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An Ghníomhaireacht um Chaomhnú Comhshaoil

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Report Series No.117

Monitoring of Priority Substances in Waste Water Effluents

STRIVE

Environmental Protection Agency Programme

2007-2013

SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

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EPA STRIVE Programme 2007–2013

Monitoring of Priority Substances in Waste Water Effluents

Monitoring Criteria for Priority Chemicals Leading to Emission Factors

(2007-WQ-LS-1-S1)

STRIVE Report

End of Project Report available for download on http://erc.epa.ie/safer/reports

Prepared for the Environmental Protection Agency

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DISCLAIMER

The EPA STRIVE Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Table of Contents

Acknowledgements **ii**

Disclaimer **ii**

Details of Project Partners **iii**

Executive Summary **vii**

1 Background and Objectives **1**

1.1 Introduction 1

1.2 Main Objectives 2

1.3 Structure of the Report 3

2 Research Approach, Actions and Results **4**

2.1 Research Approach 4

2.2 Analyses 5

2.3 Development of a Risk-Based Model 11

2.4 Model Population to Determine Risk Values and Validation Using Two Sites 24

3 Key Project Outputs **28**

4 Conclusions from Research and Future Research Needs **29**

5 Recommendations for Implementation and Uptake of Research Findings **31**

References **35**

Acronyms and Annotations **37**

Appendix 1 List of Priority Substances **39**

Appendix 2 Current Outputs of Project **42**

Executive Summary

The pollution of water by chemicals and other pollutants affects all life on Earth as habitats and ecosystems are disturbed, and biodiversity is reduced. The Water Quality (Dangerous Substances) Regulations, SI 12 of 2001, prescribe water quality standards in relation to certain substances in surface waters, for example rivers, lakes and tidal waters. The Regulations give further effect to the European Union (EU) Dangerous Substances Directive (76/464/EC) and give effect to certain provisions of the EU Water Framework Directive (WFD) (2000/60/EC). In 2003 and 2004, Ireland's National Dangerous Substances Expert Group developed lists of priority action, candidate relevant pollutant and candidate general component substances for surface waters in Ireland and designed a substances screening monitoring programme as part of the implementation of the WFD.

The WFD acts as a single piece of legislation that covers rivers, lakes, groundwater and transitional (estuarine) and coastal waters. The main objective of this directive is to attain 'good' status in waterbodies that are below 'good' status at present, as well as to retain 'good' or better status where it currently exists, by 2015 (EPA, 2006[1]). The WFD also aims "*to achieve the elimination of priority hazardous substances and contribute to achieving concentrations in the marine environment near background values for naturally occurring substances"* with a list of priority hazardous substances (PHSs) being defined and established by an amendment to the WFD in 2001 (European Parliament 20 November 2001). In doing so, the priority pollutants were legally defined as "*substances identified in accordance with Article 16 (2) and listed in Annex X*" of the WFD and were selected on the basis of "*their significant risk to or via the aquatic environment*" using a scientifically based methodology. The substances include certain pesticides (atrazine, simazine, tributyltin), solvents (dichloromethane, toluene, xylene), metals (arsenic, chromium, copper, lead, nickel, zinc) and certain other ions (cyanide and fluoride). Priority substances (PSs) are of particular importance in surveillance monitoring.

Many knowledge gaps exist in relation to managing PSs and PHSs in Irish waters. The objective of the EPA-funded project (*Monitoring Criteria for Priority Chemicals Leading to Emission Factors*) was to develop a model based on emission criteria in order to assist the monitoring of PSs. This project, which started in 2008, represents an important collaboration between two research centres (Dublin City University and Cork Institute of Technology) with analytical expertise, and three councils (Fingal, Cork and Dublin Councils), building capability to establish risk factors for PSs and PHSs.

The project involved a large sample number (492) to obtain a representative and statistically relevant output. The team collected samples and analysed for 33 PSs as well as collated available environmental and water quality data from a range of wastewater treatment plants (n = 9) over a 3-year sampling period. Samples were collected monthly throughout the project and also at higher frequency during wet and dry periods. A risk-based model of expected pollutants was developed based on inputs to municipal wastewater treatment plants (WWTPs) from a variety of sources with a variety of population equivalents (PEs). Notably this project focused on wastewater facilities, although, however, it was found that the impact of other sources, such as golf courses, hospitals, airports, restaurants, etc., on PSs arising from rainfall run-off can also be significant.

The project enabled the development of improved analytical methods for the determination of polycyclic aromatic hydrocarbons and pesticides in wastewaters which led to published work and PhD awards. The

1. EPA, 2006. *EU Water Framework Directive Monitoring Programme – EPA*. Prepared to meet the requirements of the EU Water Framework Directive (2000/60/EC) and National Regulations implementing the Water Framework Directive (SI No. 722 of 2003) and National Regulations implementing the Nitrates Directive (SI No. 788 of 2005). 2006. Appendix 2.1 – Priority Substances and Relevant Pollutant List for Surface Waters and Groundwater. Excel file. http://www.epa.ie/pubs/reports/water/other/wfd/

training of PhD students, researchers and postdocs on the project has greatly contributed to building environmental capacity in Ireland.

