for emissions.

Precipitation Quality and Deposition

General Remarks

The investigation of precipitation quality and deposition was relatively intensive as daily samples were collected for a full three years on each farm and at a further site for one year. In addition, weekly samples were collected at three sites for a two year period. It is considered, therefore, that the data accumulated from this sampling programme provide a comprehensive picture of the characteristics of precipitation during the period of the investigations. While there are no agreed standards for the quality of precipitation, it is possible to assess results by comparison with data for sites, the locations of which preclude or greatly reduce the likelihood of pollution. Some such data are available from previous work in Ireland.

In general, the potential for deposition of sulphur from emissions is limited in the immediate vicinity of the stacks. Furthermore, the artificial acidification of precipitation due to the conversion of SO_2 to sulphuric acid and NO_x to nitric acid takes place over considerable distances downwind of the sources of these gases and would not be expected to occur for the AAL and ESB emissions in the Askeaton area. These considerations suggested *a priori* that a major increase in sulphur deposition and the formation of artificially acidified precipitation are unlikely to occur in the area under investigations due to emissions from the Moneypoint, Tarbert and AAL plants.

Results of Preliminary Measurements

The preliminary measurements of precipitation quality and deposition made between April and September 1995 on the Somers farm indicated that the deposition rates of non-marine sulphate (i.e. total sulphur minus estimated contribution from marine salts) and nitrate were relatively low and not much greater than those measured by Bowman (1991) in the late 1980s near Loughs Gortglass and Doolough, north west of Askeaton in Co. Clare and in west Galway. Furthermore, the levels of fluoride in samples were low and metal concentrations comparable to those recorded for the sites being monitored in Cos. Kerry and Wicklow. However, due to the restricted period over which these measurements were made and the weekly sampling frequency used, it was considered that the data were only indicative and that the situation merited a more detailed study. Thus the daily sampling programme was instituted in November 1995.

Quality of Precipitation in Daily Samples

The mean annual concentrations, weighted for precipitation volume, of the main constituents measured in the precipitation on the Somers and Ryan farms and at AWW are given in Table 5.3 for each year in the 1996-1998 period*. The data are presented in this form in order to allow comparison with figures reported for other areas in Ireland and with unpolluted and polluted sites in other parts of Europe. It should be noted that the figures exclude the values for days on which precipitation was less than 0.5 mm. On collection, 200 ml is added to the sample in washing down the funnel; thus on days when there is little or no precipitation, the sample mostly consists of washwater and this can lead to spurious analytical results.

The concentrations of non-marine sulphate and of nitrate at the Askeaton sites generally fall within the ranges for the sites in Cos. Clare and Galway and the unpolluted sites in Norway and the UK. Ammonia

* The years indicated here start in the November of the previous year. Thus "1996" refers to the period from the beginning of November 1995 to the end of October 1996.

Table 5.3

The annual *minimum* and volume weighted mean pH and the annual volume weighted mean concentrations (μeq/l) for hydrogen ion, nitrate, ammonium, chloride, non-marine sulphate and sodium in the precipitation samples greater than 5mm at Ryan and Somers Farms for the years 1996, 1997 and 1998. Corresponding values for Gortglass and Doo Lough in Clare and Maam Valley in Co. Galway for the years 1987, 1988 and 1989 are also given. Mean concentrations for hydrogen ion, nitrate, ammonium and non-marine sulphate are given for unpolluted and artificially acidified locations in Western Europe

Location	Year	pH Min	pH Mean	H+ Ion μ eq/l	Nitrate μ eq/l	NH4 μ eq/l	N.M. SO4 μ eq/l	Cl μ eq/l	Na μ eq/l
Ryan Farm	1996	4.08	4.83	15	10	24.1	28.7	268	224
	1997	4.11	4.89	13	10	18.3	24.2	225	179
	1998	4.49	4.99	10	7	21.6	24.4	286	266
Somers Farm	1996	4.30	4.89	13	11	27.4	23.1	181	151
	1997	4.12	4.83	15	9	15.5	21.0	167	138
	1998	4.47	4.95	11	6	16.1	19.7	183	179
AWW	1998	4.37	5.18	6	7	19.5	18.6	245	228
Gortglass	1987	3.25	4.80	16	11	22	26	269	147
Co Clare	1988	3.87	4.77	17	8	12	11	367	231
	1989	3.85	4.72	19	5	13	17	269	197
Doo Lough	1987	4.02	4.86	14	8	10	15	273	178
Co Clare	1988	4.06	4.84	15	8	10	9	316	300
	1989	3.48	4.56	27	5	11	11	276	210
Maam Valley	1987	3.78	4.81	15	9	12	13	248	148
Co Galway	1988	3.90	4.86	14	9	9	8	307	313
	1989	3.67	4.70	20	7	8	9	335	238
Artificially Acidified									
Birkeness (Norway)[1]				69	41	42	71		
E Scotland (Glen Dye)[2]				35-46	28-42	22-33	39-49		
E Midlands England (High Muffles)[2]				41-72	36-47	40-64	51-82		
S E England (Barcombe Mills)[2]				12-24	19-31	16-50	33-52		
Unpolluted									
Kårvatn (Norway)[1]				17	5	6	12		
W Scotland (Polloch)[2]				12-15	9-11	5-8	14-17		
W Wales (Llyn Brianne)[2]				12-24	12-18	12-20	22-30		

[1]Overrein *et al.*, 1981
[2]Vincent *et al.*, 1996

concentrations, which are particularly influenced by local emissions, are somewhat higher at Askeaton than the other Irish sites, possibly reflecting more intensive livestock production. Fluoride concentrations were low and less than the detection level of 0.1 mg/l F in most cases. Chloride and sodium concentrations recorded were relatively high reflecting the strong marine influence at this location.

Values for pH and hydrogen ion concentrations at Askeaton also fell within the ranges recorded at the remote locations in Ireland and the unpolluted sites abroad. There had been reports of both highly acidic and alkaline "mists" affecting the Askeaton area. However, this is not supported by the data which show that variations of pH (Fig 5.7) were well within the normal range. One sample from the Somers farm had a distinctly alkaline pH of 8.3 but values for other parameters suggested contamination of this sample with organic matter.

The metal concentrations recorded in the monthly samples of precipitation collected on the farms in the 1996-1998 period were again similar to those in samples collected at Valentia Island and Turlough Hill. A few anomalously high values were recorded for some metals at all of the sites and may have been due to soil particles blowing into the samplers.

The weekly samples taken on the Somers farm showed a generally similar composition to the daily samples taken at that location. It is assumed, therefore that the weekly samples taken on the White and Hannon farms are also representative of the quality of precipitation at those sites. On this basis, the quality of the precipitation at all four farms may be said to be similar and to be reflective of generally unpolluted conditions.

Deposition Rates Based on Daily Samples

The deposition rates were calculated as the products of the annual volume-weighted mean concentrations and the total annual volume of precipitation, as recorded on the farms. These calculations were carried out both excluding and including the concentrations measured on days when precipitation was less than 0.5mm. The results are given in Table 5.4 where they are contrasted with data for the other sites in Ireland and for unpolluted and polluted areas in the UK and mainland Europe.

The annual deposition rates of non-marine sulphate and nitrate on the Somers and Ryan farms in the measurement period were clearly within the ranges typical of unpolluted areas throughout Europe and were also similar to the rates at the other west coast sites. Ammonium deposition rates were somewhat higher than those for the unpolluted European sites and, as with the ammonia concentrations, probably reflects the intensity of livestock rearing in the area. The Glencree site in Co. Wicklow has deposition rates for non-marine sulphate and nitrate which lie closer to the values for the polluted European sites. This is attributed to the influence of relatively polluted precipitation borne on easterly winds on the Irish east coast, presumably originating in the UK or mainland Europe (Bowman, 1991).

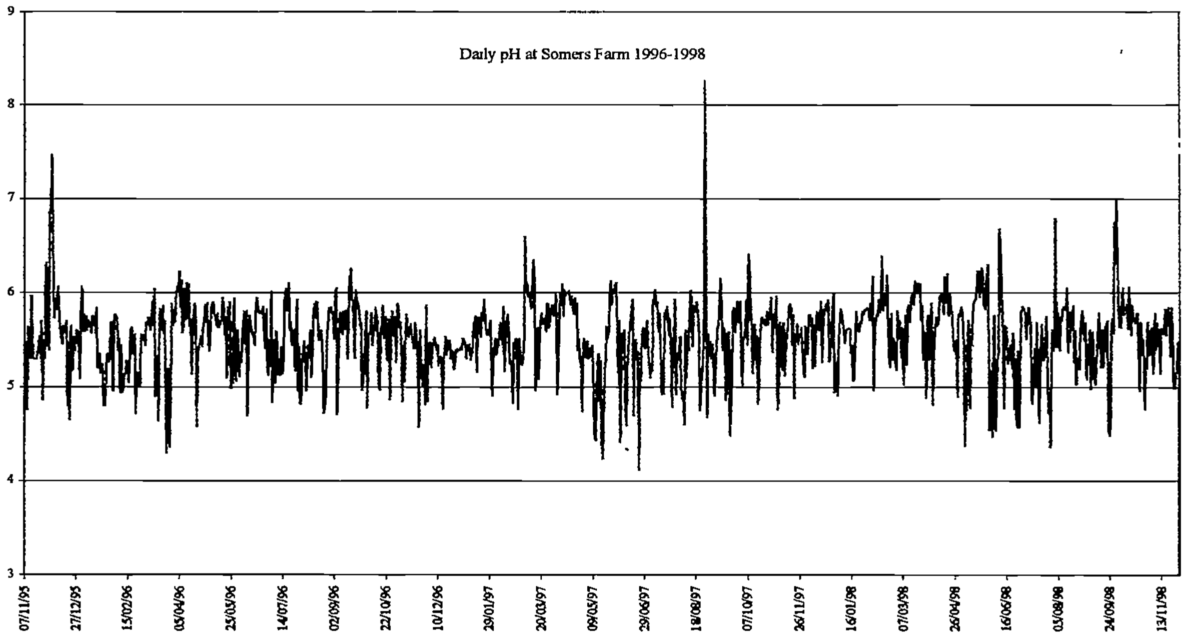
The relatively low rate of sulphur deposition measured on the farms is a key finding of the investigations. Excessive sulphur enrichment of soils was considered the most likely effect of the emissions in the area which could be conceivably linked to animal ill-health. Such an effect now seems to be ruled out and this is largely confirmed by the soil analyses undertaken by Teagasc (See Chapter Three).

