Publication title	Review of Best Practice in relation to Iodine-131 Ablation Discharges to Sewer
Project Code	RP005-0003
Volume number	Volume 1
Version	Final Report Version 3.1
Date	March 2010
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EXECUTIVE SUMMARY

This document has been produced by Enviros Consulting Ltd (Enviros) on behalf of the Radiological Protection Institute of Ireland (RPII). It presents a review of best practice in relation to the management of iodine-131 (I-131) ablation discharges to sewer and recommends a waste management strategy that could be adopted in the Republic of Ireland.

Currently, there are three hospitals in the Republic of Ireland at which thyroid ablation therapy procedures (large therapeutic administrations of I-131 for thyroid cancer treatment) are carried out. Two are located in Dublin (St James' and St Luke's hospitals) and one in Cork (Cork University Hospital). Each of these hospitals has a single bed, self-contained, secure and shielded ablation suite.

Patients typically receive between 3 and 8 GBq I-131 as sodium iodide per administration and generally receive one administration as part of their treatment.

Based on current administrations and discharges, the potentially most exposed group of individuals comprises hospital plumbers, who may have to deal with blocked pipes exiting the ablation suite. For these individuals, their exposure arises from 'one-off' events (i.e. a single blockage) and as such is controlled by the activity given in a single administration rather than the total activity administered through a year. Based on this scenario their assessed exposure could be of the order of 50 to 70 µSv per incident, with a conservative likelihood of occurrence around once per year.

A secondary exposure group is identified as sewage workers. The assessed dose to this group, based on current practices and discharges, is likely to be less than 4 µSv y^{-1}. Fishing communities are also assessed, with potential exposures from food consumption as well as external irradiation. In this case, the dose is determined to be 0.4 µSv y^{-1} or below.

Based on anticipated future medical requirements and associated administrations, the potential most exposed group is again the hospital plumbers, who may be exposed per 'one-off' event at around 50 to 70 µSv (assuming that current practices continue). The corresponding dose to sewage workers is assessed to be less than 6 µSv y^{-1} and that to any member of a fishing family 0.6 µSv y^{-1} or below.

There is no threshold below which radiation doses are defined as negligible, but there is a consensus view that below a few 10's µSv y^{-1}, and certainly below 10 µSv y^{-1}, the associated risks are low and the introduction of measures to further reduce such doses should be cost effective.

Doses to members of the public can be reduced through the introduction of delay storage of liquid wastes prior to discharge to the sewer system; the magnitude of such reduction being proportionate to the duration of the delay storage. Doses to hospital plumbers may be reduced (depending on maintenance requirements for delay tanks) whilst the dose to ancillary hospital staff may increase marginally if manual collection of wastes is undertaken for delay storage, although this does not represent the recognised Best Available Technology.

The cost of retrofitting delay tanks is likely to be of the order of several €100,000s. For new, purpose built, facilities the costs of introducing such delay tanks are likely to be a small fraction of the overall capital expenditure.

With this in mind, it is recommended that:

- The RPII should consider a regulatory regime based on the demonstration of BAT;

- The benefit (on the grounds of radiological protection) of retrofitting of tanks into existing facilities is grossly disproportionate to the financial and logistical issues incurred and are not recommended in the draft ICRP [2007] recommendations. Nonetheless, appropriate works control systems should be in place to minimise any potential incidents of plumber exposure;

- Where delay and decay tanks currently exist their operation can be continued;

- Fitting of delay and decay tanks into a new facility is advantageous, particularly if only one or two facilities are established. This is particularly true where multiple ablation suites may occur in the same facility and more than one patient may be undergoing treatment at one time. However, the final requirements should be assessed on a site by site basis in line with the EC guidelines for demonstrating BAT.

- Where delay and decay tanks are installed a multi-tank vacuum systems has sufficient advantages that it could be represent BAT. Using such a system a factor of 500 to 1000 reduction in activity through decay is achievable. This is considered sufficient to ensure that all possible exposure scenarios would not lead to a dose of 10 µSv being exceeded.

More defined recommendations cannot be given because Ireland does not currently have a clear assessment of future needs for nuclear medicine and currently the number and locations of potential supra-regional oncology centres has not been defined.

1. INTRODUCTION

This document has been produced by Enviros Consulting Ltd (Enviros) on behalf of the Radiological Protection Institute of Ireland (RPII). It presents a review of best practice in relation to the management of iodine-131 (I-131) ablation discharges to sewer and puts forward recommendations for a waste management strategy that could be adopted in the Republic of Ireland.

1.1 Background

In the Republic of Ireland there are three hospitals at which thyroid ablation therapy procedures (large therapeutic administrations of I-131 for thyroid cancer treatment) are carried out. Two thyroid ablation suites are located in Dublin (St James' and St Luke's hospitals) and one in Cork (Cork University Hospital). Each of these hospitals has a single bed, self-contained, secure and shielded ablation suite.

Patients typically receive somewhere between 3 and 8 GBq I-131 as sodium iodide (NaI-131) per administration and generally only receive one administration as part of their treatment[1]. Around 80% of the activity of I-131 administered to patients can be excreted in urine [Leung & Nikolic, 1998]; the majority being lost from the body within 72 hours of treatment via urine. Some I-131 is also lost via sweat and saliva and transferred to bedding and towels etc.

Patients admitted for thyroid ablation treatment typically remain in the hospital for a period of between 3 and 7 days following iodine administration to allow radioactivity to decay to levels that will not pose a radiological hazard to the families of patients and/or members of the public with whom they may come into contact. Two of the thyroid ablation hospitals discharge excreta from the in-patient toilets, and other liquid waste arising from washing facilities, direct to sewer (St James' and St Luke's). The third hospital has a single holding tank to enable decay of I-131 activity prior to discharge to sewer.

An assessment of future oncology needs in Ireland has been undertaken [Expert Working Group on Radiation Oncology Services, 2003]. However, this study did not address the use of nuclear medicines, such as I-131, for thyroid ablation treatment. Also, at present, there is some uncertainty where future treatment centres will be based. Nonetheless, consultation with medical staff in Ireland has indicated an anticipated growth in this field. A full assessment of future needs has been beyond the remit of this project, but based on the 91 patients treated in 2006, future needs (i.e. within 5 to 10 years), as anticipated by hospital staff, could be 50% higher or above.

At present RPII authorises the licensee for the custody and use of a specific activity of I-131 that can be administered over the course of a year. The authorisation is subject to the licensee having demonstrated, through carrying out a risk assessment, that a dose constraint of 300 µSv y^{-1} can be met for all critical groups identified. There is however no defined policy on best practice for the management of liquid wastes arising from thyroid ablation that are discharged to sewer. The current draft recommendations by the International Commission on Radiation Protection [ICRP, 2007] state that discharge of such waste direct to sewer, without storage to allow decay of activity, is the most appropriate management method. However, previous publications from the International Atomic Energy Agency (IAEA)

1 In a limited number of cases two administrations may be made. These are generally made six months apart and therefore it is likely that only 50% of patients receiving a double administration will do so within a single calendar year.

do identify storage for decay as a potential management option. In addition, many European Union Member States have adopted the requirement for hospitals to employ 'delay and decay' methods, although this approach is by no means uniform. For instance, in England, Wales and Scotland the need for delay and decay methods is assessed on a site by site basis, while in Northern Ireland the approach is standard practice (although the methods differ and it is not a regulatory requirement).

To meet the commitment given in Irelands National Report to OSPAR there is a need to identify a strategy to ensure best practice management procedures for these wastes accounting for:

- international recommendations;
- approaches in other Member States;
- robust radiological dose assessments; and,
- appreciation of the advantages and potential constraints for the use of holding tanks, either retrofitted to existing facilities, or applied to new supra-regional oncology centres.

1.2 Project Aims and Objectives

The aim of this project is to present to the RPII a consensus of best practice with regard to the management of I-131 ablation waste appropriate to the future requirements in Ireland. The project has the specific objectives to:

- Identify future demands for I-131 ablation in Ireland, both at a national and site specific level;
- Summarise current practices in Ireland, in other EU Countries and international advice on best practice for the management of I-131 ablation waste;
- Assess radiological dose to plumbers, sewage treatment workers and other members of the public[2] based on anticipated future discharges of I-131;
- Establish criteria for assessment and demonstration of best practice and assess benefit/disbenefit of holding tank installation; and,
- Make recommendations for requirement for fitting and retrofitting holding tanks.

1.3 Structure of this Report

The following chapters in this report cover:

2 For the purposes of radiation protection from 'controllable sources', the International Commission for Radiological Protection [ICRP, 2007] recognises three categories of individuals: workers, the public and patients. Correspondingly, three categories of exposure are recognised: occupational exposures, public exposures and medical exposures of patients. A worker is defined by the ICRP as any person who is employed (whether full-time, part or temporarily) by an employer "who has recognised rights and duties in relation to occupational radiological protection" [para 179]. Correspondingly, the ICRP limits its use of the term occupational exposure to "radiation exposures incurred at work as a result of situations that can reasonably be regarded as being the responsibility of the operating management" [para 174]. In this context, for the purposes of radiation protection, it is clear that an employee engaged in sewage treatment is to be regarded as a member of the public and all dose limitations applying under Irish regulations should be applied accordingly.

- Chapter 2 presents the output from discussions with the National Plan for Radiation Oncology and identifies, for a number of sites, the potential oncology needs;
- Chapter 3 provides the output from a review and outline consultation process and summarises different management practices over a number of EU countries. Further information in provided in Appendix 1;
- The results of the prospective dose assessment are discussed in Chapter 4. Further information on the dose assessment method is given in Appendix 2;
- Criteria for assessment and demonstration of best practice and discussion on the benefit/disbenefit of holding tank installation is given in Chapter 5; and,
- Conclusions of the study and recommendations for requirement for fitting and retrofitting holding tanks are given in Chapter 6.

2. IODINE-131 ABLATION NEEDS IN IRELAND

In 2003, the Irish Government approved the strategy for the provision of a national network of oncology services throughout Ireland. A review of this strategy, supported by recent discussions with the National Office for Oncology is provided below.

2.1 National Developments in Oncology

In 2003, a report was published 'the Hollywood report' that detailed a strategy for the development of a national network of oncology services throughout the Republic of Ireland [Expert Working Group on Radiation Oncology Services, 2003]. Radiation oncology services are currently available in both public and private facilities throughout Ireland. Radiation therapy, involving the use of linear accelerators, is available in three public hospitals (St Luke's, Cork University Hospital and University College Hospital Galway), but not in St James' Hospital, and in seven private hospitals. Iodine ablation services are available in three public hospitals, two in Dublin (St James' and St Luke's) and one in Cork (University Hospital), but not in any of the private facilities.

The Hollywood report predicts an increase in cancer incidence within the national population of 41 % from 1994 to 2015 partly as a result of population increase and partly from a relative increase in the proportion of elderly within the population. At the time of publication, around 19,000 new cases of cancer were recorded per year in Ireland with around 35-36% receiving radiation therapy at some stage of their illness. On the basis of the predicted rise in cancer incidence, an increase to over 26,750 incidences per year could be envisaged by 2015, which would equate to around 9,400 patients receiving radiation therapy treatment, assuming a 35-36% treatment rate, compared to an estimated 6,650 in 2003. However, the oncology services report notes that the World Health Organisation (WHO) recommends that oncology services should be capable of providing radiation therapy to at least 50% of patients diagnosed with cancer. Should Ireland increase its oncology services to this end[3], approximately double the number of patients could be offered radiation therapy by 2015 compared to those estimated in 2003 (i.e. approximately 13,000 or more cases).

The Expert Working Group report, however, focuses on the use of linear accelerators. The report does not address future nuclear medicine needs and no information is provided on current or future requirements for I-131 treatment. A provisional assessment[4] has therefore been based on discussions held with medical staff and this is outlined in Table 1.