The project identified issues in relation to management strategies for preventing and limiting hazardous substances and non-hazardous substances emission to water to assist in WFD compliance. A key finding in the research relates to unlicensed sources of PSs. More data should be collected on the emission sources of PSs, i.e. trade effluent discharge information, hospitals, golf courses, airports, etc., with up-to-date information on their respective discharges. Some of these sources may have a significant impact on water quality at certain times of the year and, therefore, it is recommended that these sources are also regulated and monitored. The influence of wet weather flow (WWF) and dry weather flow (DWF) conditions[2] was found to have a significant impact on the risk associated with a particular WWTP.

The key success of the research is a valuable risk-based model which can be used as a tool to assist in PS monitoring. The output of the risk-based model can facilitate the decision-making processes by identifying the likely occurrence of groups of PSs based on WWTP PEs and usage. This approach can be applied to other locations in Ireland and assist in informing the monitoring programme for the WFD. Some key recommendations arising from the project include:

- The need to improve the way that data are collected and provided for research and development purposes. This can be facilitated by a more streamlined approach to licence application and provision as well as by identifying operational efficiencies of potential sources of pollution.
- The development of tools to facilitate monitoring should be encouraged to ensure compliance with the WFD and also to identify high-risk activities and locations.
- Utilisation of the data gathered in this project to validate the current European Pollutant Release and Transfer Register (ePRTR)[3] model, which was designed based on data from the Ringsend WWTP (PE = 1.8 million).

This Synthesis Report summarises the main aims, methodologies, results and key findings from the project. More details can be found in the End of Project Report available at http://erc.epa.ie/safer/reports.

2. DWF is flow in a sewerage system during periods of dry weather in which the system is under minimum influence of inflow and infiltration. WWF is DWF combined with storm water introduced into a combined sewer system, and DWF combined with infiltration/inflow in a separate sewer.

3. ePRTR is the new Europe-wide register that provides easily accessible key environmental data from industrial facilities in EU Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland. It replaces and improves upon the previous European Pollutant Emission Register (EPER).

1 Background and Objectives

1.1 Introduction

The pollution of water by chemicals and other pollutants affects all life on Earth as habitats and ecosystems are disturbed, and biodiversity is reduced. The Water Quality (Dangerous Substances) Regulations, SI 12 of 2001, prescribe water quality standards in relation to certain priority substances (PSs) in surface waters, for example rivers, lakes and tidal waters (Clenaghan et al., 2006). The substances include certain pesticides (atrazine, simazine, tributyltin), solvents (dichloromethane, toluene, xylene), metals (arsenic, chromium, copper, lead, nickel, zinc) and certain other compounds (cyanide and fluoride). The Regulations give further effect to the European Union (EU) Dangerous Substances Directive (76/464/EC) and give effect to certain provisions of the EU Water Framework Directive (WFD) (2000/60/EC). In 2003 and 2004, Ireland's National Dangerous Substances Expert Group developed lists of priority action, candidate relevant pollutant and candidate general component substances for surface waters in Ireland and designed a substances screening monitoring programme as part of the implementation of the WFD. PSs are of particular importance in surveillance monitoring.

There are many sources of pollutants in water, including agriculture, industry, transportation and incineration (Lepom et al., 2009). Water has also been used for many years as a medium for waste discharge. Water pollutants can be transported over long distances, may be found in remote areas, and can even be found in the water many years after the substance has been banned. As society grows and becomes more affluent an increasing number of pollutants and chemicals are released into the atmosphere and water (Kullenberg, 1999). The level of pollutants present in waterbodies is most commonly judged against set environmental quality standards (EQSs) that vary among different countries.

While the monitoring methods required in the WFD are not specified, the widely accepted method involves grab sampling. Grab sampling is currently the method accepted and used for monitoring of priority pollutants (PPs) in our waters. Grab sampling is expensive and labour intensive – and it identifies compounds present at a single point in time. The WFD has identified a list of PSs that must be monitored (see Appendix 1). This is a huge challenge to the analyst.

PSs originate from many sources and are transferred to surface waters via a number of pathways. Large installations may emit PSs originating from production processes directly into surface waters, under licence from the Environmental Protection Agency (EPA) or local authorities. Gaseous emissions of PSs from combustion and industrial sources may be deposited on surrounding land, and washed into surface waters directly following precipitation (Sanders et al., 1993). Accidental or deliberate dumping of waste materials onto land may also lead to run-off of PSs into surface waters, or indirect contamination of surface waters via leaching into groundwater (Teijon et al., 2010). Wastewater treatment plants (WWTPs) are major potential point sources of PSs, that combine direct inputs from domestic, industrial and commercial effluent with diffuse inputs from surface run-off of land-deposited PPs. Measuring of PS concentrations in WWTP effluent under different conditions (e.g. wet and dry weather) may offer insight into the sources of PSs (Gasperi et al., 2008). Furthermore, as major point sources of PSs, and following the implementation of the Urban Waste Water Treatment Directive (91/271/EEC), WWTPs offer strong opportunities for the effective control of PS emissions in surface waters through the implementation of management and abatement options. Determining the concentrations of PSs in WWTP effluent is important for the protection of public health and the environment.