Other Measurements

Particulate Matter

The potential for increases over background of concentrations of particulate matter in air in the Askeaton area has been indicated above. In order to assess this potential, the monitoring networks operated by the ESB and AAL include the measurement of black smoke in addition to SO_2. This is the measurement method of particulates in air used in local authority air quality monitoring networks and is based on the stain produced on a filter paper through which air is passed; the intensity of the stain may be related to the concentration of smoke particles in air. The National Regulations referred to above include a limit for black smoke (see Table 5.1).

The annual 98 percentile concentrations recorded for the AAL stations in the period 1987-1998 were less than 40 $\mu g/m^3$ and annual medians less than 10 $\mu g/m^3$. Similar concentrations were recorded at the ESB stations in the same period. These values are well below the limits of 250 $\mu g/m^3$ and 80 $\mu g/m^3$ set, respectively, for the 98 percentile and median of daily mean concentrations in the National Regulations.



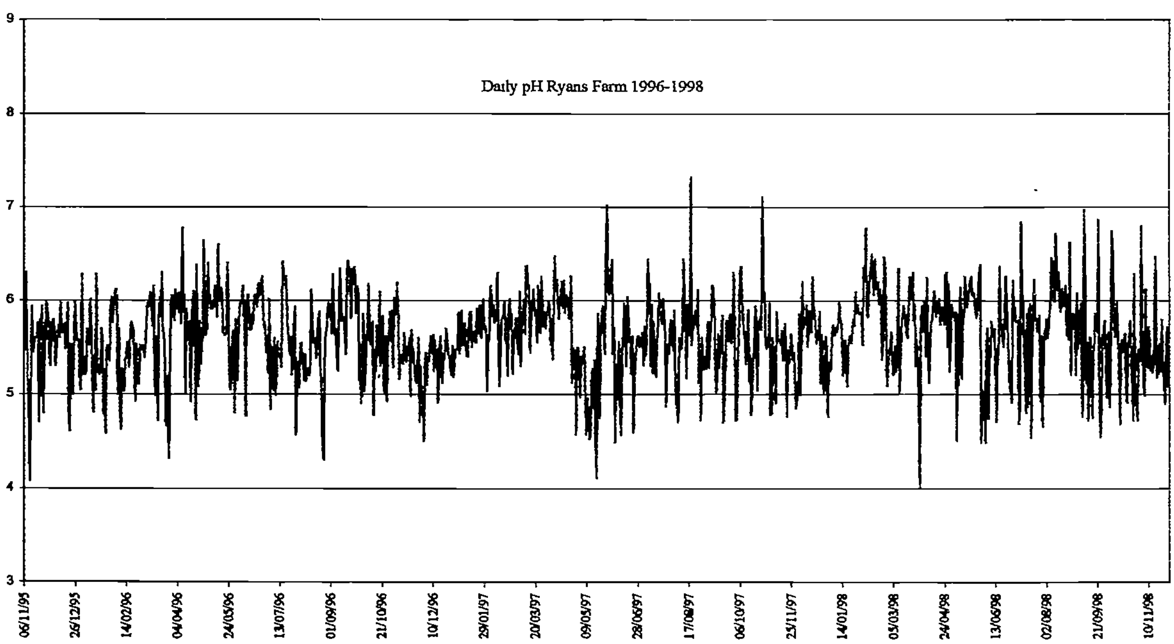


Fig 5.7 pH in daily rainfall samples on the Somers and Ryan farms, 1996-1998

Table 5.4

Annual deposition rates for non-marine sulphate, nitrate and ammonium measured on the Somers and Ryan farms in 1996-1998 and at AWW in 1998. Also shown for comparison are data for other Irish sites (Bowman, 1991) and for unpolluted and polluted sites throughout Europe (Schaug et al., 1991,1992).

Location	Non-marine Sulphate $g\ S/m^2/y$	Nitrate $g\ N/m^2/y$	Ammonium $g\ N/m^2/y$
Askeaton			
Ryan Farm	0.35 – 0.39	0.10 – 0.13	0.23 – 0.30
Somers Farm	0.28 – 0.29	0.08 – 0.12	0.17 – 0.31
AWW	0.35	0.11	0.32
Ireland –West Coast			
Maam Valley, Co Galway	0.35	0.26	NM
Gortglass L. Co. Clare	0.28	0.12	NM
Doolough, Co. Clare	0.22	0.12	NM
Ireland – East Coast			
Glencree	0.51	0.36	NM
Europe			
Unpolluted sites	0.10 – 0.55	0.06 – 0.15	0.02 – 0.18
Means	0.27	0.11	0.11
Polluted sites	0.26 – 1.79	0.16 – 1.20	0.19 – 1.36
Means	0.94	0.54	0.60

The more recent EU air quality directive (CEC, 1999) substitutes the measurement of particlulate matter with an effective aerodynamic diameter of 10 microns (PM_{10}) for the black smoke parameter. In order to assess the levels of PM_{10} in the Askeaton area, the EPA commissioned a study from Professor S. G. Jennings of UCG in spring 1998. Measurements were made on the Ryan farm using a continuously measuring instrument (TEOM). Daily mean PM_{10} levels ranged from 4.0 to 36.7 $\mu g/m^3$ with an overall mean of 11.4 $\mu g/m^3$ over the 73 days of record between February and April. The EU limit, to be achieved by 2005, is set as a daily mean of 50 $\mu g/m^3$ with an allowance for 35 exceedances of this over a calendar year. In addition, a limit of 40 $\mu g/m^3$ is set for the annual mean of the daily means. While the period of measurement at Askeaton was relatively short, the results there suggest that PM_{10} levels in the area are moderate and likely to be well within these EU limits. It is noted that measurements made later over two days near Carna in west Co. Galway showed levels of PM_{10} there to be similar to these recorded in Askeaton.

The monitoring network operated by Forbairt/Enterprise Ireland on behalf of AAL also includes the measurement of dust deposition. This measurement is made by filtering precipitation samples and weighing the solid residue. Mean deposition rates for the 1987-1994 period generally lie in the range 30 to 100 mg/m^2 per day. These rates correspond to the category "hardly noticeable", typical of rural areas and small towns. Higher values were recorded in the vicinity of Foynes. Some of the high values, at least, are attributable to the growth of algae in the collectors.

There had been reports of the deposition in the area of red dust from the waste lagoons at the AAL. However, examination of the protective filters used in the automatic SO_2 monitors deployed on the Somers and Ryan farms showed no trace of this material. Filtrates of the precipitation samples collected on the farms also gave a negative result in this respect.

Organic Substances in Soil

Samples of soil (two each) taken in 1995 from the Somers, Ryan and the control farm (see Chapter Three) were analysed for the standard range of polychlorinated dibenzofurans (PCDF) and polychlorinated dibenzo-para-dioxins (PCDD); samples were also analysed for polychlorinated biphenyls (PCBs), polychlorinated phenols and

polyaromatic hydrocarbons (PAH). Analyses were carried out by the Gesellschaft für Arbeitsplatz und Umweltanalytik mbH, in Münster, Germany.

Concentrations of PCDF/PCDD expressed as total toxic equivalent (total TEQ), ranged from 1.0 to 1.5 ng/kg of dry soil, assuming zero for concentrations less than the detection limits. Taking the detection limit as the concentration in these cases slightly increased the range to 1.1 to 2.0 ng/kg. These values are typical of background levels and may be compared with the German federal target of 5 ng/kg.

PCB concentrations in the soils ranged from 0.66 to 1.54 µg/kg, levels which are typical of agricultural land with little input from industry. The only polychlorinated phenol detected was 2,4,6 trichlorophenol; concentrations varied from 0.005 to 0.023 mg/kg in the five of the six samples where detectable levels were found. These are low concentrations and may be compared with the Dutch intervention level of 10 mg/kg for soil remediation.

The combined soil concentrations of the standard six PAH compounds* ranged form 11.8 to 33.8 µg/kg. As is normally the case, fluoranthene was present in the highest concentrations. The data for the Askeaton soils show that contamination with PAH is relatively low compared to values reported for UK agricultural soils.