In general the hospital staff interviewed identified an increasing trend in thyroid ablation treatments, but this is in part attributed to better diagnosis and increased referrals for thyroid ablation. Nonetheless, there was agreement that this need would grow further through increases in referrals, general population increase and an overall increase in the population age.

In 2006, across the three existing units 92 thyroid ablation treatments were given (using a total of 435 GBq I-131). Outline estimates by hospital staff suggest that this could rise to somewhere in the region of 150 cases within the next 5 to 10

3 The report documents that there is international consensus that approximately 50-60 per cent of patients will require this form of treatment during their cancer illness.

4 It is important to note (as detailed in Section 2.2) that the location of oncology units is to be decided at a national level and the strategy for this has not, as of yet, been finalised.

years. These staff were, however, unable to provide any estimates beyond this and the values given are solely based on their professional opinion. Nonetheless, this is broadly in line with the 50% estimate for increasing radiation therapy needs, noted above.

It is important to note that the estimates of future thyroid ablations needs determined through this consultation are in part constrained by the existing capacity and facilities within the treatment centres. Care of ablation patients is resource intensive and, for instance, the number of patients treated in some hospitals is limited by the staff and funding available. In other instances, the limitation arises from the fact that a single bed ablation suite cannot normally treat more than 50 patients in one year (i.e. preparation, treatment and cleaning of the unit requires about one week). Therefore without firm data on funding, facility and resource availability in the future, these estimates should only be considered as provisional.

Table 1 Thyroid ablation use and anticipate future requirements

Hospital	Existing Capacity	2006 Data			Anticipated patient numbers in 5 to 10 years
		Max Activity to br handled (GBq/y)	Number of Patients Treated	I-131 Activity Administered (GBq)	
St James' (Dublin)	Single bed ablation suite	138	19	99	25 (limited by current staff resources)
St Luke's (Dublin)	Single bed ablation suite	390	49	247	75 (would require two ablation suites)
Cork University Hospital	Single bed ablation suite	250	24	89	Unknown, but at minimum 25
University Hospital (Galway)*	No facility	N/A	N/A	N/A	<50 per year (based on a 1 bed facility)

*A facility at Galway has been proposed as one of a number of options. See Section 2.2. No facility currently exists at the University Hospital, and assessments undertaken here do not imply that this represents national policy.

2.2 Proposed Centres

In order to address the future needs for radiation treatment, the Hollywood report outlined a strategy for the development of a national oncology service. To meet this recommendation the National Plan for Radiation Oncology (NPRO) has been established. This body will take overall responsibility for the deployment and national coordination of oncology services in Ireland (including those services involving Nuclear Medicine). In this scheme each facility will be managed by the local hospital on behalf of the NPRO.

In the Hollywood report a total of six new centres were proposed: two in the Eastern Region (one (Dublin South) to serve the southern part and one (Dublin North) the northern part); one at Cork University Hospital; and, one at University College Hospital, Galway. These would be supported by satellite centres in southern (Waterford) and western (Limerick) Ireland.

Through consultation with the NPRO it has been determined that, at the most, thyroid ablation would be limited to three supra-regional centres (i.e. Dublin, Galway and Cork). However, it has not yet been decided whether the development of these new centres will be funded through Public-Private Partnerships (PPP) or more traditional government funding routes. It is therefore uncertain at this point whether all three centres will be established and what capacity each could have. The transfer of patients to the City Hospital in Belfast is also under consideration and if this were the case there may only be one centre established in Ireland, which would almost certainly be situated in Dublin[5]. However, no definitive strategy has yet been announced.

2.3 Potential Site Requirements for Thyroid Ablation

Based on the discussion given above it is clear that a detailed site by site assessment of future thyroid ablation needs cannot be given. However, it is reasonable to postulate that supra-regional centres may be established at Dublin, Cork and Galway, or a more limited sub-set of these, potentially restricted to Dublin alone (most likely to be situated at St James' Hospital), which could be supported by the transfer of patients to the City Hospital in Belfast.

Although the assessment is only provisional, it is likely that 150 patients from Ireland may require thyroid ablation treatment per year within the next 5 to 10 years, and this may further increase beyond that. Based on a precautionary approximate estimate of 5 GBq I-131 administration per patient this could represent an annual ablation requirement (assuming that all patients were treated in Southern Ireland) of 750 GBq per year (compared to 435 GBq in 2006).

5 It has been suggested that the current thyroid ablation facilities at St Luke could be relocated to a new facility St James.

3. REVIEW OF IODINE-131 ABLATION WASTE MANAGEMENT

Iodine-131 ablation waste management practices, and underpinning international best practices, are summarised in this chapter. A more detailed description of organisations consulted and data gathered is provided in Appendix 1.

3.1 International Advice on Best Practice

In order to identify current advice on best practice in relation to discharges of patient excreta following hospital administration of I-131 treatment, a review has been undertaken of IAEA, ICRP, EC and NCRP sources. Details of the review and findings in relation to the ICRP and IAEA are provided below. No relevant advice from either the EC or NCRP was identified. However, the EC held an international workshop on this subject in 1999 and an overview of the findings and recommendations is provided (Section 3.3).

3.1.1 International Commission on Radiological Protection (ICRP)

The ICRP policy in relation to discharges from hospitals is based solely on radiological protection, whereby doses should be below dose limits to ensure protection of the public. Draft recommendations for radiological protection in medicine [ICRP, 2007] were published for consultation in January 2007 in which it is noted that I-131 can be detected in the environment following direct discharge of patient excreta to sewer, but no detrimental radiological impacts are measurable as a result. The ICRP now consider that storage of patient’s urine to allow for decay prior to discharge has minimal benefit and doses to sewage workers and members of the public following direct release are determined to be below public dose limits. Therefore it is the position of the ICRP that direct release to modern sewer systems is appropriate.

3.1.2 International Atomic Energy Agency (IAEA)

A comprehensive review of IAEA documents has been undertaken to identify the IAEA position on best practice relating to the management of medical waste. This has involved a review of the IAEA Safety Standards documents (including Safety Fundamentals, Safety Requirements and Safety Guides) and IAEA TECDOCs.

In relation to discharges of radiopharmaceuticals following patient treatment in hospitals this review has found that, in broad terms, a strategy of ‘delay and decay’ has been suggested as the preferred management option for medical waste excreted from patients where radiological risk to members of the public may exist. However, where not warranted on the grounds of radiological protection direct release to sewer is an accepted option.

IAEA Safety Guide WS-G-2.7

Under Safety Guide WS-G-2.7 (IAEA, 2005a), it is recommended that wastes are classified to enable segregation for appropriate predisposal management. In particular, paragraph 4.10 states that ‘*waste containing radionuclides with short half-lives, which can be managed by safe storage until they decay to insignificant levels, should be segregated with priority*’. For small amounts of liquid effluent containing radionuclides, direct discharge to a sewerage system or river may be authorised. Nonetheless, storage for decay, where appropriate, is the preferred management option and is considered suitable for radionuclides with half-lives of 100 days or less. It should be noted that the report does not quantify what the IAEA considers to be ‘small amounts’.

Safety Report Series Number 40

Safety Report Series Number 40 (IAEA, 2005b) notes that some countries require that drainpipes from a nuclear medicine department, and especially from isolation wards for patients undergoing radionuclide therapy, terminate in a delay tank. This is primarily required for waste from therapy patients receiving I-131 treatment that require special radioactive waste precautions. In such instances, the use of delay and decay storage tanks is considered appropriate to minimise the environmental impacts of the release.

IAEA Safety Requirement WS-R-2

Safety Requirement WS-R-2 (IAEA, 2000) applies to the management of radioactive waste generated in medicine. It requires control to be exercised over the discharge of effluents containing radionuclides to ensure dose limits are maintained and optimised in relation to members of the public.

Protection and safety are required to be optimised in relation to the choice of waste management options (including predisposal management options) by taking into account the nature, magnitude and likelihood of exposures in relation to social and economic factors. Safety Requirement WS-R-2 does not specify one type of predisposal management option over another. However, where ‘delay and decay’ is selected as a predisposal management option prior to authorised discharge, it is required that storage is for a sufficiently long period of time to ensure that radionuclides decay below defined activity levels.

IAEA TECDOC-1000

IAEA TECDOC-1000 [IAEA, 1998] states that radionuclides used in hospitals that have relatively short half-lives should, where appropriate ‘*be disposed of following storage to allow for decay to harmless levels*’. Particular note is made of the therapeutic use of I-131 in that:

‘*patients, in general, should occupy specially equipped rooms which should have separated sanitary facilities for collecting the excreta in tanks until the radionuclides have decayed to an appropriate level, after which it may be released for dispersion in the sewer system. Alternatively, on the basis of radiological assessment, excreta may be discharged directly to the sewer if a specific authorisation is given’*[6].

3.2 Review of Approaches Adopted in Europe

In 1999, the EC held a workshop at which the regulatory framework and approaches to management of radioactive waste in medical establishments in European Member States was discussed. A review of the different approaches was published by the EC in the form of Workshop Proceedings [EC, 1999]. This has been updated through consultation with regulators in the Member States and is summarised in Table 2. Detail on the consultation process and responses are provided in Appendix A1.

6 It is noted that collection and decay storage of waste can involve manual operations that could expose hospital staff to radiological and other hazards. However, consideration should also be given to the radiological hazards that sewage workers would be exposed to as a result of direct release and to pathways of exposure to members of the public arising from subsequent release to controlled waters and use of sewage sludge.

The EC workshop described above documents for a number of Member States the approach to the management of radioactive waste, including that of patient excrete from thyroid ablation. In general it discusses that Member States aim to:

- comply with EU Legislation and Standards and with IAEA recommendations; and,
- ensure that worker or public exposure doses are at or around 0.01 mSv a year.

Throughout the European Union, significant volumes of radioactive waste are produced as a result of medical procedures and urine eliminated by treated patients accounts for a non-negligible amount of the liquid waste discharged into sewers. Approaches to handling this waste were found to differ largely between Member States, particularly with regard to treatment with I-131. In some countries, precautions such as collection of the urine from these patients or using buffer tanks in the hospital were taken to comply with authorised levels of liquid discharge. By contrast, other countries did not apply any restrictions on discharges of patient excreta on the basis that there was a negligible radiological risk associated with these.

The difference appears to relate to whether hospital plumbers have been included within the dose assessment. In stances where they are (e.g. Germany), they are generally found to be the most exposed individuals. Limits on activity concentration are therefore applied to effluents that these plumbers may come into contact with[7].

A summary of the different practices throughout the Member States as reported in EC [1999] and updated as a result of consultation responses, is provided in Table 2.