The WFD acts as a single piece of legislation that covers rivers, lakes, groundwater and transitional (estuarine) and coastal waters. The main objective of this Directive is to attain 'good' status in waterbodies that are below 'good' status at present, as well as to retain 'good' or better status where it currently exists, by 2015 (EPA, 2006). The WFD also aims to "*achieve*

the elimination of priority hazardous substances and contribute to achieving concentrations in the marine environment near background values for naturally occurring substances" with a list of priority hazardous substances *(*PHSs) being defined and established by an amendment to the WFD in 2001 (European Parliament 20 November 2001). In doing so the PPs were legally defined as "*substances identified in accordance with Article 16 (2) and listed in Annex X"* of the WFD and were selected on the basis of "*their significant risk to or via the aquatic environment*" using a scientifically based methodology.

The amendment (European Parliament 20 November 2001) also states that "*in accordance with Article 1 (c) of Directive 2000/60/EC, the future reviews of the list of priority substances under Article 16 (4) of that Directive will contribute to the cessation of emissions, discharges and losses of all hazardous substances by 2020 by progressively adding further substances to the list*". As such, the list of PSs was expanded to contain 41 substances in 2006 (EPA, 2006). This list was further expanded to contain 25 PHSs or groups of substances which are defined as "*substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern*" (EPA, 2006).

The levels of pollutants present in waterbodies are most commonly judged against set EQSs that vary among different countries. These standards dictate the maximum allowable concentrations (MAC EQSs) or range of concentrations (annual average or AA EQSs) of specific pollutants allowed to ensure compliance with the European Commission (EC) guidelines. Directive 2008/105/EC (European Parliament 2008) and SI 272 of 2009 (European Parliament 2009) define the latest EQS values for surface waters across Europe. The EU WFD was transposed into Irish Law in 2003 (EPA, 2006) and, as such, these EQS values now form the basis of PS water monitoring in Ireland. Throughout this project all results are compared with EQS values.

The European Pollutant Release and Transfer Register (E-PRTR[1]) is the new Europe-wide register that provides easily accessible key environmental data from industrial facilities in EU Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland. It replaces and improves upon the previous European Pollutant Emission Register (EPER). The development and implementation of a PRTR adapted to national needs assists governments to track the generation, release and fate of emissions of hazardous chemical substances and pollutants over time, to examine progress in reducing emissions, and to set priorities for reducing or even eliminating the most potentially damaging releases and transfers. A PRTR can help pollution prevention and lessen the burden of control regulations requiring monitoring and enforcement actions. PRTR data and information can be used for assessing risks to human health and the environment as input to dispersion models to simulate emissions and any subsequent pollution. The data collected as part of this study identified gaps in the current state of knowledge and provided a large database of both sampling and historical data that can be used in the implementation of PRTR policy here in Ireland.

1.2 Main Objectives

The project *Monitoring Criteria for Priority Chemicals Leading to Emission Factors* represents an important collaboration between two research centres (Dublin City University (DCU) and Cork Institute of Technology (CIT)) to build the capability to monitor priority and dangerous substances. The aim of this project was to develop a model of PS occurrence based on emission factors. The focus was on collating readily available data relevant to major PS risk factors identified by conceptual modelling, and to develop appropriate indicators. These indicators were applied to nine WWTP agglomerations monitored in a PS study to predict the relative risk of elevated PS loading to receiving waters across agglomerations and over time.

This work was underpinned by a number of key studies already carried out in Ireland and a vast array of literature in the area of pollutant monitoring. The impact of such a study is in the capability to identify index criteria that will assist in defining the monitoring programme in Ireland for the WFD.

1. http://prtr.ec.europa.eu/

The project aimed at establishing an index or risk value that relates population equivalents (PEs) to the occurrence and/or concentration of dangerous and priority pollutants. In order to achieve this, a number of key technical objectives were identified:

- To review existing techniques for the measurement of PPs;
- To modify and improve current analytical methods to enable detection of chemicals present in the water;
- To develop analytical approaches to determine PPs in water;
- To pre-concentrate and analyse samples of wastewater;
- To establish a relationship between source (industrial/domestic), PE and occurrence; and
- To make recommendations on how a successful monitoring programme for PPs could be established and run successfully.

1.3 Structure of the Report

This Synthesis Report summarises the main aims, methodologies, results and key findings from the project. This includes a rationale for the project, with an evaluation of some background information and the water monitoring requirements from an Irish legislative viewpoint. While selection of sampling sites and analytical method development are briefly discussed, a significant focus of the report is on the data collected and how these led to the development and population of a risk-based model. More details can be found in the End of Project Report.