Volatile Organic Compounds (VOCs) in Air

Sampling for VOCs in air was carried out in May and June/July 1995 on the Somers and Ryan farms and at Ballylongford. Modified 8-day samplers were used in the two surveys, air being pumped through absorbent-packed tubes. In May, eight daily samples were collected on the Somers farm and at Ballylongford while, in the June/July survey, the tubes were continuously exposed at these locations and at the Ryan farm for seven weeks to increase the detection ability. Analyses were carried out for 2-methylpentane, benzene, isooctane, heptane, toluene, ethylbenzene, m-xylene, o-xylene and 1,2,3-trimethylbenzene. These were considered to be a representative range of commonly found volatile organic substances. In the June/July survey, methyl ethyl ketone was added as this is released from the Wyeth plant at Askeaton. Only trace quantities of these substances were detected in the two surveys; for instance, the mean concentration indicated for m-xylene in the May samples was 0.3 $\mu g/m^3$ compared to the occupational exposure limit of 435 mg/m^3. The small amounts detected of this compound and others such as toluene are likely to have reflected ambient petroleum vapour.

VOCs in Water

In February 1995, a wide range of common VOCs were analysed for in waters used for livestock on the Somers farm. Concentrations above the detection limits, ranging from 0.1 – 10 µg/l, were not found.

Organic Compounds in Milk.

Milk samples taken on the Ryan and Somers farms in June 1995 were analysed for the standard suite of PCDF/PCDD compounds at the CSL Food Laboratory in Norwich, UK. Results (04 – 0.05 ng/kg Total TEQ in whole milk) are typical of background levels. Samples of milk in the general Askeaton area were taken in 1995 and again in 2000 as part of a national survey of dioxin levels. These also showed very low levels of the compounds in whole milk (0.003 – 0.018 ng/kg). These samples were analysed in the University of Umea, Sweden in 1995 and at the GfA laboratory in Germany in 2000. The lower detection limits employed by the latter laboratories probably accounts for the slight difference with the CSL results.

Milk samples from the Askeaton area were also analysed for pesticide levels in 1995. Theses analyses were carried out by the Pesticide Control Laboratory, Abbotstown, Co. Dublin. Of the 25 organochlorine and 48 organophosphorus compounds checked, none were found above the detection limits.

Aluminium and Fluoride Levels in Milk

As mentioned earlier, there had been local concerns that aluminium and fluoride might be involved in the animal health problems. The measurements on precipitation, described above, do not support this contention. However, measurements commissioned in 1995 by the Ballysteen/Askeaton Animal Health Committee had suggested that aluminium levels in milk from the area were elevated. It was decided, therefore, to further examine the position and to include fluoride. Samples were taken in May and again in August 1995 from a number of farms at increasing distances from the AAL plant in an easterly and southerly direction; it was considered that if contamination with these substances was occurring due to the emissions from the AAL plant, concentrations should diminish the further from the plant the samples were taken. Due to possible analytical difficulties in the

* Fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene

May survey, duplicate samples from the August survey were sent to a second laboratory for aluminium determination. In the latter case samples from two Wexford farms were taken for comparison.

The results indicated the following:

- Variation of aluminium results between dates in samples from the same farms was marked; in nearly all cases the concentrations recorded on the earlier date (mean 0.58 mg/l) were higher than those recorded in August by the same laboratory (mean <0.15 mg/l) or by the second laboratory (mean 0.04 mg/l).
- The results for aluminium in the milk for the Wexford farms in August were within the range found on that date for the Limerick farms
- There was no indication of an expected decrease in aluminium concentrations with distance from the Askeaton area; in fact, the highest levels found in May were in samples taken furthest south from the Askeaton area.
- All fluoride levels were reported as less than 1.0 mg/l as the method used is not regarded as reliable for levels below that value. It is not possible, therefore, to make any detailed comment on this substance; however it should be noted that drinking water in public supply is required to contain 0.8 to 1.0 mg/l of fluoride.

Based on the results from the August samples in particular, the surveys do not provide evidence of aluminium contamination of milk in the Askeaton area. It should be noted in addition that the measurements of aluminium in precipitation provide an alternative assurance that there is no significant contamination with the metal in the area. Furthermore, even the higher levels found in the milk, if correct, would not constitute a public health risk as they are well below those which have been associated with adverse affects on humans.

Reported Incidents of Pollution

In view of local concern that short-term pollution events were occurring in the Askeaton area, an arrangement was put in place during 1997 to allow the EPA to make a rapid response to reports of any such incidents. This replaced an earlier agreement with the Askeaton/Ballysteen Animal Health Committee to assist in such situations by collecting air samples for subsequent analysis by the Agency. Under the revised arrangement, members of the EPA's staff, based in the Limerick area responded to reports of pollution incidents by travelling immediately to the area affected, taking samples of air with standard equipment and interviewing the person making the report. The sampling equipment consisted of an electrically operated air pump together with filters designed to trap sulphur dioxide and alkaline particulates in the air, the substances most likely to be involved in a pollution event in the area.

Some of alleged incidents of pollution in the area were readily explainable, e.g. a reddish tinge on grass due to fungal rusts, coloration of trough water due to algae or dust like deposits on car bodies caused by pollen. Damaged vegetation was reported on a number of occasions and was generally attributed by the Coillte or Teagasc experts consulted to natural factors, such as frost.

Other reports of air pollution, in particular the presence of alkaline or acid vapours causing skin irritation, could not be confirmed by direct observation. One complainant was supplied with an air sampler as above for the detection of such occurrences but, in the few instances where an opportunity arose to confirm his report of skin irritation and other effects, the tests for the presence of pollutants were negative. It has been noted above that the daily precipitation samples did not suggest the occurrence of any excessively alkaline or acidic conditions consistent with the symptoms reported by the person in question. Checks on plant operating records at AAL did not suggest any unusual circumstances at the time of the reported incidents.

CONCLUSIONS

The measurements described above have addressed the main risks to environmental quality in the Askeaton area, as assessed on the basis of the industrial activities. The results indicate that the levels of the potential pollutants in the area are below those which are likely to cause harm to the environment generally, to livestock or to humans. In addition, they confirm that the levels of other substances, regarding which local concern had been expressed but which were not considered to be a significant risk based on the type of industrial activity in the area, were low and not much different to background. These conclusions are in conformity with the results of measurements undertaken by Teagasc on soils, herbage and other media on the problem farms and on other farms in the Askeaton area.

This assessment cannot be made with the same assurance for the period before 1995 as the level of monitoring was much less detailed then than it was during the investigation. However, in so far as there are measurements available for that period, in particular the SO_2 records from the ESB and AAL networks, these do not indicate that conditions prior to 1995 were substantially different to those recorded during the 1995-1998 investigations. It is noted also that the composition of the soils, as described in Chapter Three, which would be expected to reflect significant inputs of pollutants in the past, did not show above normal levels of the substances emitted from the local industrial sources.

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Chapter Six

GENERAL DISCUSSION AND CONCLUSIONS

PURPOSE OF THE INVESTIGATIONS

The main question addressed to the EPA by the Government before the investigations commenced was: what were the cause or causes of the animal health problems on the Somers and Ryan farms? However, the suggestions of similar problems on 25 other farms in the area indicated that it would be necessary also to determine whether the latter were of the same nature and severity as on the original two farms, and whether the 27 farms thus represented a cluster of disease incidences which might be attributable to the same or related causes.

Due to the fact that the investigations did not commence until well after the problems had developed, concerns had widened considerably in the Askeaton area by the time the various studies were being organised and led to the posing of two further questions. Firstly, since both the farmers and the local community had formed the strong opinion that environmental pollution was the likely cause of the problems, this possibility needed particular attention. Secondly, if it was assumed that pollution was involved, then there was also a potential threat to human health. In contrast to the animal health situation, there was little more than anecdotal evidence to support this latter possibility; however, the fact that it had become a matter of much local concern meant that its inclusion in the investigations became necessary in order to address and, if justified, allay such concern.

Besides the original question, therefore, the circumstances at the beginning of 1995 required additional matters to be addressed and the investigations, as described in the foregoing chapters and in the sectional volumes, were effectively focused on the following four questions:

1. Was there any evidence of unusually high incidence of animal disease in the Askeaton area?

2. If so, what were the causes?

3. Was there any evidence that environmental pollution contributed to increased incidence of animal disease?

4. Was there also a threat to human health?

Thus, the scope of the investigations was considerably widened from that which might have been originally envisaged in relation to the animal health problem *per se*. In effect, the Askeaton investigations became the largest and most comprehensive of their type ever to be carried out in the State. The cost of the investigations, including staff time, is conservatively estimated to be around £4.19 million.

INVESTIGATION STRATEGY

In view of the essentially *post facto* nature of the investigations, it was considered likely that the determination of the precise cause or causes of the animal health problems would be difficult. This is often the position in similar investigations and was made clear both to the Government and to the farmers and local community at the start of the investigations. Thus, the strategy which had to be followed was to examine the range of possible causes and to isolate those which offered the best explanation of the situation.

In the case of human health a different approach was needed as there was no clear evidence of unusual or excess illness at the start of the investigations. The *modus operandi* followed, therefore, was to organise a series of retrospective and prospective studies to compare the position on human health in the area of possible exposure, as defined by the locations of the 27 farms with reported animal health problems, and control areas.