Table 2 Approaches to the management of patient excreta by EC Member States

Country	Management approach		Notes
	Direct discharge	Delay and Decay	
Denmark	✓		In Denmark there is no limit for the total activity that can be discharge (that is controlled by limits for purchase and use). However, Dilution of I-131 discharges to 0.1 MBq/l required at the point where the hospital drain meets the municipal sewer
Finland	✓		Discharge limits from institutions do not apply to patient excreta that may be freely discharged to sewer as long as discharges at any one time do not exceed 100 MBq and that over the course of a year does not exceed 100 GBq.
France		✓	Effluents eliminated by patients in protected rooms (iodine dose > 740 MBq) are normally collected via bi-sectional toilets. Effluents from ordinary sanitary installations in the nuclear medicine unit are usually linked to a septic tank. Due to the length of time the material stays in the septic tank and the brief half-life of the radionuclides, volume activity

7 Please note that we not aware of the dose calculations and assumptions taken when setting this limit.

			in the collector is greatly reduced before release into the sewage network.
Germany		✓	All facilities required to have holding tanks installed and discharges from facilities must remain below a limit of 5 Bq/l at the point of discharge into the public waste water network.
Greece	✓	✓	Direct discharge to sewer allowed, provided that the waste is readily dispersible in water and the maximum concentration of radioactive substances is not greater than 3.7 MBq/l. For I-131 thyroid post-operatory therapy waste decay storage prior to discharge to sewer is required to meet this criterion.
Republic of Ireland	✓	✓	Both direct discharge to sewer and use of holding tanks are currently employed. Hospitals are authorised on activity administered not discharged.
Northern Ireland		✓	Decay storage is used, although not a regulatory requirement. Activity concentration limit of 80 kBq/l prior to discharge to sewer.
Lithuania		✓	Waste is retained in holding tanks for between 30 and 60 days prior to discharge to sewer. Two tanks are used, one being filled as the other is left to decay prior to discharge.
Luxembourg		✓	All new treatment facilities are required to install holding tanks, with patient excreta being held for a minimum of 210 days prior to discharge. Activity concentrations of I-131 in discharges from the holding tanks to sewer should remain below 5 Bq/l.
Spain	✓	✓	Clearance levels are used to determine disposal routes. Where activities are above clearance levels waste should be stored for decay.
Sweden	✓		Free release to sewer the preferred option. Decision based on direct measurements at a large hospital. External radiation exposure to sewer worker of ~2 µSv calculated on basis of 50 GBq I-131per year direct release to sewer.
The Netherlands		✓	Radioactive waste with radionuclides with half-lives below 100 days should be stored for up to 2 years to allow for decay. No specific mention is made of requirements for patient excreta.
Great Britain	✓	✓	Direct discharge to sewer allowed, but sites required to demonstrate BPM and that the critical group dose constraint of 300 µSv y^{-1} is not exceeded. Consideration being given to use of delay tanks for new facilities undertaking treatment of large numbers of patients with I-131.

A more focused discussion on the approaches in the UK and Ireland is given in Sections 3.4 and 3.5.

3.3 Current Practices in Ireland

As stated previously, three hospitals in Ireland currently provide ablation therapy. Their waste management procedures are discussed below.

St Luke's (Dublin)

St Luke's have provided ablation treatment since the 1950s. They have a single ablation suite and in 2006 treated 49 patients (247 GBq I-131 administered). They currently expect to treat 50 or 51 patients in 2007 (i.e. they will be at maximum capacity for a single ablation facility).

They administer between 3 GBq and 7.4 GBq of I-131, depending on the patient's clinical presentation, in the form of NaI-131 and are currently authorised to administer up to 390 GBq per year. This is primarily for thyroid cancer treatment, although a few hundred MBq are also administered for thyrotoxicosis treatment.

Patients are admitted to the unit on a Monday and the ablation administration is given orally on a Tuesday. The patients are then retained in the facility for a minimum of 72 hours, or until the total activity in the body is less than 1 GBq.

Patients are advised to shower twice a day (to minimise transfer of activity to bedding and clothes from sweat), to drink plenty of water (1.5 litres over the fist 2-3 hours following administration and a minimum of 2 litres within the first 24 hours), to empty their bladder regularly (to minimise dose to gonads) and to double flush the toilet each time it is used.

The ablation suite is situated on the ground floor and all facilities in the suite are routed via a dedicated drain to the main hospital foul drain system. The flow through the main hospital drain is estimated to be of the order of 100 m^3/day.

Bedding and towels etc and any solid disposal waste is stored on site in a dedicated facility for 6 weeks prior to washing or disposal.

There are no known plans for further development of facilities on this site, although the unit may be relocated to St James'(see below).

St James' (Dublin)

St James' have provided ablation treatment since 2003. They have a single ablation suite and in 2006 treated 19 patients (99 GBq I-131 administered). They currently expect to treat 20 to 25 patients in 2007 (the limit that can be managed with their current staff resources).

They use a standard administration of 3.7 GBq of I-131 in the form of NaI-131, with higher activities administered for specific indications, and are currently authorised to administer up to 141.5 GBq per year. This is primarily for thyroid cancer treatment.

Patients are admitted to the unit on a Sunday and the ablation administration is given orally on a Monday. The patients are then retained in the facility for about 4 days, or until the total activity in the body is less than 600 MBq.

Patients are advised to shower twice a day (to minimise transfer of activity to bedding and clothes from sweat), to drink plenty of water (they are advised to drink a minimum of 2 litres per day), to empty their bladder regularly (to minimise dose to gonads) and to double flush the toilet each time it is used.

The ablation suite is situated on the second floor and all facilities in the suite are routed via a dedicated drain to the main hospital foul drain system. The flow through the main hospital drain is estimated to be of the order of 500 m^3/day.

Bedding and towels (and patient clothes if they wish) are washed in a dedicated washing machine in the ablation suite. They are then monitored and if activity is at background (10-20 cps) released to the general hospital laundry service. If not, they are stored to allow decay. Any other solid disposal waste is stored on site in a dedicated facility for 6 weeks until activity has reached background prior to disposal.

It has been suggested that a supra-regional oncology centre could be established at St James' through the relocation of the St Luke's facilities. Although development plans have not been finalised it was suggested that the combined hospital facility may host three ablation suites. The future waste management arrangements for such an ablation suite have not been defined.

Cork University Hospital

Cork University Hospital is authorised to administer up to 250 GBq of I-131 per year. The hospital has provided ablation treatments since 1979/1980. They have a single ablation suite and in 2006 treated 24 patients (89 GBq I-131 administered). The hospital also treated 168 patients for thyrotoxicosis in 2006 (62 GBq administered). They expect to treat about 25 thyroid ablation patients and about 150 thyrotoxicosis patients in 2007.

They use a standard administration of 3.7 GBq of I-131 in the form of NaI-131 for thyroid ablation patients and 370 MBq for thyrotoxicosis treatment.

Patients are admitted to the unit on a Monday and the ablation administration is given orally on a Tuesday. The patients are then retained in the facility for 6 days.

Patients are advised to shower twice a day (to minimise transfer of activity to bedding and clothes from sweat), to drink plenty of water (they are advised to drink a minimum of 2 litres per day), to empty their bladder regularly (to minimise dose to gonads) and to double flush the toilet each time it is used.

The ablation suite is situated on the ground floor and discharges from the toilet in the suite are routed via a dedicated drain (with a single man-hole interception chamber) to a below ground storage tank. The tank has a capacity of 1000 litres, sufficient to hold liquid waste arising from 2 to 4 weeks of ablation treatment (depending upon water use by each patient). Once the tank is full, the effluent is held as long as possible prior to the next ablation treatment, at which time it will be emptied through a valve system to the main hospital foul drain system. The flow through the main hospital drain is estimated to be of the order of 400 m^3/day. The holding time once the tank is full will depend upon the schedule of ablation administrations. In some instances this could be a number of weeks, but in others it may have to be emptied immediately. The hospital was not able to provide records of the schedule of administration or of emptying the tank, therefore calculation of the average holding time of effluent in the tank was not possible. However, if the tank is emptied after three ablation treatments are given and a total of 24 ablations per year are made, it is not unreasonable to assume that, on average, it is emptied approximately every 6 to 7 weeks (the mean storage time for effluent would be half this, about 23 days, i.e. of the order of three half-lives of I-131).

The site has experienced problems with pipe blockage and sewage effluent back-up into the ablation suite and also overflow from the man-hole to surrounding ground (discussed more fully in Section 5.1.3). These problems have now been addressed through construction of the interception chamber and discharges from washing facilities are routed direct to the main foul sewer. The interception chamber provides an overflow system to route effluent direct to the main sewer in case of a blockage in the pipes leading to the tank inlet or in the tank itself.

Bedding and towels etc and any other solid waste is stored on site in a dedicated facility until activity has reached background (10-20 cps) prior to washing or disposal.

There are no known plans for further development of facilities on this site.

University Hospital (Galway)

Galway University Hospital do not currently provide ablation treatment. However, they anticipate that if a supra-regional centre is established at the hospital that it would have a single bed ablation suite. Scoping calculations to estimate the volume of a holding tank required are being made on hypothetical waste water generation rates and if required a two tank system to provide in-situ decay, as well as redundancy may be considered. However, no detailed review or feasibility study of potential designs has yet been completed and the hospital is awaiting guidance from the RPII as to national requirements before they finalise their waste management strategy.

3.4 Approach in Great Britain and Northern Ireland

3.4.1 Great Britain

Throughout Great Britain there are over 100 medical facilities involved in I-131 radiation therapy with discharges of I-131 from treatment facilities ranging from 1 GBq to 668 GBq per year and authorisations up to 1000 GBq per year exist. Only one facility currently has routinely used delay and decay tanks (University College London, UCL Hospital).

The UCL Hospital has now put in a by-pass pipe for their ablation suites so that the waste can be fed directly to the sewers, thus avoiding the holding tanks. This decision was made, and agreed to by the Environment Agency, following a BPM assessment that indicated that, at the current level of use, direct feed to the sewers was the most appropriate disposal method. This change of practice was implemented as the doses to maintenance workers was greater than that to the critical workers at the sewerage treatment plant. At the maximum workload (i.e. all 10 suites in operation) the dose to maintenance personnel who carried out routine preventative maintenance on the tanks (excluding incidents such as blockages) gives rise to a dose of 600 – 1000 µSv/yr whereas for the same workload the dose to the critical worker at the sewage plant is approx 200 µSv/yr.

The need for delay and decay tanks for the storage of patient excreta prior to discharge to sewer is currently determined on a case by case basis with Best Practical Means (BPM) being used to determine site requirements. In conducting the BPM options assessment, it is required that public dose is minimised, but not at the expense of excessive doses to workers and provided that the costs of applying BPM are not grossly disproportionate to the benefits derived from the process.[8]

8 Note that BPM (and the associated 'Best Practicable Environmental Option' method) is a uniquely British approach to optimisation. In general the EU applies 'Best Available Technique', broadly defined as 'the most effective and advanced stage in the development of activities and their methods of operation which indicates the practicable suitability of particular techniques for providing the basis for emission limit values designed to

The replacement of this approach with that of BAT is currently under consideration, but the status of any legislative revision is unknown.

3.4.2 Northern Ireland

Two hospitals in Northern Ireland (the Royal Hospital and the City Hospital, both in Belfast) offer thyroid ablation treatment.

Within Northern Ireland the practice of delay and decay is standard, however, it should be noted that this practice was recommended by the Chief Medical Officer and is not a regulatory requirement in itself.

The Royal Hospital decay stores urine in containers while delay and decay tanks have been installed at the City Hospital concurrently with the development of a new facility and three unit ablation suite. These units discharge under vacuum to a 4 tank system (one tank is maintained as back-up). Each tank has a volume of 4,000 litres. Tank 1 one is filled for 30 days before the next tank starts. Tank 1 is allowed to decay until day 88 when one third of the tank is checked and released to sewer. The tank is refilled with water and on day 89 another 1/3 of the tank is released to sewer and refilled with water. On day 90 the entire tank is released to sewer and then flushed with water and released to sewer. Effluent will therefore be held for between 58 and 88 days (a mean retention time of 73 days, i.e. about 9 half-lifes, or a factor of 500 reduction).

The regulatory view in Northern Ireland is that delay tanks are BAT, particularly where they employ vacuum technology and therefore for any new installation or substantial refurbishment they would expect to see holding tanks installed.

prevent, and where that is not practicable, generally to reduce the emissions and the impact on the environment as a whole'. BPM and BAT are not synonymous. Nonetheless, they both tackle the same issue in similar ways, seeking to introduce the best approach commensurate with not incurring grossly disproportionate costs to achieve benefits. It is likely that over the next few years Britain will move away from the BPM approach and adopt the more mainstream BAT terminology.

4. RADIOLOGICAL RISK ASSESSMENT

The possible radiological exposure of workers and other members of the public associated with the management of I-131 ablation waste is summarised in this chapter. A more detailed discussion on the assessment approach and results is given in Appendix A2.