2 Research Approach, Actions and Results

2.1 Research Approach

2.1.1 The collaboration and work plan

This project was a large-scale collaboration involving groups in two counties and tasks were divided. CIT co-ordinated sampling efforts with Cork County Council, and DCU co-ordinated sampling efforts with Fingal County Council for Swords WWTP, and Dublin City Council and Celtic Anglian Water for samples from Ringsend WWTP. DCU managed the project. The End of Project Report provides detailed methods for the sampling and analysis of samples for pesticides, polycyclic aromatic hydrocarbons (PAHs) and metals in the PP list. Details on site characteristics and catchment maps are also provided in the End of Project Report, together with details of data available for each site relating to PE, practices in the catchment, traffic and rainfall.

This research was composed of three individual projects with identified outputs as shown in Fig. 2.1. These three projects were redivided into nine interlinked work packages. The project involved a large sample number (>400 samples) to obtain a representative and statistically relevant output. It also involved training researchers (two PhD and one postdoctoral fellowship) in the area of environmental analysis and monitoring, where there is a definite need for expertise in Ireland.

2.1.2 Project elements

This 3-year collaborative research project involved:

- Analytical method development and optimisation for the determination of PP chemicals;
- Collection of water quality data on wastewaters;
- Collection and compilation of data on chemical usage, PEs and licensed activities;
- Study of chemical occurrence relating to wet weather flow (WWF) and dry weather flow (DWF); and

Project 1: Development of solid-phase extraction methods for the determination of priority pollutants and analysis by GC and LC-MS	• Literature review • Suitable analytical methods for groups of chemicals • Solid-phase extraction methods for groups of chemicals • Peer-reviewed publications • Presentations at national and international conferences • PhD thesis
Project 2: Development of high-throughput online extraction and analysis methods for the determination of priority pollutants using LC-MS	• Development of LC-MS/MS (for determination of ~40 PPs using triple-quad MS) • Peer-reviewed publications • Presentations at national and international conferences • PhD thesis
Project 3: Development of an index that relates emission of organic priority and dangerous pollutants and their occurrence in the environment	• Model of pollutant occurrence in treatment works of different PEs – to include temporal variability and meteorological conditions, e.g. rainfall • Project web page

Figure 2.1. Project plan showing three distinct components. GC, gas chromatography; LC-MS, liquid chromatography mass spectrometry; PP, priority pollutant; PE, population equivalent.

- Development of a model taking all the analytical data, compiled additional data and identification of risk based on all available information.

In order to obtain essential supplementary information on local activities, usage criteria, etc., reconnaissance studies of each of the selected sites were carried out. Reconnaissance studies of WWTPs highlighted that valuable information is being lost, as it is not being recorded. In many cases, there is no requirement for plant operators to record information, for example when a treatment process at a plant is not operating efficiently or indeed at all. Figure 2.2 illustrates how the elements of the work in the project were divided into (a) model development, (b) sample collection, and (c) analytical methods development.

Nine wastewater treatment sites were chosen for this study, seven in Cork and two in Dublin (Fig 2.3a and b, Table 2.1). Each of the sites represented a different demographic and type of population. The devised sampling plan allowed the evaluation of domestic, industrial and agricultural inputs and emission factors, while also affording the opportunity to compare levels and styles of treatment and the removal efficiencies achieved by such. Including the Ringsend WWTP in the sampling plan had the added benefit of facilitating monitoring of the largest WWTP in the country, serving our most heavily populated city, and operating well over capacity. More information on the sampling plan and sampling sites is available in the End of Project Report.

2.2 Analyses

2.2.1 Analytical protocol

A focus of this project took into account the recommendation that selected relevant pollutant and general component substances should be sampled at dangerous substances monitoring sites on the basis of the site's upstream activities. This project focused on wastewater facilities. It was noted that the determination of PSs is challenging and costly and that capacity to undertake the required programme is not yet available in Ireland. The latter was a real impetus for research to design a tool that can assist a monitoring programme driven by PEs and local activity. The data obtained from the analytical work from Components 1 and 2 led to the completion and validation of the risk-based model and testing of that based on the occurrence of PP chemicals.

Analytical methods were developed or adapted for the determination of the PSs/PHSs in each of the samples collected. Because two PhD students in analytical science were being trained as part of this project, emphasis was placed on determination methods for PAHs and pesticides. Determination of metals was carried out by a contract laboratory at the end of the project. Figure 2.4 shows the typical analytical protocol