POSSIBLE CAUSES OF THE ANIMAL HEALTH PROBLEMS

In the course of the meeting with the local community in April, 1995, and reiterated in the explanatory booklet issued in June of that year, the following factors were listed as possible causes of the animal health problems, acting either singly or in combination with the others:

- Infectious Agents (Bacteria/Viruses/Parasites)
- Nutritional Deficiencies/Imbalances (Protein/Carbohydrate/Mineral/Trace Elements)
- Toxic Substances ingested in Diet (Food or Water)
- Environmental Pollution, e.g. Air Pollution (Emissions/Dust)
    - Direct Effects (e.g. through inhalation)
    - Deposition Causing Mineral Imbalance in Plants/Animals
- Farm Environment (e.g. poor housing, inadequate preventive medicine programme, inadequate breeding management procedures)
- Sabotage

Only the last of these possibilities could be ruled out immediately with some certainty

Infectious Agents

The possibility that animal health problems in the Askeaton area were due primarily to a single infectious agent had to be considered. Since they dealt with the period when these problems were at their most severe, the retrospective studies of the Somers and Ryan farms and the 25 additional holdings with self-reported animal health problems provided, perhaps, the most important evidence for the determination of the cause of the animal health problems.

These studies provided no evidence of a widespread or unusual infective disease in the Askeaton area. Rather, a variety of ailments was described, all of which are experienced to varying degrees on farms elsewhere at some stage. However, there were limitations to the reliability of the information gathered during the studies and the absence of national data pertaining to the incidence of infectious disease on farms made statistically valid comparisons difficult.

The relatively severe level of disease on the Somers and Ryan farms did stand out and pointed to possibly unusual circumstances in these cases. However, it is important to note that the nature of the diseases and the timing of their peak development did not coincide on these two farms.

It is also noted that there were no observations of any unusual ailments affecting cows or calves over the two year (1996-1998) trial monitoring of animal health and production on the Somers and Ryan farms and at Abbotstown. On the contrary, the most notable result was the marked reduction of the level of disease on the two Askeaton farms compared to that reported for previous years.

Further evidence for the absence of common infectious agents is provided by the observations on animal health made during the longitudinal study (involving four of the self-declared "problem" farms) and by the information from the survey of farm experience conducted in parallel with the human health studies.

Overall, therefore, the results of the investigations indicate that the involvement of a single infectious agent in the animal health problems in the Askeaton area is highly unlikely.

Nutritional Deficiencies/Imbalances

Nutritional imbalances or deficiencies, possibly allied to an environmental stressor such as poor weather, could offer explanations for several of the animal health problems observed on the Askeaton farms. This was the view of the US EPA consultants invited to the area in 1995 and it received particular attention over the course of the investigations.

The detailed analyses of the soils and herbages on the Somers and Ryan farms carried out in 1995, and supplemented by further observations up to 1998, did not reveal any significant anomalies. The bulk of the concentrations recorded for the major and trace elements fell within the national ranges for these substances and did not suggest any unusual nutritional deficiencies or imbalances. In the case of soils, there were some anomalously high and low values for a number of elements, with possibly adverse implications for grazing livestock; however, these were explainable in terms of local geological or soil features. No correlations were found between these anomalies in soil and herbage and animal symptoms. Indeed, the animal health investigation found no clinical evidence of major or trace element deficiencies and only minor biochemical deviations were found.

The main threat to herbage quality from the potential pollutants emitted in the area was considered to be excess sulphur deposition as this could lead to interference with uptake of trace elements into the plant tissue. While preliminary measurements made in 1994 had suggested that an increase in sulphur levels in herbage had occurred since the early 1980s, the more detailed work carried out in 1995 as part of the investigations did not support this assessment. Further confirmation that sulphur levels were within normal ranges was provided by the monitoring of the herbage on the Somers farm which was continued up to 1998. The position is in conformity with the relatively low deposition rate of sulphur in the area as shown by the environmental measurements.

The quality of the silage on the two Askeaton farms, and particularly on the Ryan farm, was poor at the time of sampling in spring 1995 and would not have been suitable as the sole source of nutrition for dairy cows. On both farms, the dry matter digestibility was relatively low, although this appears to be typical of silage in the Co. Limerick area including that on the farms covered by the Retrospective Studies. Poor quality silage requires supplementation with feed concentrates to meet the animal's energy requirements. There are no reliable records of the amounts of these dietary supplements fed to the animals on the farms before the trial monitoring commenced.

There are some indications, therefore, that the quality of livestock nutrition provided by the silage on the two farms may have been less than adequate, at least in the period immediately preceding the commencement of the investigations. As these observations were made at the time when the worst animal health problems occurred on the Ryan farm it is possible that poor quality silage may have been a contributory factor in the development of some of these problems in that case. However, as the problems on the Somers farm peaked earlier, it is not possible to say if the 1995 observations on silage quality are of relevance to the most severe animal ill-health experienced there.

Ingested Toxic Substances in Diet

The possibility that a toxic or otherwise noxious substance ingested in food or water accounted for the animal health problem was considered. If this were the case, the expectation would be of a similar set of, probably unusual, symptoms in the affected animals. The veterinary observations showed clearly that this was not the position.

In addition, it is noted that toxic levels of metals or organic compounds were not detected by the analyses carried out on the soils, herbage and water supply on the farms, on tissues taken from animals on the farms and on milk and horticultural produce from the general Askeaton area. The experimental feeding of soil from the Somers farm to rats without any evidence of adverse effects provides a further indication of the absence of toxic substances in the soil.

It is also noted that the pollutants emitted by the local industries in large quantities, e.g. aluminium oxide and sulphur dioxide, are not of their nature significantly toxic, and are considerably diluted in the atmosphere before reaching ground level.

The indications are, therefore, that the involvement of a toxic substance is a very unlikely explanation for the animal health problems.

Environmental Pollution

Environmental pollution had become the most commonly voiced, local explanation for the animal health problems by the time the investigations commenced and, naturally, also raised questions of human health impacts. While this attitude appeared to be based mainly on circumstantial evidence, viz the proximity of the AAL plant and the ESB stations, it was, nonetheless, understandable in the absence of systematic investigations.

Certainly, the fact that the emissions of SO_2 from these three sources account for more than half of the total national emission would give pause for thought, even though their release from high stacks would be expected to minimise local impacts.

The data from the existing air quality monitoring networks, and the various measurements made as part of the investigations, did not bear out the suggestion of pollution and showed clearly that the levels of potential pollutants on the farms and in the general Askeaton area were either at or near background levels (e.g. dioxins in soils and sulphur in precipitation) or at levels above background but well within EU and national standards (SO_2 in air) in the 1995-1998 period. In respect of SO_2, data from the previously established air quality monitoring networks in the area indicate that this favourable position had persisted at least since the mid 1980s.

The position is not unexpected in view of the nature of the industrial activities in the area and the model-based predictions of emissions dispersal which suggested a relatively low risk of pollution. However, it does not concur with pollution incidents reported by some individuals during the course of the investigations, involving skin irritation and other discomforts. Some of these reported incidents were attributed by such individuals to fugitive emissions from the AAL plant. While the SO_2 and sodium hydroxide associated with the activities at AAL in particular are potential causes of such effects, the measurements of air and precipitation quality do not support the involvement of these substances in episodes of acute atmospheric pollution. For example, the highest hourly average concentrations of SO_2 recorded do not suggest that concentrations for shorter periods could reach those required to cause the physical effects described. In the case of precipitation, the maximum and minimum pH levels recorded would not have been consistent with the occurrence of highly acid or alkaline conditions which could give rise to skin irritation or other contact effects. It is important to note in this context that even transitory events (e.g. plume grounding), leading to high concentrations of pollutants, would have been detected given the short measurement time (hourly) in the case of SO_2 and sampling period (daily) in the case of precipitation.

Damage to vegetation was another commonly reported allegation of pollution impact during the investigations. Where examined, such damage was considered to be of natural occurrence and due either to adverse weather or the influence of sea salt. Similar damage was observed in other parts of the country at the times it was reported in the Askeaton area. The monitoring of selected tree plots by Coillte in plantations adjacent to Askeaton (see Appendix A), which showed that tree condition was similar to the national position in the 1996-1998 period, bears out this assessment. A small number of other suspected effects of pollution was reported, including colour changes in grass and coloration of water held in field receptacles; where it was possible to investigate these occurrences, they were also explainable as natural phenomena.

In general, the environmental quality data indicated that pollution was an unlikely cause of either animal or human health problems in the area. This assessment is consistent with the results of the soils and herbage measurements and of the observations on animal disease.

On-Farm Environment

Observations made on the Ryan farm at the start of the investigations in 1995 did reveal potential on-farm circumstances that may have contributed to the reported animal health problems. These included poor cubicle design (cows), poor quality silage, signs of over-grazing and out-wintering of cows in poor weather. In addition, there was evidence that stocking rates had exceeded the estimated carrying capacity of the farm and that expert veterinary assistance had not been sought to the extent which would have been warranted by the level of disease occurring at the time. These are clearly factors with potential to cause serious animal health problems. In addition, as noted in Chapter Two, the weather in the winters of 1993/94 and 1994/95 was particularly severe and, in combination with inadequate nutrition, would have represented a significant additional stress for pregnant cows kept outdoors.