4.1 Assessment Methodology

The assessment methodology is based on an approach originally developed by the Environment Agency of England and Wales [Mitchell, 2002] which has been subsequently updated by Enviros taking into account data presented by NRPB [McDonnell 2004]. This considers the exposure of candidate (hypothetical) critical groups (CCGs) which depends on the:

- activity discharged to sewer from a site;
- extent of dilution of activity in the sewer;
- extent of dilution of activity in sewage effluent in a receiving watercourse;
- fate of dewatered sewage solids; and,
- CCG specific exposure pathways and rates.

It is important to note that the rate of I-131 decay (half-life of ~8 days) is such that the potential exposure of members of the public from sewage sludge application to land is negligible. Terrestrial exposure pathways have not therefore been considered further. Equally, an initial estimate of occupational exposure around decay tanks was undertaken and the annual dose found to be in the order of nanosieverts per year. Accordingly, external exposure of hospital workers in the vicinity of shield tanks has not been considered further[9].

This assessment focuses on radiological exposure of plumbers, sewage workers and other members of the public who may be exposed via direct contact with sewage materials or via aquatic pathways following sewage discharge to receiving waters.

Details of the sewage works servicing each current or anticipated thyroid ablation hospital in the Republic of Ireland are given in Table 3.

In each instance treated sewage effluent is discharged to sea and sewage solids applied to agricultural land. Other relevant assumptions and supporting data applied in the dose assessment are provided in Appendix A2.

9 The holding tank facility at the City Hospital in Belfast is heavily shielded and there is no measurable elevation in exposure of workers from I-131 in the tanks.

Table 3 Sewerage works servicing hospital oncology suites in the Republic of Ireland

Hospital	City	Sewage Works	Population serviced	Mean sewage Flow Rate (m^3/day)	Point of Effluent Discharge
St James	Dublin	Ringsend	1.9 million	400,000	Long sea outfall Dublin Bay
St Luke's	Dublin	Ringsend	1.9 million	400,000	Long sea outfall Dublin Bay
University Hospital	Galway	Mutton Island	115,000	47,000	Long sea (1 km offshore) outfall Galway Bay
University Hospital	Cork	Little Island	413,000	59,500	Long sea outfall to the outer mouth of the River Lee Estuary

The Environment Agency methodology considers internal and external exposure via a range of pathways for a number of CCGs[10]. Using these data and additional information presented by NRPB [McDonnell 2004] for each actual, or potential, oncology unit, exposure of the following candidate critical groups were considered:

- hospital plumbers;
- sewer workers;
- sewage treatment workers; and,
- coastal fishermen and their families.

For plumbers, sewer and sewage workers, only adults were considered. For the coastal fishermen, other family members (e.g. children and infants) who may consume fish caught, were considered. A summary of exposure pathways considered for each critical group is provided in Table 4.

10 Potential exposure pathways associated with discharges to river have not been considered as all sewage works considered discharge to sea.

Table 4 Candidate Critical Groups and Exposure Pathways

Candidate Critical Group	Inadvertent ingestion of sludge/soil	Inadvertent inhalation of sludge/soil	Time spent next to blocked pipe	Time spent in man accessible pipes	Occupancy at STW	Fish consumption	Crustacean consumption	Mollusc consumption	Handling of nets / sediment	Inadvertent ingestion of water	Inadvertent ingestion of sediment	Time spent over sediment
Hospital plumber			✓									
Sewer worker	✓	✓		✓								
STW worker	✓	✓			✓							
Coastal Fishing Family - Adult						✓	✓	✓	✓	✓	✓	✓
Coastal Fishing Family - Child						✓	✓	✓		✓	✓	✓
Coastal Fishing Family - Infant						✓				✓	✓	✓

4.2 Dose Assessment Results

4.2.1 Dose per Unit Administration

For each hospital the dose to sewer worker, sewage treatment workers and fishermen and their families have been calculated based on activity administered (normalised to 100 GBq y^{-1}) using the method discussed above. This approach assumes that 80% of activity administered is discharged to sewer. For Cork hospital it also assumes that sewage effluent is held on average for 3.5 weeks[11] (i.e. 3 half-lives) prior to release to sewer. These dose per unit administration (100 GBq y^{-1}) values are given in Table 5.

Table 5 Dose per unit administration

Oncology Unit	Dose (μSv y^{-1}) per annual unit administration (100 GBq)				
	Sewer worker	Sewage Treatment workers	Coastal Fisherman		
			Infant	Child	Adult
St James	1.05	0.07	0.01	0.03	0.13
St Luke's	1.05	0.07	0.01	0.03	0.13
Cork	0.13	0.06	0.001	0.004	0.016
Galway	1.05	0.73	0.01	0.03	0.13

The higher dose to the sewage treatment worker at Galway arises because of the lower flow rate through the sewage works. The lower doses at Cork arise because of the loss of activity during storage in the holding tank.

11 This would be consistent with the assumption that on average the tank is emptied every 6 to 7 weeks.

4.2.2 Dose based on Current and Future Use

The dose per unit administration values given in Table 5 have been combined with current and anticipated future requirements (summarised in Table 6) and the results given in Figures 1 and 2[12].

Table 6 Current and anticipated future administrations of I-131

Hospital	I-131 administration (GBq/y)			
	Activity per Administration (GBq)	2006 Administration	Anticipated future requirement	Current authorised limit
St Luke's, Dublin	3 – 7.4	247	378	390
St James, Dublin	5.5[13]	99	138	138
Cork University Hospital	3.7	89	93[14]	250
University Hospital, Galway	N/A	0	250	0
Total		435	859	778

In addition to the candidate critical groups given in Table 5 a further critical group, hospital plumbers has been considered. In this instance their exposure will tend to be governed by the activity administered at any one time (i.e. how much activity could be retained in a pipe following a blockage), rather than the amount administered over the course of a year. The dose per unit (1 GBq) administered for a plumber unblocking a pipe has been conservatively calculated as 11.4. µSv per 1 GBq administered.

Figure 1 shows that based on current discharges, the potentially most exposed group are hospital plumbers who may be called to fix a blocked pipe exiting the ablation suite.

For these individuals, their exposure arises from a 'one-off' exposure event (i.e. a single blockage) and as such is controlled by the activity given in a single administration (rather than the total activity administered through a year). Based on this scenario their exposure could be of the order of 50 to 70 µSv per event. As noted previously this is based on highly pessimistic assumptions and through the use of appropriate work control systems should be avoidable.

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12 It is important to note that the current authorised limits for I-131 administration at the existing thyroid ablation suites are sufficient to accommodate anticipated future medical treatment requirements (the University Hospital Galway does not currently provide thyroid ablation and therefore has no authorisation limit).

13 In September 2008 the RPA to St James advised that the standard activity administered is now 3.7 GBq, with higher activities only being used for specific indications.

14 Since the report was completed the Chief Physicist for Cork University Hospital has advised that a more realistic estimate of anticipated future requirements should be based upon the increases given for St Luke's/St James Hospitals. This figure is likely to be approximately 140 GBq.

The corresponding dose to sewage workers in the Dublin area is assessed to be less than 4 µSv y^{-1} and that to any member of a fishing family 0.4 µSv y^{-1} or below. The dose to corresponding CCGs at Cork is about an order of magnitude less due to the loss of activity during storage.

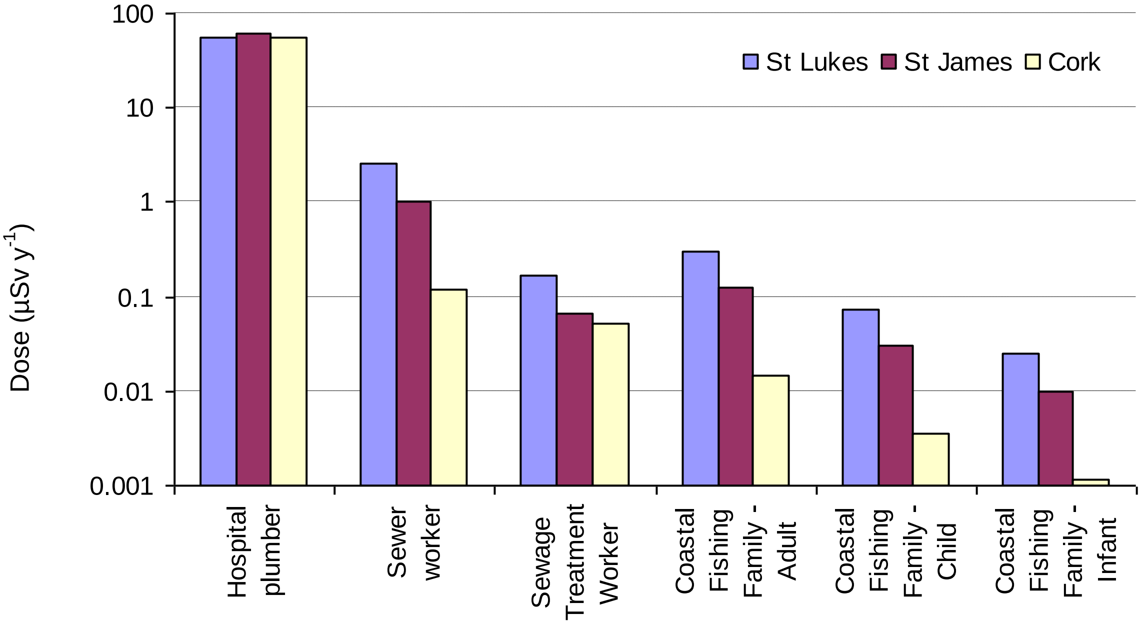

Figure 1 Annual dose from hospitals at current authorised discharge limits

Figure 2 shows that, based on anticipated future administrations, the potential most exposed group are again hospital plumbers.

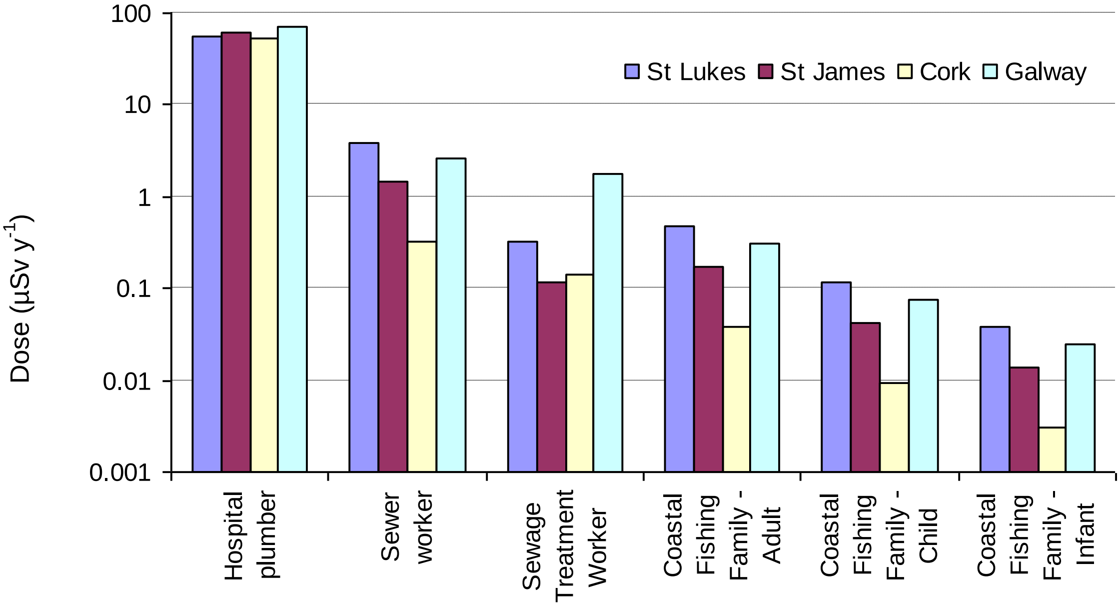

Figure 2 Annual dose from hospitals at anticipated future administration requirements

As hospital plumber exposure depends upon activity administered their exposure remains the same. The predicted dose to sewer works in the Dublin area is of the order of 6 µSv y^{-1} and that to any member of a fishing family 0.4 µSv y^{-1} or below. The dose to corresponding CCGs at Cork is about an order of magnitude less due to the loss of activity during storage. Although potential discharges from a site a Galway could be of the order of 250 GBq y^{-1}, doses to all CCGs with the exception of plumbers is low (<10 µSv y^{-1}).