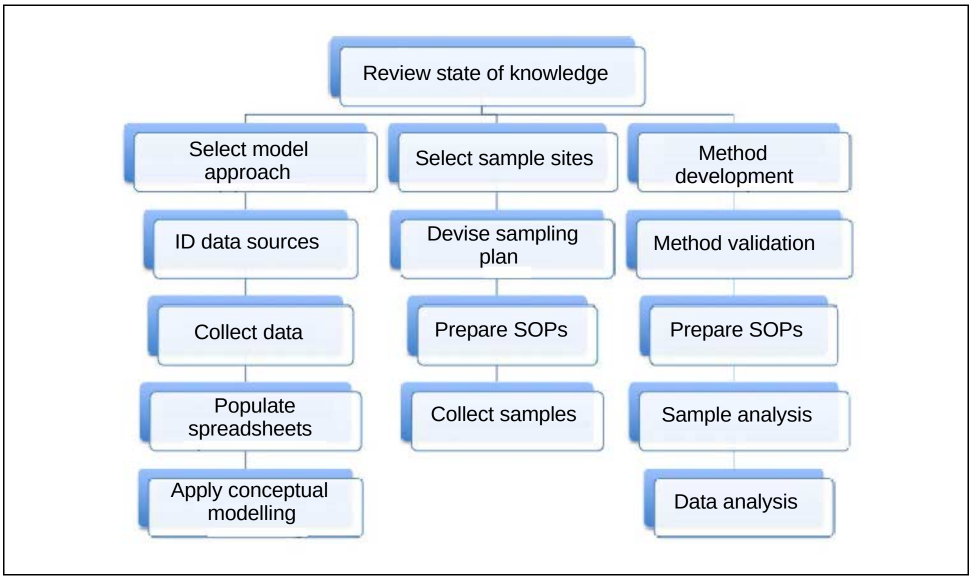

Figure 2.2. Division of work within the project. SOP, standard operating procedure.

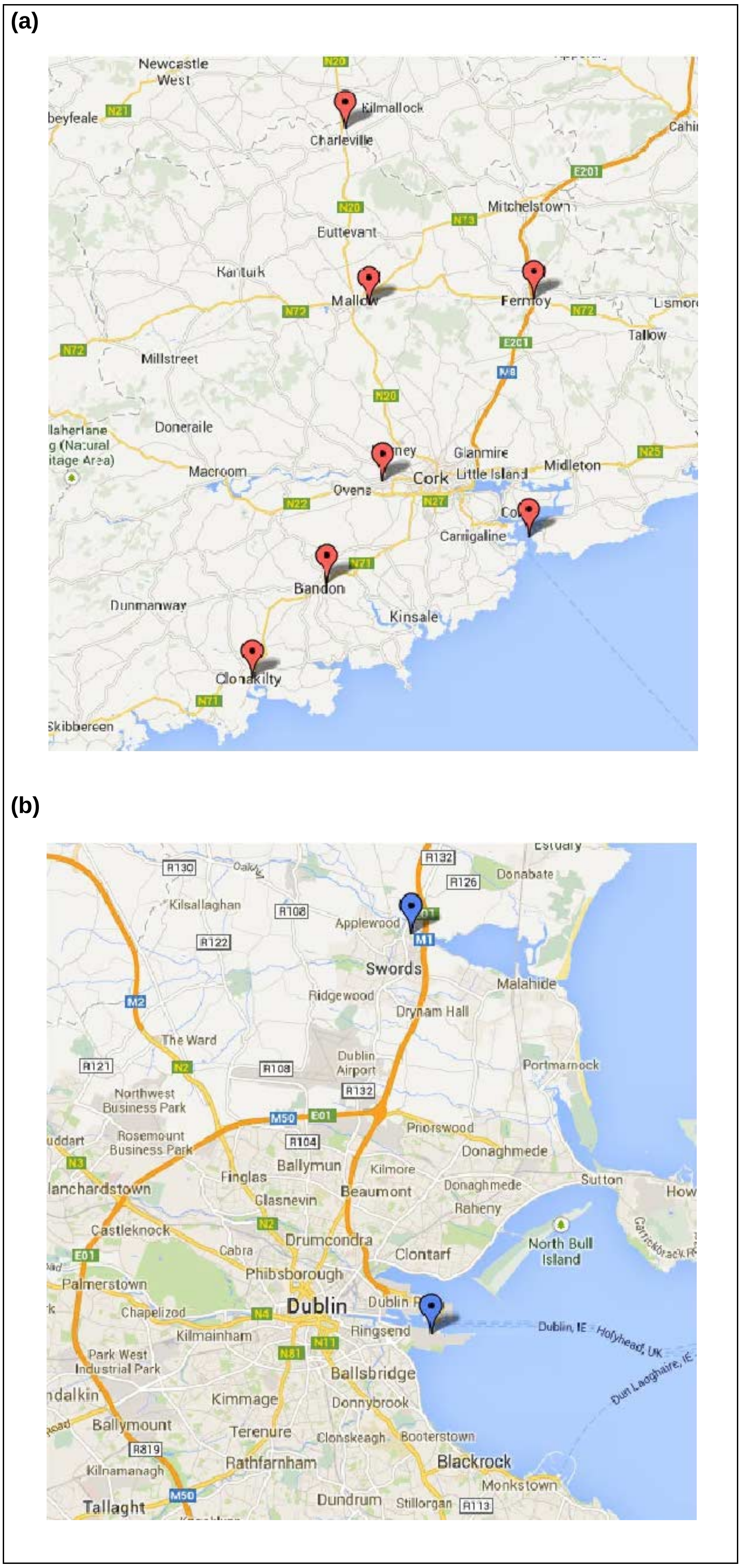

Figure 2.3. Maps showing (a) Cork wastewater treatment plants (red) and (b) Dublin wastewater treatment plants (blue) included in this study.