Some of these potential problem situations were also noted on the Somers farm in 1995. However, in this case they represented, at least partly, a follow-on from the 1992-93 period when the worst of the animal ill-health occurred at that location; this resulted in the over-stocking of the farm due to the forced retention of stock unsuitable for sale. Thus, some of the deficiencies noted in 1995, such as over-grazed pastures, may be regarded as a result rather than a possible contributory cause of the animal health problems on that farm. The information available regarding on-farm circumstances in the period up to 1993 when problems, particularly mortality, were worst is limited and does not allow any firm conclusions on the particular factors which may have been involved in the situation then. The difficulty is increased by the very limited recourse to the services of the Regional Veterinary Laboratory throughout most of the time when excessive livestock losses occurred, with consequent

lack of information on the causes of death. It is noted, however, that poor weather may have been a contributory factor in relation to some of the skin problems on this farm in 1994/95.

The observations suggest, therefore, that on-farm circumstances cannot be discounted as contributing to the animal health problems in these two cases. The argument for this is clearly more supportable in the case of the Ryan farm than on the Somers farm. On the former, at least, it is likely that the situation was exacerbated by the out-wintering of pregnant cows on poor quality silage in unfavourable weather conditions.

Overview on Animal Health

The most important point regarding the outcome of the investigations which emerges from the above discussion is that the results from the different aspects are consistent with one another. In particular, the fact that the livestock did not appear to be affected by a common ailment is backed up by the evidence from the soils and herbage and the environmental studies. These did not provide evidence for the presence of a natural or introduced agent which could have given rise to an area-wide problem of animal health. In particular, the non-concurrence in the timing and the nature of the diseases on the two severely affected farms is inconsistent with the presence of a pollutant which would be expected to have given rise to contemporaneous and similar effects. In the case of the less serious problems reported for the additional 25 farms, the same inconsistency is present regarding their timing and variety.

It is clear, therefore, that neither the involvement of off-farm factors, particularly pollution, nor the influence of factors such as unusual diseases or anomalies in the soils or herbages, can be adduced as likely causes of the animal health problems on the Somers and Ryan farms. Thus the results of the investigations suggest that the situations on the Somers and Ryan farms were largely attributable to on-farm factors of the types cited above and which are common to farms elsewhere. The reasons for the severity of the disease conditions which arose on the Somers farm are largely a matter of speculation at this stage – both because of the retrospective nature of the present investigations and the very limited contemporary recourse to expert veterinary assistance while the problems were at their worst. In relation to the Ryan farm, several specific on-farm factors have been identified, viz infectious disease, nutrition, housing, and inclement weather.

Further credence is given to the involvement of on-farm factors by the performances on the two farms during the 1996-1998 Monitor Study which were within national norms for enterprises of their type and size. This outcome indicates that, whatever the factors involved in the problems of the earlier period, they were no longer present after 1995. As stated above, there is no convincing basis for implicating off-farm factors in this respect. Admittedly, several improvements to facilities were made on the farms before the monitoring commenced and later; however, this was necessary in order to comply with standard Teagasc guidelines for dairy farms and these guidelines were also followed for other aspects of management during the trial, e.g. in relation to nutrition.

There had been local suggestions that the improvement in farm performance was attributable to better control of the industrial emissions in the area after 1995. However, the measurements of air quality and precipitation during the period of the trial monitoring on the farms did not indicate any significant change in conditions compared to the situation before 1996. Indeed, as pointed out above, the data from the ESB and AAL networks show that, at least in the case of SO_2 levels, there was very little change over the period since monitoring commenced in the mid 1980s, despite some fluctuations in the emissions of the gas from the main sources in the area. Furthermore, there were no significant changes in the control of these emissions in the period before and after the trial commenced. It is unlikely, therefore, that improvements in environmental quality were the reason for the changed performances on the two farms after 1996.

HUMAN HEALTH

The foregoing discussion of the possible reasons for the animal health problems have implications for the concerns regarding human health. If there are no grounds for believing that the cause of the animal health problems is off-farm factors, then the basis for thinking that there might be a link between those problems and any human ailments is considerably weakened. While this does not mean necessarily that there were no unusual human health problems in the notional exposed area (that encompassing the 27 farms reporting animal health problems), most of the various studies undertaken showed that the health experience of the population living there was much the same as that in the control areas.

Some differences were statistically significant, e.g. in relation to absenteeism rates in primary schools and the mortality rates of certain groups; however, the numerical differences involved are very small in relation to the populations compared and are likely to be due to a variety of factors. The human health survey showed a higher

rate of illness in the "exposed" area compared to some, but not all, of the control areas. Being based on a self-reporting exercise, there has to be recognition of potential bias of these results as they are liable to a degree of subjectivity. A similar caveat attaches to the diary study which showed above average rates of human ill-health on a number of the farms participating in the study. It is noted that, in all these cases of self-reported ill-health, the ailments appeared to be of a minor nature as there was very little recourse to medical advice. It is also relevant to note that the concern generated by the animal health problems and the suggestion that these were due to pollution, is likely to have affected recall in the Askeaton area.

Despite these limitations, the human health studies should give assurances to the local community that, whatever the cause of the animal health problems, it is not at greater risk of ill health or disease than persons in the surrounding areas and the national population. In particular, the fears expressed at the start of the investigations that there were excessive rates in the Askeaton area of serious diseases, such as cancer, and of other major health problems, such as miscarriages, can now be regarded as unfounded.

CONCLUSIONS

The foregoing discussion suggests that the following answers to the questions posed at the beginning of the Chapter are justified.

Was there any evidence of unusually high incidence of animal disease in the Askeaton area?

While there was undoubtedly an unusually high incidence of animal disease on a small number of farms in the Askeaton area, neither the number of farms involved, nor their distribution, suggests that this was evidence of a phenomenon affecting the wider Askeaton area as a whole (i.e. the area encompassed by this investigation).

If so, what were the causes?

In view of the foregoing conclusion, this question, in its wider sense, is redundant. The likely causes of disease on the Ryan farm in 1994 and 1995 were multi-factorial in origin and it was not possible to identify all the contributory factors. However, the combined effect of out-wintering pregnant cows during the poor weather of 1994 and 1995 together with inadequate pre-calving nutrition would have increased the number of animals with heightened susceptibility to disease. The lack of contemporaneous information precludes a similar assessment of the situation on the Somers farm.

Was there any evidence that environmental pollution contributed to an increased incidence of animal disease?

There was no evidence that this was the case.

Was there a threat to human health?

In view of the conclusions on animal health, there is little basis for the concern that the problems in the latter area represented a threat to human health. An independent human health problem arising from atmospheric emissions in the area is unlikely in view of the ambient levels of pollutants measured during and before the investigations. The specific studies comparing human health experience in the Askeaton area with that in control areas showed none or only minor differences between the populations compared.

CLOSING COMMENTS

In summary, while the findings in regard to the causes of the animal health problems have not been as conclusive or precise as the two farmers directly involved, as well as the wider community in the Askeaton area, would have wished, the information collected has enabled a number of possible causes to be largely ruled out of consideration. While this may appear to be an unsatisfactory outcome to some, it is hoped, nonetheless, that it will give assurances that the problems were not due to agents, particularly environmental pollution, with a potential to cause area-wide harm, both to livestock and humans.

It is possible that if the protocol for the investigation of serious incidents of animal or human health, already published as a response to the Askeaton situation (*see* Appendix B), had been developed at the time that the animal health problems first came to attention, these investigations would not have been necessary. Certainly, they would not have been so detailed or as lengthy. Investigations of the farms in the earlier stages may have

been able to identify management aspects requiring attention and forestalled the serious problems which subsequently developed. However, as said at the beginning of this discussion, the delayed intervention allowed a situation to develop which, from the point of view of the farmers and local community, could not be addressed satisfactorily by a limited study. In one sense, the more detailed work which had to be undertaken may have been useful if it can provide some assurances in the future of the compatibility of industrial development with farming in the Irish countryside.

RECOMMENDATIONS

The experience gained in this investigation highlighted a number of deficiencies in the approach to dealing with the type of potential problem which came to notice in Askeaton. In particular, it was considered that there was a need for an early response so that timely observations could be made and unnecessary concerns avoided. This led to the development of a protocol by the investigating team, and endorsed by the parent agencies, setting out the steps to be taken in the event of a situation like that at Askeaton arising in future. The protocol was issued in 1997 and is attached here as Appendix B. It has proved useful in dealing with a number of incidents since that time.

There are several other matters which, in the opinion of the personnel involved in the Askeaton investigations, need to be addressed so that, *inter alia*, proper expertise and baseline data are available in the State. These are listed below.

Animal Health

1. A National Toxicology Centre should be created to provide comprehensive expert support for the investigation of suspected pollution incidents which adversely affect human, animal, or environmental health. It is understood that a proposal along these lines has already been submitted to the Government by the Irish Society of Toxicology.

2. The Department of Agriculture Food and Rural Development should undertake, as a matter of priority, the establishment and maintenance of a database to record the national incidence of common indigenous diseases of livestock. This will allow the definition of norms for animal health problems, thus facilitating comparative assessment of the significance of problems on individual farms or groups of farms.

Human Health

3. There should be a computerised system of monitoring congenital abnormalities based on the EUROCAT model of congenital abnormalities registry.