4.3 Summary of Critical Group Dose

For each hospital the most exposed group is that of the hospital plumber receiving a dose of between 50 to 70 µSv per incident of which we have assumed that there is one per year. It is important to note that although some plumbing problems have been encountered at Cork more stringent control measures have been put in place to prevent any future exposure. It is also important to note that estimates of the exposure of the plumber at Cork was between 3 and 10 µSv, the numbers presented here are therefore likely to be conservative.

The next most exposed member of the public, a sewer worker, currently receives a dose of less than 4 µSv y^{-1}. Whilst this increases with future increased demand the dose remains below 6 µSv y^{-1}. Doses to all other members are below 1 µSv y^{-1} and remains so under future demand scenarios.

The University Hospital Galway does not currently treat patients and as such does not have an authorised limit for I-131 administrations. The most exposed group in the future for University Hospital Galway, should they start to provide ablation therapy, is the hospital plumber who could potentially receive a dose of 71 µSv y^{-1} (based on a typical administration of 250 GBq y^{-1}). The next most exposed member of the public was calculated to receive a dose of less than 3 µSv y^{-1} as a result of future predicted administrations.

5. ASSESSMENT OF BEST PRACTICE

A number of options exist for the disposal of patient excreta following thyroid ablation. The relative merits and potential issues associated with different options are detailed in the following sections.

5.1 Ablation Waste Management Options

Ablation waste management options included direct discharge to sewer and various methods for delay and decay. Due to the relatively short half-life of I-131 (~8 days) a significant reduction in activity can be achieved through storage:

- Factor of 10 reduction in activity though 26 days storage;
- Factor of 100 reduction in activity through 53 days storage;
- Factor of 500 reduction in activity through 72 days storage; and,
- Factor of 1000 reduction in activity through 80 days storage.

5.1.1 Direct Discharge to Sewer

Ablation suite facilities can discharge directly to sewer. In this instance the outflow from the toilet and, in some instances, washing facilities are routed from the suite direct to the main hospital foul drain. In these instances the suites tend to be located so that the distance to the main drain is minimised and that the routing of the pipes is exterior to the building. Direct discharge to sewer remains the predominant method of disposal of ablation waste in Great Britain and is used by two out of the three hospitals in Ireland which currently have ablation suites.

5.1.2 Collection in containers

The container storage method of I-131 decay involves the collection of urine in plastic containers by patients. These are then transported by hospital workers to a dedicated storage area to allow for decay prior to disposal. This process is used by one hospital in Northern Ireland.

5.1.3 Holding tanks

The use of holding tanks removes the requirement on patients and hospital staff to collect and transport urine to dedicated storage areas. Tanks are fed by pipes direct from dedicated toilets within ablation suites. In some instances, split toilets may be employed to enable urine to be segregated and transported separately to the holding tanks for decay prior to discharge. Tank capacity can be optimised to the anticipated number of patients to be treated to ensure that storage can occur for an appropriate time prior to discharge. Two tanks are often employed so that as one tank fills, the other can be left to decay, being emptied as the first tank reaches capacity. In some instances an additional back-up tank will be maintained empty as a contingency measure. In instances where there isn't a contingency tank the option to redirect sewage inflow from the holding tanks direct to sewer typically exists.

Two types of collection system have been identified; gravity and vacuum fed. These are briefly discussed below.

Gravity fed collection systems

Gravity fed systems rely on the flow of water and urine from toilets direct to holding tanks via dedicated pipes. The flow rate and thus dose implications will vary depending upon the flow rate and routing of pipe work throughout the treatment facility. The flushing action of toilets serves to provide initial dilution of urine; however, this also results in a greater volume of effluent entering the holding tanks thus resulting in a greater capacity requirement (or a reduction in the potential holding time). A single tank gravity fed system is used by Cork University Hospital.

Vacuum collection systems

Vacuum collection systems operate under vacuum and therefore water volume requirements for flushing can be minimised. Although this minimises dilution in pipes the rapid transport of waste from the ablation suite to the holding tanks due to the vacuum pressure reduces exposure during transport within pipe work. This approach is similar to that in the City Hospital Belfast.

5.2 Radiological Protection and Determination of Best Practice

As outlined in Chapter 3 there is no consistent approach to the regulation of radioactive discharges to sewer across the European Member States. The IAEA have indicated a preference for delay and decay storage, but equally state that where dose implications are negligible direct discharge to sewer is acceptable [15]. More critical the most recent view of the ICRP in their draft 2007 recommendations is that for I-131, delay storage is not typically justified on the grounds of radiological protection.

Overall, it is considered that risk based regulation is consistent with IAEA and ICRP recommendations and is also consistent with the approach taken in Great Britain and Northern Island. This does not exclude the requirement for delay and decay, but instead requires, on a site by site basis, that the benefits and disbenefits of the proposed management options are considered and that the best practicable means (BPM) or Best Available Technique (BAT) is determined and applied.

Such an approach is not inconsistent with that already in place in Ireland where individual sites have submitted risk assessments and where limits for activity levels administered exist. However, it is important to stress that within the UK sites are regulated based on what is discharged, rather than what is administered. This places a requirement on operators to monitor, assess and report discharges. In a limited number of cases it also requires the operator to demonstrate (through environmental monitoring) that radiological risks to members of the public are below the level of regulatory concern.

Within Great Britain and Northern Ireland the concept of BPM is underpinned by the statutory requirement placed on the environment protection agencies to ensure that exposures of members of the public and the population as a whole resulting from the disposal of radioactive waste are kept 'as low as reasonably achievable'

15 There is no definition of negligible, but the IAEA Basic Safety Standards imply that doses less than 10 µSv per year can be regarded as below concern. In the UK this would also be 'subject to demonstration that BPM is being applied'. Whilst BPM terminology may be superseded, the general sentiment is likely to remain applicable.

(ALARA). ALARA stems from the three ICRP'60 basic principles of (i) justification of a practice, (ii) optimisation of protection, and (iii) individual dose and risk limits[16].

BPM is currently the process through which the ALARA requirements for radioactive wastes are satisfied. Consequently the respective agencies for England and Wales (Environment Agency), Scotland (Scottish Environment Protection Agency, SEPA) and Northern Island (Environment and Heritage Service, E&HS) require operators to apply BPM so as to minimise the volumes and activities of radioactive wastes that are generated and have to be discharged to the environment, and to reduce the impacts of waste management on people and the environment.

As a matter of principle, these agencies do not define a lower threshold of dose or environmental contamination below which BPM does not apply. Operators are thus required to minimise discharges to the point to which it would not be sensible to reduce them any further. What is 'sensible' is considered through the assessment, on a site specific basis, of factors such as cost-effectiveness, technological status, operational safety and social and environmental factors. This concept, referred to as proportionality, is thus fundamental to the assessment of what constitutes BPM. Within Great Britain and Northern Island the agencies apply this concept by ensuring that operators do not expend effort, whether in time, trouble or money, that would be grossly disproportionate to the resulting benefits (e.g. reduction in discharges, environmental protection, reduction in radiological dose etc). Put simply, BPM requires site operators to ensure that the measures in place to manage radioactive wastes are not unreasonably costly.

Balancing costs against environmental benefits within the BPM process typical considers the following attributes:

- considerations of risk and exposure;
- environmental considerations;
- technological considerations;
- health and safety considerations; and,
- cost effectiveness.

These criteria are considered, on a site by site basis in the following section.

Although the approach in different Member States can vary, doses that are at, or broadly around, 10 µSv are generally considered to not require further reduction unless it is clear that BPM/BAT is not being applied. Any reasonable interpretation also seems to lose the 'gross disproportionality' criterion at this point and BPM/BAT should be viewed within reasonable or proportionate cost benefit bounds.

16 As noted previously, the 'Best Available Technique' principle is broadly similar and likewise underpins the optimisation of dose reduction, particularly at low doses where costs should be proportionate to benefits. At higher doses the concept of costs not being 'grossly disproportionate' to benefits is more widely applied. Although not defined, the application of a 10 µSv y^{-1} criterion to define 'low' doses would be broadly in line with practice throughout many of the EU Member States.

5.3 Assessment Criteria

5.3.1 Reduction in Radiological Exposure

As noted previously the dose implications of I-131 discharges direct to sewer, under current and anticipated future needs are very low (< 6 µSv y^{-1}) for all CCG considered with the exception of hospital plumbers (ca. 50-70 µSv per incident). In the latter case it may be reasonable to assume that any such dose is reasonably avoidable based on the appropriate management of facilities support workers. Nonetheless, as noted earlier in this report, inadvertent exposure of plumbers has occurred (although the exposure levels were still very low, < 10 µSv).

Decay storage would lead to a reduction in activity discharged and hence public exposure of between a factor of 10 to 1000 for mean storage periods up to approximately 80 days. Although the storage time will depend upon the balance between tank volume and rate of foul water arising, it has been assumed that in general, vacuum systems reduce the requirement for toilet flush water and hence for any particular tank volume will allow greater storage times.

The public dose associated with the different management options possible are summarised in Table 7.

Table 7 Public exposure under different management options

Disposal method	Comments
Direct discharge to sewer	Doses to members of the public (other than hospital plumbers) are very low, typically less than 6 µSv y^{-1}.
Collection in Containers	Reduced further (by a factor of 100 to 1000 depending upon storage time).
Gravity fed tanks	Reduced further (by a factor of 10 to 100 depending upon storage time).
Vacuum pumped tanks	Reduced further (by a factor of 100 to 1000 depending upon storage time).

5.3.2 Reduction in Environmental Impact

Activity concentrations of I-131 are detectable in the marine environment around Ireland. Although measured levels are not believed to have any impact on the environment, any process that leads to their reduction may be considered to comply with the Republic of Irelands commitment to the OSPAR agreement. The implications for delay and decay storage on these are detailed in Table 8.

Table 8 Environmental concentrations under different management options

Disposal method	Comments
Direct discharge to sewer	Environmental concentrations low (although measurable).
Collection in Containers	Reduced by a factor of 100 to 1000 depending upon storage time.
Gravity fed tanks	Reduced by a factor of 10 to 100 depending upon storage time.
Vacuum pumped tanks	Reduced by a factor of between 100 and 1000 depending upon storage time.

5.3.3 Technological Feasibility Impact

The technological feasibilities for each option are variable and are discussed in Table 9.

Table 9 Technological considerations for different management options

Disposal method	Comments
Direct discharge to sewer	Minimal technological requirement requiring only a dedicated outflow from the ablation suite to the main hospital sewer.
Collection in Containers	No technological requirement – containers are man-handled and securely stored prior to discharge via an uncontrolled disposal point to sewer after activity has decayed
Gravity fed tanks	Requires appropriate positioning of tanks in relatively close proximity to the ablation suite. Inflows into tanks may become blocked. Tanks may have to be periodically flushed through to prevent sewage solid accumulation.
Vacuum pumped tanks	Requires a sophisticated pump and tank control system, but the vacuum technology is well established. Water use is minimised, narrow gauge pipe work can be used and routed through a building and the rapid transport of material along the pipes minimises any external exposure and potential for blockages.

5.3.4 Heath and Safety Impact

The health and safety considerations for hospital staff associated with each option are described in Table 10.

Table 10 Health and safety considerations for different management options.