Table 2.1. Overview of the wastewater treatment plants (WWTPs) in this study.

WWTP and code	Treatment	Type of treatment	Agglomeration PE	Plant PE	Area (ha)	Receiving waters
Ballincollig BG	Secondary	PS, SS, AS (aeration basin)	16,339	15,000	760	Freshwater – river
Bandon BN	Secondary	PS, AS (OD)	8,178	20,000	458	Freshwater – river
Charleville CE	Secondary	PS, SS, AS (OD)	2,984	6,415	274	Freshwater – river
Clonakilty CY	Secondary	PS, SS, AS (OD)	7,500–15,000	15,000	750	Estuarine
Fermoy FY	Secondary, NR	PS, SS, AS (OD; A-A-AT) PR	5,800	12,960	394	Freshwater – river
Mallow MW	Secondary, NR	PS, SS, AS (A-A-AT) PR	7,091	12,000	595	Freshwater – river
Ringaskiddy RY	None	None	14,864	0	967	Estuarine
Ringsend RD	Tertiary	PS, SS, AS (Sequencing batch reactors) UV disinfection	2,870,333	1,640,000	26,728	Estuarine
Swords SD	Secondary	PS, SS, AS (A-A-AT)	50,000	60,000	2,673	Estuarine

Area, area of catchment; PE, population equivalent; NR, nutrient removal; PS, primary settlement; SS, secondary settlement; AS, activated sludge; PR, phosphorus removal; OD, oxidation ditches; A-A-AT, anaerobic, anoxic and aeration tanks. This information was gathered from the EPA wastewater license applications of the respective WWTPs and from the EPA Urban Wastewater Report, 2007.
Note: Ringaskiddy is listed as having a plant PE of zero due to the lack of treatment at this site. This site is located in an area with several pharmaceutical companies and acts as a combined pumping system for this catchment.

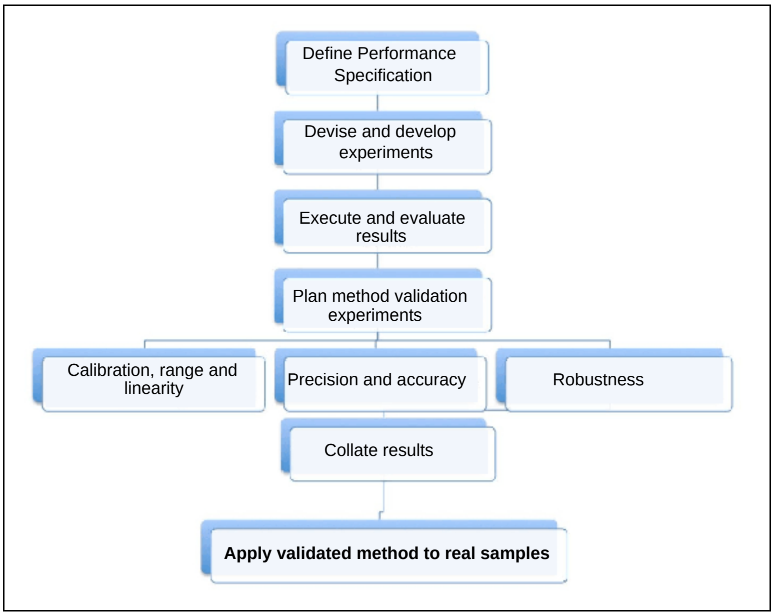

Figure 2.4. Outline of analytical protocol used for the determination of polycyclic aromatic hydrocarbons, metals and pesticides.

used in the project for PAHs and pesticides. For details of full analytical methods, method development, validation and analytical standard operating procedures please refer to the End of Project Report.

Method development was carried out in both CIT and DCU, with CIT focusing on the development of an online solid phase extraction liquid chromatography tandem mass spectrometry (SPE-LC-MS/MS) method for the determination of pesticides, while DCU developed an improved method for PAH determination by gas chromatography mass spectrometry (GCMS). Standard operating procedures (SOPs) were developed for the methods, as well as for the sample handling and extraction procedures implemented by the project team. These SOPs are available in the End of Project Report.

2.2.2 *Analytical results*

All samples from all nine sites were analysed for the eight priority PAHs listed in the WFD (see Appendix 1). For the purpose of this report, Ballincollig and Ringsend WWTP sites are taken as examples. For full analytical results from each of the nine sites included in this study, please refer to the End of Project Report.

2.2.2.1 Ballincollig WWTP analytical results

Table 2.2 summarises the occurrence and detected levels of each of the PAHs in the WWTP effluent samples collected and analysed for Ballincollig. The results are compared with the EQS levels applicable to the respective PAHs.

Table 2.2 shows that naphthalene, anthracene and fluoranthene, the more water-soluble PAHs were detected in all samples collected, while the less water-soluble, higher octanol/water partition coefficient PAHs, were less frequently detected. Of these PAHs, there were exceedances of the EQS limits for benzo-b/k-fluoranthene, indeno-1,2,3cd-pyrene and benzo-ghi-perylene.