4. A system of surveillance of morbidity in general practice should be established using a series of GP sentinel practices.

5. Information systems within the health service should be structured such that they allow easy epidemiological investigation for studies such as this. This would particularly involve the use of a unique identifier and the geocoding of episodes. Such a system would need to be as real time as possible.

6. A focus of environmental epidemiological expertise and the ability to communicate such knowledge to local communities rapidly and authoritatively needs to be established.

7. If similar investigations such as this occur in the future it would be appropriate to ensure a local office and key worker(s) are put in place in the affected community to provide an easily accessible source of information or focal point for liaison with the community.

8. Investigations such as this should normally be concluded within a year. This presumes that adequate resources are made available to allow this to occur.

General

9. Issues relating to the resourcing of inter-agency investigations of this nature should be examined by the agencies concerned. Where they are not already in place, procedures should be implemented to allow agencies recruit expert and support staff on short-term contract as required.

Appendix A

ASKEATON TREE HEALTH SURVEY

(Undertaken by Coillte Teo.)

ASKEATON TREE HEALTH SURVEY

INTRODUCTION

Coillte established five forest condition plots in the general vicinity of Askeaton in 1996, in conjunction with the Forest Service and the EPA as part of the investigations of animal health problems. The plots were set up according to UNECE methodologies (ICP Forests, 1994). Two species (Norway spruce and Sitka spruce) and a total of 132 trees were represented in the survey (Table A1).

Results of the observations made on the plots in 1996 and 1997 were reported in the second and third interim reports on the animal health investigations (EPA, 1997, 1998). The results of the 1998 observation are set out below together with an overall comment on the outcome of the survey.

Table A1.

Plot details

Plot Number	Forest	Species	# trees in plot	Planting year
1	Glin	Sitka spruce	35	1967
2	Carrickerry	Sitka spruce	25	1966-1967
3	Curraghchase	Norway spruce	22	1960
4	Foynes	Sitka spruce	25	1965
5	Cratloe	Sitka spruce	25	1973-1976
Total			**132**	

1998 OBSERVATIONS

Defoliation and discoloration were visually assessed in the crowns of the sample trees between July 14th and July 16th 1998, According to the methods employed in the EU Level I and Level II surveys.

Results

<u>Defoliation and Discoloration</u>
Overall mean defoliation decreased in 1998 (Table A2) by 1.0 per cent, but remained slightly higher than 1996. In contrast, overall mean percent discoloration increased by 0.4 to 9.4 per cent. Although there has been a continual increase in mean discoloration since the survey began in 1996, it is not a cause for concern, since the discoloration levels still remain very low. With regards to species, defoliation levels decreased in both species, while discoloration levels increased in both species. The changes in defoliation and discoloration were more pronounced in Norway spruce than Sitka spruce.

Table A3 shown mean defoliation and discoloration by plot. Two of the five plots showed noticeable changes in their condition between 1997 and 1998. The condition of Carrickerry improved considerably, while that of Foynes disimproved. With regards to defoliation there was an improvement observed at three of the five plots, and in particular Carrickerry, where

Table A2.
Mean per cent defoliation and discoloration by species.

		% Defoliation			%Discoloration		
Species	No. trees	1996	1997	1998	1996	1997	1998
Norway spruce	22	14.1	13.4	11.6	4.8	7.0	8.0
Sitka spruce	110	15.3	16.9	16.1	7.5	9.4	9.6
Total/Mean	**132**	**15.1**	**16.3**	**15.3**	**7.0**	**9.0**	**9.4**

Table A3.
Mean per cent defoliation and discoloration by plot.

Plot No.	Forest	Defoliation (%)			Discoloration (%)		
		1996	1997	1998	1996	1997	1998
1	Glin	14.9	17.3	11.9	6.4	9.7	7.6
2	Carrickerry	25.6	29.0	16.6	12.0	15.8	7.6
3	Curraghchase	14.1	13.4	11.6	4.8	7.0	8.0
4	Foynes	11.4	11.8	22.0	6.6	5.6	15.8
5	Cratloe	9.4	9.4	15.6	5.2	6.0	8.4

defoliation decreased by 12.4 per cent. Defoliation increased in the remaining two plots, and almost doubled in Foynes. The overall result of these changes was a very different trend in defoliation levels among plots in1998, than in either of the previous two years. In terms of discoloration, three of the five plots showed an increase in mean discoloration levels, with an almost three-fold increase observed in Foynes. Discoloration levels decreased at two of the plots, with levels halving at one of the plots (Carrickerry).

The data were divided into defoliation and discoloration classes as set out in the UN/ECE Manual used in the Level I and Level II surveys. Five defoliation classes are recognised: 0 (10% defoliation), 1 (11-25% defoliation), 2 (26-60% defoliation), 3 (>60%defoliation), and 4 (dead). Trees with less than 25 per cent defoliation (i.e. classes 0 and 1 combined) are generally considered to be in good condition. Almost 89 per cent of the trees surveyed had less than 25 per cent defoliation (Table A4). This represents and increase of approximately 9 per cent in this class in comparison to 1997 data. It is also the highest figure since the survey began in 1996. Corresponding to this, there was a decrease in the number of trees in defoliation class 2. As was the observation made in both 1997 and 1996, there were no trees in either defoliation class 3 or 4.

Table A4.

Percent Sitka spruce and Norway spruce in different defoliation classes.

Species	n	Defoliation Class				
		0 (0-10%)	1 (11-25%)	2 (26-60%)	3 (>60%)	4 (dead)
Sitka spruce	110	41.8	46.4	11.8	0.0	0.0
Norway spruce	22	54.5	36.4	9.1	0.0	0.0
Total	**132**	**43.9**	**44.7**	**11.4**	**0.0**	**0.0**

Five discoloration classes are also recognised (Table A5). Almost 96 per cent of the trees surveyed had less than 25 per cent discoloration. Although this figure is very high, it represents a decrease of approximately 2 per cent from the 1997 figures. This decrease corresponds with an increase in the number of trees with greater than 25 per cent discoloration. However, no trees in the survey had greater than 60 per cent discoloration.

Table A5

Percent Sitka spruce, and Norway spruce in different discoloration classes.

Species	n	Discoloration Class				
		0 (0-10%)	1 (11-25%)	2 26-60%)	3 (<60%)	4 (dead)
Sitka spruce	110	70.9	24.5	4.5	0.0	0.0
Norway spruce	22	68.2	27.3	4.5	0.0	0.0
Total	**132**	**70.5**	**25.0**	**4.5**	**0.0**	**0.0**

Comment on 1998 Results

The results are very comparable with those obtained in the two previous surveys, in 1996 and 1997.

OVERALL COMMENT ON SURVEYS

The Askeaton tree surveys were carried out according to methods and procedures agreed for the EU-wide national surveys. The results from all three Askeaton surveys are very similar to those from the national surveys, which indicate our forests are generally healthy, particularly so when compared to polluted areas elsewhere in the EU. Levels of damage (defoliation and needle discoloration) were generally within the bounds of natural levels, and variation in damage levels was attributed to natural causes particularly exposure and/or aphid outbreak. There was no indication of pollution damage to trees in any of the years of the surveys (1996-8).

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Appendix B

PROTOCOL FOR THE INVESTIGATIVE APPROACH TO SERIOUS ANIMAL HEALTH/HUMAN HEALTH PROBLEMS

PROTOCOL FOR THE INVESTIGATIVE APPROACH TO SERIOUS ANIMAL HEALTH/HUMAN HEALTH PROBLEMS

Environmental Protection Agency
Department of Agriculture and Food
Department of Health/Health Boards
Teagasc

Note

This protocol was prepared by the EPA in collaboration with the other agencies involved in the Askeaton Animal Health Investigation, viz Department of Agriculture and Food, Teagasc and the Mid Western Health Board

PROTOCOL FOR THE INVESTIGATIVE APPROACH TO SERIOUS ANIMAL/HUMAN HEALTH PROBLEMS

BACKGROUND TO THE ASKEATON INVESTIGATION

The animal health problems first came to notice after 1988 on the dairy farm of Mr Liam Somers at Ballysteen, Askeaton, Co. Limerick. They were characterised by ill-thrift and weight loss in cows which became progressively worse over the following years with relatively high numbers of deaths of animals occurring in 1992-1993. Accompanying these problems were a decline in milk production and an increase in infertility as well as loss of calves at birth. While the incidence of animal deaths declined in 1994-1995, the problems of ill-thrift and reduced milk production persisted. This farm was leased to DAF in October 1995 for the purpose of conducting cattle health trials as part of the investigation.

Severe animal health problems were also reported on the farm of Mr Justin Ryan at Toomdeely, Askeaton, but it is not clear when these commenced. The incidence of animal deaths on this farm was particularly high in the winter of 1994-1995. As on the Somers farm, the normal calving pattern was lost so that lactation and grass growth were no longer synchronised. This farm was purchased by the State in November 1995 to conduct trials similar to those on the Somers farm.

Subsequently, 25 other farmers in the area indicated to the investigating team that they had had or were currently experiencing animal health problems. All of these farmers were interviewed in depth regarding their stated problems and a detailed monitoring of five of the more seriously affected farms was put in place. The other farms were subjected to less intense monitoring; all were offered advice on dealing with any problems present.