Disposal method	Comments
Direct discharge to sewer	Health and safety to hospital workers is negligible as there is limited potential for pipe blockage and plumber exposure.
Collection in Containers	Plastic containers of urine will have to be handled and transported by patients and staff. This could potentially lead to elevated worker exposure. There is a real possibility of spillage.
Gravity fed tanks	Instances of pipe blockage, sewage back-up and over spill onto land have been identified with potentially both radiological and microbiological implications for worker health and safety.
Vacuum pumped tanks	It is probably that vacuum systems are less likely to block (because of the negative pressure). There is therefore limited potential for pipe blockage and plumber exposure. The transport time of sewage effluents through the pipes is so rapid that there are also no external exposure implications for hospital staff.

5.3.5 Capital and Maintenance Costs

Retrofitting of 5 below ground storage tanks at the University Colleague London hospital in the UK incurred a capital cost of 750,000 Euros [Nuttall & Griffiths, 2006] while that at City Hospital in Belfast installation of 4 basement tanks during the development of a new facility was of the order of 750,000 Euros.

Without detailed specifications of what is required it is not possible to provide defined costs. However, it is clear that installation of tanks within a new facility is of the order of several 100,000 Euros. Retrofitting costs may be well in excess of this, particularly if the ablation suite has to be relocated (based on discussion with hospital staff this could in itself incur an additional cost of 100,000 Euros).

Although a detailed assessment of costs have not been undertaken it is believed that a vacuum tank system would not be significantly more expensive than a gravity fed one when the overall costs are considered.

Typically maintenance costs are minor compared to the capital expenditure incurred. Nonetheless each hospital consulted with, which currently discharges to sewer, expressed concern over availability of funding for the retrofitting of holding tanks. They anticipated that any capital expenditure requirement in excess of 100,000 to 200,000 Euros would significantly affect the financial viability of the service and could lead to closure of the ablation unit.

5.3.6 Other Impacts

Based on discussions with the existing ablation treatment providers in Ireland, the following potential issues associated with the retrofitting of tanks were identified.

Availability of space for retrofitting of tanks, or increasing tank capacity was considered extremely limiting or unavailable. Depending upon the location of the current ablation suite the requirement for holding tanks could incur the need to relocate the suite to a different site within the hospital complex (or to at least install a more extensive drainage system suitable for carrying high I-131 activity effluent). The potential to relocate the ablation suite was considered to be neither financially or logistically possible.

Concern was also raised as to potential public and worker perception of storage of waste from the ablation suite, particularly by local residents (especially if a planning application was needed for retrofitting of tanks) or by maintenance or other facilities management staff who may be non-radiological workers. In all instances it was acknowledged that the potential dose implications are negligible, but that this does not necessarily mitigate against adverse worker/public reaction, particularly when workers are highly unionised.

5.4 Assessment Summary and Conclusions

Based on the information given in the previous section the results have been summarised in Table 11.

Table 11 Summary of Ablation Waste Management Implications

Assessment Criteria	Direct discharge	Container storage	Gravity fed tank	Vacuum Tank
Reduction in Radiological Exposure	Negligible	High	Moderate	High
Reduction in Environmental Impact	Negligible	Negligible	Negligible	Negligible
Technological Feasibility Impact	Negligible	Negligible	Moderate	Moderate
Health and Safety Impact	Negligible	High	Moderate	Negligible
Capital & Maintenance Cost Impacts	Negligible	Negligible	High	High
Other Impacts	Negligible	Negligible	High	High

Overall it can be concluded that under the scenarios considered:

- Direct discharge to sewer does not lead to any significant exposure, has no additional cost burden or other identifiable disbenefits. Hospital plumbers may receive elevated exposure, but blockages are unlikely and this exposure could be fully managed.

- Container storage is another low cost option. Although dose to a hospital plumber is significantly reduced (because activity in the urine is allowed to decay before disposal) other workers could also accrue additional exposure (e.g. following spillage). Although decay storage will significantly reduce activity discharged to sewer it is questionable whether this has any real benefit for other members of the public or the environment under the scenarios considered.

- Gravity fed tank storage is a potentially high cost option and could lead to the elevated chance of pipe blockage, through inappropriate disposal of materials down the toilet, and plumber exposure. Although there are no technological issues associated with this, other factors such as space, particularly close to the ablation suite, may be limiting in instances where retrofitting of tanks could be considered. For new facility construction these are likely to be less of an issue.

- Although the application of vacuum technology to delay and decay tanks is relatively new, the technology itself is mature and well tested. Sewage, under negative pressure is transport rapidly from the ablation suite to the tanks minimising potential for blockage or other exposure routes on route. There is therefore less potential for plumber exposure. A vacuum system such as this also means that tanks and suite do not need to be located in close proximity. Nonetheless, new build costs are of the order of several 100,000 Euros and retrofitting could be more costly. Although there is clearly a dose saving for a plumber, the exposure to other members of the public is low and hence the value of reducing it further may not be considered as practicable.

The discussion above is based on the scenario that there is a modest increase in ablation treatment at the existing facilities and that one new facility is commissioned. It would seem reasonable to suggest that the advantages offered by vacuum tanks means that they almost certainly represent best available technology (BAT[17]). However, is their cost justifiable?

It is important to note that the UK regulators assume that BPM and BAT are broadly similar[18], both aiming to ensure that a logical and transparent approach to the identification and selecting of processes, operations and management systems with the objective to reduce discharges is achieved.

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17 The IPPC Directive defines BAT as follows: “best available techniques” shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole. ‘Techniques’ shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned, ‘Available’ techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator. ‘Best’ shall mean most effective in achieving a high general level of protection of the environment as a whole.

18 In fact, UK guidance suggests that BPM, plus BPEO, in conjunction with discharge authorisations or other statutory limitations, can be taken to be synonymous with BAT.

Although the UK regulators do not define a lower limit at which BPM (and therefore BAT) is applicable, they do as discussed in Section 5.2 clearly advise that the controls emplaced should not be grossly disproportionate to the time effort and cost entailed.

For the existing facilities that discharge direct to sewer it is hard to find justifiable reasons for the retrofitting of tanks (whether these be gravity fed or vacuum). Particularly as the consultation with hospital staff indicated that if the costs were significant, then it might call into question the justification for continuing to provide the service

Clearly an increase in the number of ablation treatments provided is likely. It is important to note that the increases anticipated could be accommodated within the existing authorised limits. However, to what extent these estimates are biased by the existing capacities of the suites (compared to a true estimate of future needs at a national level) is uncertain.

The potential for new facility development is a clear possibility as is the centralisation of treatment facilities. The implications of this and our final recommendations are given in the following chapter.

6. RECOMMENDED APPROACH FOR ABLATION WASTE MANAGEMENT

A number of potential scenarios for the future use of nuclear medicine in Ireland exist. Although it is possible that existing facilities may continue to be used, the Government commitment to the development of oncology services is clear and it is therefore probable that one, or a number of new facilities, will be developed forming supra-regional centres. Under one extreme scenario all ablation treatment could be concentrated at one new facility in Dublin.

If all discharges were focused on one sewage works then clearly there would be an increased exposure of sewage workers. However, based on the existing anticipation of future needs, this exposure would still be low (< 10 µSv y^{-1}). There would also be an increase in exposure for other members of the public, but again doses would still be very low (< 1 µSv y^{-1}). Nonetheless, current estimates of future needs may be low and higher doses could be incurred.

Monitoring of radioactivity in the marine environment around Ireland has been reported [RPII, 2007]. This shows activity concentrations of I-131 in seaweed in the Dublin Bay area of ca. 100 Bq kg^{-1} (dry weight). In other coastal locations activity concentrations of the order of 3 to 4 Bq kg^{-1} (dry weight) is found. Based on these it can be assumed that if:

- I-131 administration within hospitals in Dublin increased in line with expectations, but there was no transfer of patients from other areas and discharges were made direct to sewer, environmental activity concentrations would increase and that in seaweed could increase to ca. 150 Bq kg^{-1} (dry weight);

- Dublin becomes the single national centre for thyroid ablation in the Republic of Ireland and discharges were made direct to sewer, environmental activity concentrations would increase and that in seaweed could increase to ca. 250 Bq kg^{-1} (dry weight);

- Decay storage of around 50 days or greater was introduced activity concentrations in the environment would be significantly reduced. Those in seaweed would be of the order of 2 to 3 Bq kg^{-1} (dry weight) even under the scenario where a single national facility is located in Dublin.

In the assessment presented in the previous chapter the hospital plumber was identified as the critical group potentially receiving 50-70 µSv per incident. It is important to note that this assessment assumes a one-off incident resulting in exposure to sewage effluent from one patient. A large supra-regional facility could have three ablation suites. A blockage could therefore result in the accumulation of excreta from more than one patient which could result in increased exposure of the plumber to a dose of the order of 100 to 200 µSv.

The cost of installing holding tanks at the city Hospital in Belfast was less than 1% of the overall facility development cost. Clearly where new facilities are being developed the funding and other logistic issues associated with retrofitting a tank do not apply. Therefore the argument that such an action is grossly disproportionate is much more difficult to apply.

Similar logic to that given above is being applied within the UK and countries such as Luxemburg where installation of delay and decay tanks is being considered for new facilities. It is interesting to note that in Northern Ireland vacuum tank systems are considered as BAT. This is not based on the argument of dose saving solely for sewer or sewage treatments works, but also minimisation of potential exposure of plumbers and reduction of discharges in line with the UK policy of compliance with OSPAR.

With this in mind, our final recommendations are that:

- The RPII should consider a regulatory regime based on the demonstration of BAT that demonstrates a driver to cleaner technology, i.e. recognising a limit beyond which older, more polluting plant should be replaced, subject to the costs not being excessive[19];

- The benefit (on the grounds of radiological protection) of retrofitting of tanks into existing facilities is grossly disproportionate to the financial and logistical issues incurred and is not recommended in the draft ICRP [2007] recommendations. Nonetheless, appropriate works control systems should be in place to minimise any potential incidents of plumber exposure;

- Where delay and decay tanks currently exist their operation can be continued;

- Fitting of delay and decay tanks into a new facility is advantageous, particularly if only one or two facilities are established. This is particularly true where multiple ablation suites may occur in the same facility and more than one patient may be undergoing treatment at one time. However, the final requirements should be assessed on a site by site basis in line with the EC guidelines for demonstrating BAT.

- Where delay and decay tanks are installed a multi-tank vacuum systems has sufficient advantages[20] that it could be represent BAT. Using such a system a factor of 500 to 1000 reduction in activity through decay is achievable. This is considered sufficient to ensure that all possible exposure scenarios would not lead to a dose of 10 µSv being exceeded.

19 BAT concept used in OSPAR Convention for protection of the marine environment of North-East Atlantic for all types of industrial installations including nuclear. It is applied internally in nuclear context in many other European countries, e.g. France, Germany, Spain, Sweden an the EU has common rules on permitting for industrial installations, set out in the Council Directive 96/61/EC - Integrated Pollution Prevention & Control (IPPC) Directive [1996], concerned with minimising pollution from various point sources throughout EU, IPPC Directive invokes concept of BAT

20 For instance pipe blockages and hence the potential for exposure of a plumber are reduced and the reduction in water usage can help achieved greater storage times

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APPENDICES

A1. CONSULTATION ON ABLATION WASTE MANAGEMENT

In order to determine current practices relating to the management of patient ablations following I-131 treatment, a questionnaire was developed in consultation with RPII. The questionnaire aimed to elucidate from consultees:

- the number of medical treatment facilities that administer therapeutic doses of I-131 and the annual activity discharged;
- whether holding tanks are required for the treatment of patient excretions prior to discharge and how many facilities have such facilities;
- what processes and considerations are taken into account when determining the need for holding tanks; and,
- whether radiological dose to members of the public are assessed and, if so, typical ranges.