Table 2.3 summarises the occurrence and detected levels of each of the pesticides in the wastewater effluent samples collected in Ballincollig. The results are compared with the EQS levels applicable to the respective pesticides, where available.

Table 2.3 shows that 11 of the priority pesticides were detected in samples from Ballincollig WWTP. Of these pesticides, there were exceedances of the EQS limits for the chlorfenvinphos and di(2-ethylhexyl) phthalate (DEHP). Of the 13 samples collected at this site, only diuron was found to occur in all samples based on the frequency of occurrence.

Ten samples collected at Ballincollig WWTP were microwave-digested, stored and sent to the Centre for Microscopic Analysis (CMA) in Trinity College Dublin for analysis by inductively coupled plasma mass spectrometry (ICPMS). The analysis determined trace

Table 2.2. Results of polycyclic aromatic hydrocarbon analysis for Ballincollig Wastewater Treatment Plant. Results are compared with their respective maximum allowable concentration environmental quality standard (MAC EQS).

Parameter	Target EQS	Frequency	Range		Percentile			
		n = 16	Min. × 10^{-4}	Max. × 10^{-3}	25 × 10^{-4}	50 × 10^{-4}	75 × 10^{-3}	90 × 10^{-3}
Naphthalene (µg/l)	1.2	16	5.44	1.69	6.70	8.72	1.21	1.42
Anthracene (µg/l)	0.1	16	<LOD	0.23	2.38	6.89	0.85	1.32
Fluoranthene (µg/l)	0.1	16	<LOD	0.19	1.01	2.57	0.33	0.35
Bb/k fluoranthene (µg/l)	0.003	9	<LOD	0.40	<LOD	<LOD	0.03	19.9
Benzo-a-pyrene (µg/l)	0.05	8	<LOD	0.30	<LOD	0.2.4	6.56	18.3
Ind-pyrene + Bghi (µg/l)	0.002	11	<LOD	0.42	<LOD	0.72	19.1	23.2

Bb/k fluoranthene, benzo-b- and benzo-k-fluoranthene; Ind-pyrene, indeno-1,2,3cd-pyrene; Bghi, benzo-ghi-perylene; <LOD, below limit of detection.

Table 2.3. Results of pesticide analysis for Ballincollig Wastewater Treatment Plant. Results are compared with their respective maximum allowable concentration environmental quality standard (MAC EQS).

Parameter	Target EQS	Frequency	Range		Percentile			
		n = 13	Min.	Max.	25	50	75	90
Alachlor (µg/l)	0.7	5	5.1^{E-02}	1.3^{E-01}	8.31^{E-02}	8.61^{E-02}	$9.78E^{-02}$	1.05^{E-01}
Atrazine (µg/l)	2.00^{E+00}	10	ND	2.1^{E-01}	6.36^{E-03}	4.35^{E-02}	$1.48E^{-01}$	1.61^{E-01}
Chlorfenvinphos (µg/l)	3.00^{E-01}	9	3.0^{E-01}	2.2^{E+00}	6.10^{E-01}	7.89^{E-01}	$1.20E^{+00}$	1.73^{E+00}
Diuron (µg/l)	1.8	13	ND	6.2^{E-01}	8.23^{E-02}	2.06^{E-01}	$2.46E^{-01}$	3.45^{E-01}
Malathion (µg/l)		7	ND	9.9^{E-01}	9.06^{E-02}	1.36^{E-01}	$5.38E^{-01}$	8.52^{E-01}
Simazine (µg/l)	4	9	1.5^{E-02}	1.7^{E-01}	4.61^{E-02}	5.67^{E-02}	$1.17E^{-01}$	1.26^{E-01}
Fenitrothion (µg/l)		9	ND	7.8^{E-01}	1.40^{E-01}	1.83^{E-01}	3.30^{E-01}	5.20^{E-01}
Pirimiphos methyl (µg/l)		9	ND	6.9^{E-01}	1.15^{E-01}	2.63^{E-01}	4.50^{E-01}	4.86^{E-01}
Chlorpyrifos (µg/l)	0.1	3	ND	6.0^{E-02}	1.19^{E-02}	2.16^{E-02}	3.92^{E-02}	4.98^{E-02}
Di(2-ethylhexyl) phthalate (DEHP) (µg/l)	1.3[1]	11	ND	1.4^{E+01}	8.20^{E-01}	1.60^{E+00}	2.01^{E+00}	2.20^{E+00}
Mecoprop (µg/l)		2	2.0^{E-02}	3.4^{E-01}	1.03^{E-01}	1.74^{E-01}	2.46^{E-01}	2.89^{E-01}

[1]No MAC EQS value available so taken as annual average EQS (AA EQS) for this compound.
ND, not detected.

Table 2.4 Results of inductively coupled plasma mass spectrometry analysis for metals collected at Ballincollig Wastewater Treatment Plant. Samples were analysed for 15 metals in a total of 10 samples. EQS, Environmental quality standard.