In addition to animal health problems, there was local concern that human illnesses and minor ailments in the area were linked with the livestock health problem. Most of these incidents related to respiratory problems although there were suggestions of other effects such as skin rashes and miscarriages. Several studies were initiated by the Mid-Western Health Board in the latter part of 1995 in order to determine if these and other ailments were and are occurring at unusual levels in the Askeaton area.

In order to complement these animal and human health studies, investigations of soils and herbage on the Somers and Ryan farms and of environmental quality in the Askeaton area have been carried out, respectively, by Teagasc and the EPA. Other studies examined the contaminant levels in vegetables grown locally and the health of trees in nearby forestry plantations.

Results from the various studies and measurements have been published in two interim reports published in December, 1995 and June, 1997. A further interim report, covering the work undertaken in 1997, is in preparation.

IMPLICATIONS FOR FUTURE INVESTIGATIONS

The experience gained in the current investigations of animal health problems in the Askeaton area of County Limerick has emphasised the need for early intervention and for a systematic and co-ordinated approach to any future problems of this nature. In the Askeaton case, the State agencies did not become involved in a co-ordinated way for some years after the problems were first manifested and the opportunity to make observations at the most critical period was therefore limited.

A further disadvantage in the Askeaton investigation arose from the relative lack of comparable data at a national level on the incidence of both animal and human health problems, particularly the former. Due to the absence of national baseline data, it was difficult to make a definitive assessment regarding the incidence of disease on the 25 additional farms reporting problems in the Askeaton area and to determine whether or not rates were significantly higher than national norms.

RECOMMENDED APPROACHES TO THE CONDUCT OF FUTURE INVESTIGATIONS

Based on the Askeaton experience, the following are suggested as the main requirements which need to be addressed so that any further investigations of situations comparable to that which occurred in Askeaton are undertaken in a timely, orderly and efficacious manner.

- Arrangements to ensure that the relevant State agencies, e.g. the Regional Veterinary Laboratories or Teagasc, are made aware of the problem at an early date
- An agreed procedure between the relevant agencies and other parties for their involvement in any investigation deemed necessary
- The identification of a co-ordinator for the investigation.
- The establishment and regular updating of national data bases on the incidence and nature of animal and human health problems and related information
- Monitoring programmes to be in operation to assess the environmental impact of large industrial plants and other waste emitting operations

SPECIFIC PROCEDURE FOR DEALING WITH ANIMAL HEALTH PROBLEMS

1. Notification of Problem

The primary responsibility for bringing any animal health problem which is not readily explainable or treatable to the attention of the Regional Veterinary Laboratory (RVL) will rest with the private veterinary practitioner (PVP) or herdowner. the assistance of the professional and farming bodies will be sought in ensuring that the rvls are made aware of potentially serious problems as early as possible. when significant animal health problems are identified, the senior research officer (SRO) at the RVL will initiate a laboratory investigation and seek a full report from the PVP. The SRO will also inform the department of agriculture and food's (DAF) local superintending veterinary inspector of the nature of the problem.

2. Involvement of Other Agencies

The following steps will be taken:

(a) If, on the basis of the report from the PVP, the SRO considers that the issue requires a wider investigation, e.g., into farm management practices, land fertility, or other matter, he will consult the Teagasc CAO for the area to consider whether a joint DAF/Teagasc investigation (with the added involvement, where appropriate, of the PVP) is warranted. If environmental factors are considered to be involved, the local authority and, where appropriate, the EPA will be invited to join in these consultations. In addition, the local Health Board will be notified of the matter and may join the discussions if the Board considers this relevant to its responsibilities.

(b) Alternatively, where the problem first comes to the notice of Teagasc, the CAO will initiate contact with the SRO of the appropriate RVL as at (a).

3. Undertaking of Investigations

(a) Where a joint DAF/Teagasc approach has been initiated at 2(a), it will encompass a full range of investigative procedures as considered appropriate by each body. The SRO will be responsible for the co-ordination of the investigation at this stage.

(b) Where it has been decided that a joint DAF/Teagasc investigation is warranted, the Director of the Veterinary Laboratory Service and the Head of the Animal Health and Welfare Division of DAF will be so advised by the SRO and will be apprised of the nature of the problem.

4. Further Action

(a) When above actions fail to find a resolution a report will be sent to the Animal Health and Welfare Division of DAF and to Teagasc for consideration by a joint Ad Hoc Committee comprising the following:

DAF - Head of the Animal Health and Welfare Division
- SSRO from Abbotstown, SSVI and SAI from HQ

Teagasc - Representatives to be nominated.

The committee will recommend appropriate further action.

(b) If, following the investigations carried out at 3(a), the possible involvement of environmental factors is still not ruled out, the relevant local authority and the EPA will participate in the Ad Hoc Committee's deliberations. The local Health Board will be notified of the convening of the Committee and may join the discussions if the Board considers this relevant to its responsibilities.

5. Epidemiological Investigations

In cases where the reported animal health problems involve a number of farms in an area, the investigations to be undertaken at 2 (a) or following the considerations at 4 (a) may include application of appropriate epidemiological sampling and monitoring techniques.

6. Assignment of Costs

The herdowner will be responsible for fees due to the PVP. DAF will waive laboratory fees for tests arising form the investigation at 3(a) and 4, but will continue to charge laboratory fees that arise in the normal way. Teagasc will waive fees on grounds of hardship.

7. Co-ordination of an Investigation

It is important that a co-ordinator be identified for any investigation deemed necessary. In the case of the Askeaton investigation, the EPA was assigned the role through a Ministerial request; however, this reflected the particular circumstances in the Askeaton case where the relatively late intervention of the State agencies led to public opinion focusing strongly on an environmental factor as the causative factor. The current proposals are intended to avoid such situations by ensuring early involvement of the appropriate bodies.

In the case of future animal health problems, the co-ordination of the initial assessment will be the responsibility of the SRO of the relevant RVL. Co-ordination of any further investigations required following the considerations of the Ad Hoc Committee will be decided by the Committee having regard to the main emphasis of those investigations.

SPECIFIC PROCEDURE FOR DEALING WITH HUMAN HEALTH PROBLEMS

In cases where the prime concern is human health, the responsibility for an initial enquiry and any follow-up study deemed necessary will be a matter for the public health agencies, e.g. the appropriate Regional Health Board.

Arising from the Askeaton investigation, the Mid Western Health Board has consulted with the other Health Boards as to the approach to be adopted in cases where there are apparent clusters of human ailments. The appended document sets out, *inter alia*, a procedure to deal with such situations (see Reactive Cluster Investigation - Short Term, p. 181). This procedure may also be implemented in cases where the public health agencies are drawn into an investigation of animal health because of subsequent expressions of concern for human health.

ENVIRONMENTAL INVESTIGATIONS

Where the initial assessment of an animal and/or human health problem has concluded that a detailed investigation is needed and that, additionally, there is a possibility that an environmental pollutant is involved, the following procedure will be implemented by the local authority and/or the EPA, as appropriate, as part of the general investigation:

- An assessment will be carried out of the pollutant emission potential of all local industry and any other relevant activity

- A risk analysis will be undertaken for any pollutant likely to be emitted to the local environment in relation, particularly, to the animal or human health problem observed, including, where necessary, modelling of the dispersion of emissions

- The available environmental monitoring data and any other relevant measurements for the area affected by the problem will be collated

- Any measurements or additional monitoring deemed necessary to fill gaps in the database on local environmental quality will be undertaken

NATIONAL DATA BASES

The establishment of a database to record the national incidence of disease in livestock will be undertaken by DAF as a matter of priority. This will allow the definition of norms for animal health problems, thus facilitating comparative assessment of the significance of problems on individual farms or groups of farms.

In relation to human health, the Mid Western Health Board has consulted with the other Health Boards on the development of a national database on health events and environmental agents. The attached document sets out the mechanics of this development (see Long-term Surveillance Systems, p. 3)

ENVIRONMENTAL MONITORING

The EPA is presently developing national environmental monitoring programmes, including the monitoring of air quality and deposition. As part of these programmes, the Agency will be assessing the local environmental monitoring needs in relation to the potential impacts of activities controlled by IPC Licensing. Where there is the possibility of a local impact, appropriate monitoring systems will be established to clarify the situation. In keeping with its responsibility to oversee the environmental pollution control activities of the local authorities, the monitoring arrangements instituted by the authorities to measure the environmental impact of potentially polluting activities under their control will be assessed by the Agency.

Disease Cluster Investigation Protocol

October 1997

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INTRODUCTION

We have outlined a short-term and long-term response to clusters. The short-term reactive response is labour intensive and expensive. A proper long-term strategy depends on geographical coding and adequate surveillance systems being developed and would remove a significant proportion of the labour and expense whilst bring vital health information to the attention of the boards. We have outlined the main issues involved in developing these.

REACTIVE CLUSTER INVESTIGATION

Short-Term

The steps that are laid out below represent a series of stages through which the investigation of a reported perceived cluster of adverse health events should be taken. They should act as a set of guidelines that could be implemented immediately in each health board area. A number of milestones are highlighted at which an explicit decision should be made whether the investigation should be continued.

Step 1. Communicate with and meet person making allegation

The person(s) who is dealing with the allegation should meet face to face with the person who is making the allegation in order to explore their initial ideas, concerns and expectations. Where it is deemed to be appropriate, communication with the community should take place. The community perception of the risk must be clearly understood.
DECISION TO CONTINUE?