The questionnaire was emailed to contacts at the organisations responsible for radioprotection throughout European Member States. The organisations contacted are detailed in Table A1.

Table A1 Distribution of ablation management questionnaire

Country	Organisation
Bulgaria	National Centre of Radiobiology and Radiation Protection
Bulgaria	Environmental Executive Agency
Czech Republic	Sate Office for Nuclear Safety (SONS)
England & Wales	Environment Agency
Finland	Radiation and Nuclear Safety Authority (STUK)
Germany	Federal Office for Radiation Protection (BFS)
Hungary	Public Agency for Radioactive Waste Management
Hungary	Ministry for Environment and Water
Italy	Radiation Protection Agency
Lithuania	Ministry of Health: Radiation Protection Centre
Luxembourg	Division de la Radioprotection
Netherlands	National Institute for Public Health and the Environment
Northern Ireland	Environment & Heritage Service (E&HS)
Poland	Central Laboratory for Radiation Protection
Romania	Institute of Public Health CNCAN
Scotland	Scottish Environment Protection Agency (SEPA)
Slovakia	Regional Authority of Public Health
Slovenia	Slovenian Nuclear Safety Administration (SNSA)
Spain	Consejo de Seguridad Nuclear (CSN)
Sweden	Swedish Radiation Protection Institute (SSI)

Of the organisations contacted, only 5 completed questionnaires were returned, giving a 25% response rate. Those who returned questionnaires were:

- Radiation and Nuclear Safety Authority (STUK), Finland;
- Radiation Protection Centre, Lithuania;
- Direction de la Sante, Radiation Protection Department, Luxemburg ;
- Federal Office for Radiation Protection (BfS), Germany ; and,
- Environment Agency, England and Wales.

A summary of the responses received are detailed in Table A2.

In addition Enviros staff visited the City Hospital in Belfast and met with staff from NI E&HS to seek input on their views.

Table A2 **Summary of questionnaire responses in relation to discharges of I-131 following medical treatment**

Organisation	I-131 treatment		Holding tanks				Comments	Public dose
	No. facilities	Annual discharge to sewer	Required?	No. of facilities with tanks	Holding time (days)	Guidelines for installation		
STUK, Finland	20	2 TBq	No				National discharge limits do not apply to the excreta of patients receiving radioactive substances from medical treatments. May be discharged unlimited to sewer.	Not assessed.
Direction de la Santé, Luxemburg	1	< 0.1 MBq	Yes	1	150 filling + 210 holding	Discharges to stay below 5 Bq/l	All new nuclear medicine departments are required to install holding tanks	Not assessed
Radiation Protection Centre, Lithuania	1	310-1200 GBq (estimate)	Yes	1	30-60	None	Two tanks of 25 m^3 are installed. As one is filled, the other is left to decay prior to discharge.	Assessed, but no details provided.
BfS, Germany	~200	100 GBq	Yes	All	Variable	Tanks must ensure discharges to sewer remain below 5 Bq/l at point of entry		Not assessed (5 Bq/l limit ensures doses are low)
Environment Agency, England & Wales	~100	10 TBq	Yes (if BPM)	1	unknown	None	BPM assessment required to determine whether holding tanks are required.	< 300 µSv/y based on highest discharge from single facility without holding tanks

A2. DOSE ASSESSMENT METHODOLOGY

A2.1 Introduction

A dose assessment tool (DAT) was developed for the specific scenarios determined in the project. It was largely based on the NRPB-W-63 methodology [McDonnell, 2004]. This provides a simple, generic assessment methodology for discharges from small users.

The current major hospitals undertaking iodine ablation therapy were considered as discharge locations. These are St James' and St Luke's in Dublin with the resultant discharges being both processed through the Ringsend STW and the University Hospital in Cork and the University Hospital in Galway.

A2.2 Scenario

The hospitals have a limit on the amount of radioactivity that they can administer in an annual period. Two discharge scenarios were considered for each hospital, these were assessment at:

1. current levels of administration; and,

2. anticipated future level.

These are based on the data presented in Table 1 of the main report.

A2.3 Discharge data

Discharge data, were calculated on the current authorised administration levels. It was assumed that 80% of the activity administered would end up in the sewer system before the patient was allowed to return home [Leung & Nikolic, 1998].

The average administration for each hospital was calculated from the 2006 patient data presented in Table A2.1 by dividing the total activity administered in a year by the number of patients treated. This average administration value was then multiplied by the number of anticipated patients in the future to determine future administration levels. The 2006 administration data was used as a baseline for current discharges. Limits for administration were used based on 2006. However, it should be noted that no patients are yet treated at University Hospital in Galway. Data is summarised in Table A2.1 below for each of the hospitals considered.

Table A2.1 Administrations and discharges

Hospital	Patient data (2006)				Future patients (y^{-1})	Future discharges (GBq y^{-1})
	Number of patients (y^{-1})	Authorisation limit (GBq y^{-1})	Total Administration (GBq y^{-1})	Average administration (GBq)		
St James	18	138	99	5.5	25	138
St Luke's	49	390	247	5.0	75	378
University Hospital Cork	24	250	89	3.7	25	93
University Hospital Galway	N/a	N/a	N/a	5.0*	50	250

* Based on discussions with medical physics staff

A2.4 Dispersion data

The data for each STWs is presented in Table A2.2. In addition, the coastal volumetric exchange rate was set to 100m^3/s and the river volumetric flow rate was set to 50 m^3/s based on generic default values presented in the Environment Agency Initial Assessment Tool [Mitchell, 2002].

Table A2.2 WWTW data

Hospital	City	Sewage Works	Population serviced by sewage works	Mean Flow Rate through sewage works (m^3/day)	Point of Effluent Discharge
St James	Dublin	Ringsend	1.9 million	400,000	Long sea outfall Dublin Bay
St Luke's	Dublin	Ringsend	1.9 million	400,000	Long sea outfall Dublin Bay
University Hospital	Galway	Mutton Island	115,000	47,000	Long sea (1 km offshore) outfall Galway Bay
University Hospital	Cork	Little Island	413,000	59,500	Long sea outfall to the outer mouth of the River Lee Estuary

2.4.1 Activity Concentration calculations

In order to estimate doses, the following calculations were carried out to determine the appropriate concentrations in the following locations:

- Activity in a blockage in a small drainage pipe within the hospital;
- Activity retained in a man accessible sewer pipe before the STWs;
- Activity in the influent to the STWs; and

- Activity in the effluent from the STWs.

Activity in small pipe blockage was calculated as the product of the mean administration and the fraction initially excreted. Where the fraction initially excreted was determined as the activity excreted during the first 6 hours which, based on the biological half life, equate to approximately 17% of the initial administration. The mean administration is based on the total annual administration from each hospital in 2006 divided by the number of patients treated in that year. For Galway hospital which does not yet have an ablation suite an average administration of 5 GBq per patient was assumed.

The activity retained in a man accessible pipe (MAP) before the STWs was calculated on the amount of material retained on the interior surfaces of a MAP following discharges occurring over the course of year. This calculation is a function of both the biological and physical half life to determine the quantity of material discharged into the sewer system and the fraction deposited onto the surfaces and the retention half life on the sewer walls. It was assumed that 5% of the material discharges uniformly at weekly intervals over the course of the year [McDonnell, 2004] and the retention half life was 72 days [Fenner and Martin, 1997]. The overall fraction of activity retained was determined as 0.15% of the annual discharge.

Figure A2.1 presents this information based on 1 administration per week of 5 BGq.

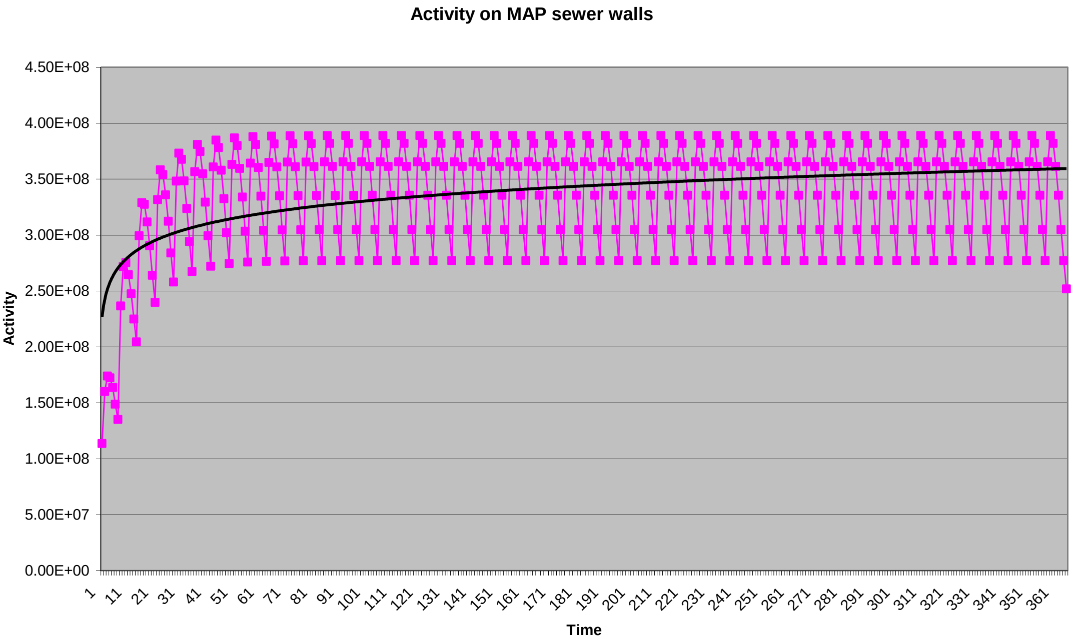

Figure A2.1 Retention of Activity on Man Accessible Pipe Walls

Activity in influent to the STWs is calculated by annual activity administered multiplied by the excretion ratio to determine the annual discharge which is then divided by the sewage flow rate. It is assumed that there is uniform mixing of the activity throughout the influent. The excretion ratio of 80% was used for each facility.

Activity in effluent from STW is calculated from the influent (described above) allowing for the time taken to process the influent through the STWs, (based on 15 hours for effluent residence time). This product was then multiplied by the fraction of material not retained in the sludge, assuming 20% retention, i.e. 80% of the activity is discharged in the effluent.

A2.5 Candidate Critical Groups

A number of hypothetical candidate critical groups (CCG) were considered in this assessment. These were based on those groups who, through the nature of the discharge and the environment and their activities were thought to have the potential for increased exposure resulting from the discharges from the appropriate hospital. The appropriate CCGs were carefully considered for each location. The Environment Agency Initial assessment tool [Mitchell, 2002] considers 6 CCGs. These are:

- a sewage treatment worker;
- a child playing in brook downstream of the effluent;
- a river angler family consuming fish caught in the river downstream of a STWs;
- a farming family where sludge is applied to the land;
- an irrigation water family where river water is applied to the land; and,
- a coastal fishing family consuming fish and shell fish caught in the sea.

Using this approach as a guide and the data present in Table A2.1 it was determined that the sewage treatment worker and coastal fishing family CCGs were applicable to all discharge locations. The river angling family was not applicable nor was a child playing in a brook, a farming family or irrigation family CCGs in any of the locations considered. In addition, and in keeping with NRPB-W63 [McDonnell, 2004], two further occupationally exposed CCGs were included, these were the:

- hospital plumber (dealing with any blockage in small pipes on the premises); and,
- sewer worker (dealing with maintenance in pipe between the hospital and the STWs.

The public critical groups included the age groups of adults, children and infants. The occupationally exposed critical groups were assessed for adults only. Table A2.3 summarises the CCGs included in the assessment.

Table A2.3 Candidate critical groups assessed

CCG	Cork	Galway	Dublin
Hospital plumber	Yes	Yes	Yes
Sewer worker	Yes	Yes	Yes
Sewage Treatment Worker	Yes	Yes	Yes
Coastal Fishing Family - Adult	Yes	Yes	Yes
Coastal Fishing Family - Child	Yes	Yes	Yes
Coastal Fishing Family - Infant	Yes	Yes	Yes

A2.5.1 Exposure pathways

A number of exposure pathways were considered. For the occupationally exposed CCGs these included:

- Inadvertent ingestion of sludge/soil;
- Inadvertent inhalation of sludge/soil;
- External dose from time spent next to blocked pipe in hospital;
- External dose from time spent in man accessible pipes; and,
- External dose from time spent next to effluent and sludge tanks at STWs.

For the public CCGs the following exposure pathways were considered:

- Consumption of fish;
- Consumption of crustacean;
- Consumption of molluscs;
- External dose from time spent handling of nets;
- Inadvertent ingestion of water;
- Inadvertent ingestion of sediment; and,
- External dose from time spent over sediments.

For each CCG a number of different exposure pathways were considered. These are summarised in Table A2.4.

Table A2.4 Candidate Critical group and exposure pathways

CCG	Inadvertent ingestion of sludge/soil	Inadvertent inhalation of sludge/soil	Time spent next to block pipe	Time spent in man accessible pipes	Occupancy at WWTW	Fish consumption	Crustacean consumption	Mollusc consumption	Handling of nets / sediment	Inadvertent ingestion of water	Inadvertent ingestion of sediment	Time spent over sediment
Hospital plumber			✓									
Sewer worker	✓	✓		✓								
Sewage Treatment Worker	✓	✓			✓							
Coastal Fishing Family - Adult						✓	✓	✓	✓	✓	✓	✓
Coastal Fishing Family - Child						✓	✓	✓		✓	✓	✓
Coastal Fishing Family - Infant						✓				✓	✓	✓

A2.5.2 Habit data

The Habit data used in the assessment is presented in Table A2.5.

Table A2.5 Habit data

Candidate Critical Group behaviour																
		Occupational Exposure Pathways						Public Exposure pathways								
CCG	Age group	Inadvertent ingestion of sludge / soil	Inadvertent inhalation of sludge / soil	Time spent next to block pipe	Time spent in man accessible pipes	Occupancy adjacent to holding tanks	Occupancy at WWTW	Fish consumption	Crustacean consumption	Mollusc consumption	River water consumption	Handling of nets / sediment	Inadvertent ingestion of water	Inadvertent ingestion of sediment	Time spent over sediment	Breathing Rate
		kg/h	kg/h	h/y	h/y	h/y	h/y	kg/y	kg/y	kg/y	l/y	kg/y	l/y	kg/h	h/y	m^3/h
Hospital plumber	Adult			2.0												1.2
Sewer worker	Adult	5.0E-06	1.0E-06		2.0											1.2
Sewage Treatment Worker	Adult	5.0E-06	1.0E-07				2000									1.2
Coastal Fishing Family - Adult	Adult							100	20	20		2000	0.5	5.0E-06	2000	1.2
Coastal Fishing Family - Child	Child							20	5	5			0.5	1.0E-05	300	0.6
Coastal Fishing Family - Infant	Infant							5					0.2	2.0E-05	30	0.22

A2.6 Reference data

The reference data used in the assessment are detailed in Table A2.6 and A2.7

Table A2.6 Dosimetric and Reference Data

Iodine 131 Reference data			Units	Reference
Physical Half life		2.20E-02	y	ICRP [1983]
Decay constant		3.59E-03	h-1	Calculated
Energy	Gamma	3.80E-01	MeV	ICRP [1983]
	Mean Beta	1.90E-01	MeV	ICRP [1983]
Lung class	Default	Fast		ICRP [1996]
Inhalation DPUI	Adult (m)	7.40E-09	Sv / Bq	ICRP [1996]
	Child (m)	1.90E-08	Sv / Bq	ICRP [1996]
	Infant (m)	7.20E-08	Sv / Bq	ICRP [1996]
Ingestion DPUI	Adult (i)	2.20E-08	Sv / Bq	ICRP [1996]
	Child (i)	5.20E-08	Sv / Bq	ICRP [1996]
	Infant (i)	1.80E-07	Sv / Bq	ICRP [1996]
External dose rates	Above beach sediments	5.70E-05	(µSv/h)/(Bq/kg)	Mitchell (2002)
	Above raw WWTW tanks	6.20E-05	(µSv/h)/(Bq/kg)	Mitchell (2002)
	Above sludge conditioned soil	6.20E-05	(µSv/h)/(Bq/kg)	Mitchell (2002)
Concentration Ratios	Coastal Fish	10	(Bq/kg per Bq/l)	McDonnell [2004]
	Crustacea	10	(Bq/kg per Bq/l)	McDonnell [2004]
	Mollusc	10	(Bq/kg per Bq/l)	McDonnell [2004]
Kd	Coastal sediment	20	(Bq/kg per Bq/l)	McDonnell [2004]
Partitioning coefficients for STWs	Sludge	0.2	-	Mitchell (2002)
	Effluent	0.8	-	Mitchell (2002)

Table A2.7 Other parametric data

Parameter	Value	Unit	Reference
Fraction of 'local' fish ingested	0.50	-	
Fraction of 'local' crustacean ingested	1.00	-	
Fraction of 'local' mollusc ingested	1.00	-	
Sewage density	1000	kg/m3	
Sediment density	1600	kg/m3	
Point source Empirical factor	1.10E-13	-	Hunt [1984]
Semi infinite source empirical factor	2.60E-13	-	Hunt [1984]
Suspended sediment load	2.50E-05	kg/l	

A2.7 Calculations

To estimate doses to the selected CCGs for the highlighted exposure pathways the following environmental concentrations were calculated:

- Concentration in filtered sea water;
- Concentration in coastal fish;
- Concentration in crustaceans; and,
- Concentration in coastal sediment.

The calculation methods for each of these parameters are outlined in NRPB W63 [McDonnell, 2004].

A2.7.2 Dose calculations

To estimate doses for the CCGs the following calculations were carried out:

- Inadvertent ingestion of sediment;
- Inadvertent inhalation of sediment;
- External dose from time spent fixing hospital small pipe blockage;
- External dose time spent in man accessible pipe;
- External dose from time spent over tanks at WWTW;
- External dose handling nets; and,
- Ingestion dose.

Inadvertent ingestion of sewage / sediment / water

For occupationally exposed pathways the concentration of influent is divided by the density of the sewage to determine the activity concentration (Bq/kg). This is then multiplied by the intake of sediment (in kg/y), the occupancy of time spent in locations were intake could occur (in h/y) and the ingestion dose per unit intake (Sv/Bq).

For the public CCGs the activity concentration based on influent is replaced with the activity concentration of sediment. For the coastal family CCG the concentration in coastal sediment is used, for the river family CCG the river concentration in river sediment is used.

For the public CCGs the activity concentration in filtered water (coastal and river for the coastal fishing and river angler CCGs respectively) and the inadvertent ingestion rate of water was used to determine the inadvertent ingestion of water.

Inadvertent inhalation of sediment

The activity concentration of the influent (Bq/kg) is multiplied by the inhalation rate (m^3/h), the airborne concentration above the tanks (kg/m^3), occupancy above tanks (h/y) and the dose per unit intake for inhalation (Sv/Bq).

External dose from time spent fixing hospital small pipe blockage

The method to calculate the external dose from small pipes is based on that presented in NRPB-W63 [McDonnell, 2004]. The activity in the pipe as defined earlier, based on average administration for the specific hospital and the first 6 hours excretion (17% of the administration), is used to calculate the external dose associated with fixing any blockage within the hospital plumbing system It was assumed that it takes 2 hours to fix any blockage in the pipe. The activity in the pipe is multiplied by the time taken to fix the blockage and the product of the gamma energy (0.38 MeV) and a point source empirical factor of 1.1E-13 taken from McDonnell [2004]. This is a cautious assumption based on the first 6 hours excretion being collected where the activity will be the greatest. Furthermore, good practice would require all pipe work to be marked and local rules requiring health physics support to be available to ensure protection of anyone working on the system.

External dose time spent in man accessible pipe

The method to calculate the external dose from time spent in man accessible pipes is based on that presented in NRPB-W63 [McDonnell, 2004]. It was assumed that it takes 2 hours to undertake any maintenance in MAPs.

External dose from time spent over tanks at WWTW

The activity concentration in influent (Bq/kg) is multiplied by the time spent adjacent to the tanks (h/y) and the dose per unit exposure (Sv/h per Bq/kg).

External dose handling nets

The method to calculate the dose from handling nets is taken from the simple approach proposed by Hunt [1984].

Ingestion dose

Ingestion doses for fish, crustacean and molluscs are based on the activity concentrations for each of the foods (Bq/kg), the appropriate ingestion rates (kg/y) and dose per unit intake (Sv/Bq). The intake rates and dose per unit intake vary for the different age groups considered. The dose is modified to account for the fraction of food type caught locally. It is assumed that the coastal CCG consumes coastal fish, crustaceans and molluscs, whilst the river angler CCG consumes river fish, crustaceans and molluscs.

A2.8 Results

Doses to candidate critical groups from each of the four hospitals are provided below.

Table 12 Doses from discharges from St Luke's Hospital – Dublin

CCG	Dose (µSv/y)		
	Current administration	Anticipated future administrations	Authorised limit discharge
Hospital plumber	5.73E+01	5.73E+01	5.73E+01
Sewer worker	2.58E+00	3.95E+00	4.08E+00
Sewage Treatment Worker	1.68E-01	3.22E-01	3.32E-01
Coastal Fishing Family - Adult	3.09E-01	4.72E-01	4.87E-01
Coastal Fishing Family - Child	7.45E-02	1.14E-01	1.18E-01
Coastal Fishing Family - Infant	2.44E-02	3.74E-02	3.86E-02

Table 13 Doses from discharges from St James'Hospital – Dublin

CCG	Dose (µSv/y)		
	Current administration	Anticipated future administrations	Authorised limit discharge
Hospital plumber	6.25E+01	6.25E+01	6.25E+01
Sewer worker	1.03E+00	1.44E+00	1.44E+00
Sewage Treatment Worker	6.74E-02	1.17E-01	1.17E-01
Coastal Fishing Family - Adult	1.24E-01	1.72E-01	1.72E-01
Coastal Fishing Family - Child	2.99E-02	4.15E-02	4.16E-02
Coastal Fishing Family - Infant	9.80E-03	1.36E-02	1.37E-02

Table 14 Doses from discharges from University Hospital Cork

CCG	Dose (µSv/y)		
	Current administration	Anticipated future administrations	Authorised limit discharge
Hospital plumber	5.27E+01	5.27E+01	5.69E-02
Sewer worker	1.16E-01	1.21E-01	6.59E+00
Sewage Treatment Worker	5.09E-02	6.63E-02	3.27E-01
Coastal Fishing Family – Adult	1.39E-02	1.45E-02	1.79E-01
Coastal Fishing Family – Child	3.35E-03	3.50E-03	3.91E-02
Coastal Fishing Family – Infant	1.10E-03	1.15E-03	9.43E-03

Table 15 Doses from discharges from University Hospital Galway

CCG	Dose (µSv/y)		
	Current administration*	Anticipated future administrations	Authorised limit discharge*
Hospital plumber	0.00E+00	7.11E+01	N/A
Sewer worker	0.00E+00	2.61E+00	N/A
Sewage Treatment Worker	0.00E+00	1.81E+00	N/A
Coastal Fishing Family – Adult	0.00E+00	3.12E-01	N/A
Coastal Fishing Family – Child	0.00E+00	7.54E-02	N/A
Coastal Fishing Family – Infant	0.00E+00	2.47E-02	N/A

* The University Hospital Galway does not currently treat patients and as such does not have an authorised limit for administrations.

A2.9 References

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