Step 2. Written allegation where possible

The person making the allegation should be asked to convey their questions and concerns, together with all available details about the cluster in writing.

Step 3. Response team

When it is appropriate to the requirements of a given cluster notification, a response team should be set to conduct the investigation. It should consist of a public health specialist and an AMO from the area concerned, other staff may have to be involved (esp. clerical staff) depending on the scale and complexity of the problem.

Step 4. Produce map of area

A map of the area from which the cluster is derived should be drawn up showing the DEDs of concern

Step 5. Clarify initial time, space and causal concerns

The investigator should ask the person(s) who is making the allegation to identify the time period and geographical area which is giving rise to concern. He/she should also be asked to offer an initial suggestions as to the likely cause(s)

Step 6. Establish case details

The person making the allegation will have to supply some information about each of the cases in the perceived cluster so that further details may be sought directly. It is important that the individuals concerned have given their consent for their details to be passed on to the investigator. It must be stressed to the person ,making the allegation that without such case details, no investigation can be carried out.
DECISION TO CONTINUE?

Step 7. Explore for other cases

Following the collection of information on reported cases it will be necessary that other cases be sought out from local GPs so that potentially involved cases are not inadvertently excluded.

Step 8. Calculate basic statistics (SMR, SIR)

Following the collection of this basic data, some simple statistics about mortality and disease incidence should be calculated and compared to baseline data.
DECISION TO CONTINUE?

Step 9. Case verification

If these initial statistics suggest that a true increase in disease may be occurring, it will be necessary to explore the details about each of the cases in order to establish exact diagnoses. This will include the examination of laboratory, radiological and pathological reports.

Step 10. If verified, and no hypothesis, consider case study

If the verification reveals that the cases are real, but no likely cause is evident, a detailed case study may have top be set up.

DECISION TO CONTINUE?

Step 11. If verified, and plausible hypothesis, consider case-control study

If the verification reveals that the cases are real and a certain cause(s) is evident, a case-control study may have to be set up.

Step 12. Written report

The person who is making the initial allegation should be told at the outset that he/she will be furnished with a report of the investigation regardless of what stage the investigation is carried to.

Long-Term

Surveillance Systems

Surveillance systems that provide baseline and ongoing data on both health events and environmental agents would be necessary for the effective and efficient investigation of clusters of adverse health events.

A. Health

Mortality data is useful for monitoring the incidence of diseases with high case fatality rates. In most cases, however, it will be necessary to supplement mortality data with morbidity data and behavioural risk factor data. The latter will be necessary because of the association between many diseases that are reported in clusters and the lifestyles that people lead.

The data sources should be person based and geographically coded. They should also be easily accessible. The sources of data and the categories in which it should be collected are laid out below.

1. **Mortality**
   - Death certificates
   - Cancer Registry
   - HIPE

2. **Morbidity**
   - Registers e.g.
     - EUROCAT
     - National Cancer Registry
   - HIPE
   - GP data
   - Drug usage
   - Laboratory data e.g. genotyping

3. **Ad hoc surveys e.g. lifestyle risk factors**

B Environment

The sources of data on environmental data are equally diverse and include the following:

- Census data (socio-economic factors)
- EPA database
  industrial chemicals
- Local authorities
  Air, water and land quality monitoring
- Radiological Protection institute of Ireland
  Radon
  Other radiation

TECHNICAL DEVELOPMENTS REQUIRED

Geo-coding

In order for a cluster to be adequately investigated, it is necessary to be link the health events that are part of the alleged cluster to the geographical area that is potentially affected. There are two ways of achieving this:

DED coding

This involves the inclusion of the DED code in which an individual resides as part of the routine data that is collected in all health information systems as well as in the census of population

Grid co-ordinates

This serves the same purpose as DED coding but involves the linking of geographical co-ordinates to each case in the potential cluster and provides for more accurate spatial analysis.

Unique identifier

This is an identification number that runs right through all information systems which contain information on human health events. It allows for "Record Linkage" whereby the record of one individual can be followed through lots of other information systems.

GIS Systems

Statistical Expertise

The expertise of a statistician who was trained in the techniques required for the investigation of clusters as well as small area statistics would be necessary

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An Ghníomhaireacht um Chaomhnú Comhshaoil

Bunú

Achtaíodh an tAcht fán nGníomhaireacht um Chaomhnú Comhshaoil ar an 23ú lá d'Aibreán, 1992 agus faoin reachtaíocht seo bunaíodh an Ghníomhaireacht go hoifigiúil ar an 26ú lá d'Iúil, 1993.

Cúraimí

Tá réimse leathan de dhualgais reachtúla ar an nGníomhaireacht agus de chumhachtaí reachtúla aici faoin Acht Tá na nithe seo a leanas san áireamh i bpríomhfhreagrachtaí na Gníomhaireachta·

- ceadúnú agus rialáil próiseas mór/ilchasta tionsclaíoch agus próiseas eile a d'fhéadfadh a bheith an-truaillitheach, ar bhonn rialú comhtháite ar thruailliú (Integrated Pollution Control-IPC) agus cur chun feidhme na dteicneolaíochtaí is fearr atá ar fáil chun na críche sin;
- faireachán a dhéanamh ar cháilíocht comhshaoil, lena n-áirítear bunachair sonraí a chur ar bun a mbeidh rochtain ag an bpobal orthu, agus foilsiú tuarascálacha tréimhsiúla ar staid an chomhshaoil,
- comhairle a chur ar údaráis phoiblí maidir le feidhmeanna comhshaoil agus cuidiú le húdaráis áitiúla a bhfeidhmeannas caomhnaithe a chomhlíonadh,
- cleachtais atá fónta ó thaobh an chomhshaoil de a chur chun cinn, mar shampla, trí úsáid iniúchtaí comhshaoil a spreagadh, cuspóirí cáilíochta comhshaoil a leagan síos agus cóid chleachtais a eisiúint maidir le nithe a théann i bhfeidhm ar an gcomhshaol,
- taighde comhshaoil a chur chun cinn agus a chomhordú;
- gach gníomhaíocht thábhachtach diúscartha agus aisghabhála dramhaíola, lena n-áirítear líontaí talún, a cheadúnú agus a rialáil agus plean náisiúnta bainistíochta um dhramháil ghuaiseach, a bheidh le cur i ngníomh ag comhlachtaí eile, a ullmhú agus a thabhairt cothrom le dáta go tréimhsiúil;
- córas a fheidhmiú a chuirfidh ar ár gcumas astúcháin COS (Comhdhúiligh Orgánacha Sho-ghalaithe) a rialú de bharr cáinníochtaí suntasacha peitril a bheith á stóráil i dteirminéil,
- na rialúcháin OMG (Orgánaigh a Mionathraíodh go Géiniteach) a fheidhmiú agus a ghníomhú maidir le húsáid shrianta a leithéad seo d'orgánaigh agus iad a scaoileadh d'aon turas isteach sa timpeallacht,
- clár hidriméadach náisiúnta a ullmhú agus a chur i ngníomh chun faisnéis maidir le leibhéil, toirteanna agus sruthanna uisce in aibhneacha, i lochanna agus i screamhuiscí a bhailiú, a anailísiú agus a fhoilsiú, agus
- maoirseacht i gcoitinne a dhéanamh ar chomhlíonadh a bhfeidhmeanna reachtúla caomhnaithe comhshaoil ag údarás áitiúla

Stádas

Is eagras poiblí neamhspleách í an Ghníomhaireacht Is í an Roinn Comhshaoil agus Rialtais Áitiúil an coimirceoir rialtais atá aici Cinntítear a neamhspleáchas trí na modhanna a úsaidtear chun an tArd-Stiúrthóir agus na Stiúrthóirí a roghnú, agus tríd an tsaoirse a dhearbhaionn an reachtaíocht di gníomhú ar a conlán féin Tá freagracht dhíreach faoin reachtaíocht aici as réimse leathan feidhmeannas agus cuireann sé seo taca breise lena neamhspleáchas Faoin reachtaíocht, is coir é iarracht a dhéanamh dul i gcion go míchuí ar an nGníomhaireacht nó ar aon duine atá ag gníomhú thar a ceann

Eagrú

Tá ceanncheathrú na Gníomhaireachta lonnaithe i Loch Garman agus tá cúig fhoireann chigireachta aici, atá lonnaithe i mBaile Átha Cliath, Corcaigh, Cill Chainnigh, Caisleán an Bharraigh agus Muineachán

Bainistíocht

Riarann Bord Feidhmiúcháin lánaimseartha an Ghníomhaireacht Tá Ard-Stiúrthóir agus ceathrar Stiúrthóirí ar an mBord Ceapann an Rialtas an Bord Feidhmiúcháin de réir mionrialacha atá leagtha síos san Acht

Coiste Comhairleach

Tugann Coiste Comhairleach ar a bhfuil dáréag ball cunamh don Ghníomhaireacht Ceapann an tAire Comhshaoil agus Rialtais Áitiúil na baill agus roghnaítear iad, den chuid is mó, ó dhaoine a ainmníonn eagraíochtaí a bhfuil suim acu i gcúrsaí comhshaoil nó forbartha Tá réimse fairsing feidhmeannas comhairleach ag an gCoiste faoin Acht, i leith na Gníomhaireachta agus i leith an Aire araon

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