Parameter	Target EQS	Frequency	Range		Percentile		
		n = 10	Min.	Max.	50	75	90
Boron (µg/l)		10	33.68	61.33	44.74	55.20	60.73
Vanadium (µg/l)		0					
Chromium (µg/l)	0.6–4.7	4	1.37	3.63	1.86	2.42	3.14
Cobalt (µg/l)		0					
Nickel (µg/l)	20	4	1.41	7.74	4.61	5.85	6.98
Copper (µg/l)	5.0–30	10	3.82	11.62	5.70	6.97	9.07
Zinc (µg/l)	8–100	10	40.31	70.76	56.74	60.77	64.82
Arsenic (µg/l)	20–25	0					
Selenium (µg/l)		0					
Molybdenum (µg/l)		0					
Cadmium (µg/l)	0.08–0.25	0					
Tin (µg/l)	0.0002	2	1.16	1.18	1.17	1.18	1.18
Antimony (µg/l)		1	1.15	1.15	1.15	1.15	1.15
Barium (µg/l)		9	2.23	10.89	3.10	7.39	10.45
Lead (µg/l)	7.2	2	1.05	22.11	11.58	16.85	20.00

levels of 15 WFD priority metals and trace elements in the samples. The results of this analysis are presented in Table 2.4.

As shown in Table 2.4, all samples collected were found to contain levels of trace elements, with zinc present in the highest concentrations.

2.2.2.2 Ringsend WWTP analytical results

Table 2.5 summarises the occurrence and detected levels of each of the PAHs in the wastewater effluent samples collected and analysed. The results are compared with the EQS levels applicable to the respective PAHs.

Table 2.5 shows that the most water-soluble PAHs, naphthalene, anthracene and fluoranthene, were detected in all samples collected, while the less water-soluble, higher octanol/water partition coefficient PAHs were slightly less frequently detected. Of these PAHs, the EQS limits for the indeno-1,2,3cd-pyrene and benzo-ghi-perylene were exceeded (marked in bold in Table 2.5).

Table 2.5. Results of polycyclic aromatic hydrocarbon analysis for Ringsend Wastewater Treatment Plant. Values in bold indicate levels above environmental quality standard (EQS) values.

Parameter	Target EQS	Frequency	Range		Percentile		
		n = 50	Min.	Max.	50	75	90
Naphthalene (µg/l)	1.2	50	<LOD	5.37×10^{-02}	2.29×10^{-04}	2.98×10^{-03}	2.18×10^{-02}
Anthracene (µg/l)	0.1	50	<LOD	4.10×10^{-02}	2.00×10^{-05}	9.95×10^{-03}	2.96×10^{-02}
Fluoranthene (µg/l)	0.1	50	<LOD	2.49×10^{-02}	1.06×10^{-05}	1.25×10^{-02}	1.83×10^{-02}
Bb/k fluoranthene (µg/l)	Σ = 0.003	46	<LOD	1.51×10^{-04}	3.41×10^{-06}	6.05×10^{-06}	1.03×10^{-05}
Benzo-a-pyrene (µg/l)	0.05	43	<LOD	9.02×10^{-03}	5.42×10^{-06}	1.71×10^{-03}	5.68×10^{-03}
Ind-pyrene + Bghi (µg/l)	Σ = 0.002	42	<LOD	**5.74×10^{-02}**	5.94×10^{-06}	8.21×10^{-06}	1.88×10^{-05}

Bb/k fluoranthene, benzo-b- and benzo-k-fluoranthene; Ind-pyrene, indeno-1,2,3cd-pyrene; Bghi, benzo-ghi-perylene; <LOD, below limit of detection.

Table 2.6. Results of pesticide analysis for Ringsend Wastewater Treatment Plant. Values in bold indicate levels above environmental quality standard (EQS) values.

Parameter	Target EQS	Frequency	Range		Percentile		
		n = 36	Min.	Max.	50	75	90
Alachlor (µg/l)	0.7	15	<LOD	**7.11×10^{-01}**	1.35×10^{-01}	2.87×10^{-01}	3.57×10^{-01}
Atrazine (µg/l)	2.0	30	<LOD	**8.1×10^{-01}**	1.75×10^{-01}	2.74×10^{-01}	4.42×10^{-01}
Chlorfenvinphos (µg/l)	0.3	19	<LOD	**$5.8 \times 10^{+00}$**	$2.12 \times 10^{+00}$	$2.81 \times 10^{+00}$	$3.43 \times 10^{+00}$
Diuron (µg/l)	1.8	36	<LOD	**$1.8 \times 10^{+00}$**	2.11×10^{-01}	7.26×10^{-01}	9.72×10^{-01}
Isoproturon (µg/l)	1.0	10	<LOD	7.5×10^{-03}	2.65×10^{-03}	2.87×10^{-03}	3.65×10^{-03}
Malathion (µg/l)		18	<LOD	$2.7 \times 10^{+00}$	6.48×10^{-01}	$1.03 \times 10^{+00}$	$1.60 \times 10^{+00}$
Simazine (µg/l)	4.0	24	<LOD	$1.8 \times 10^{+00}$	2.46×10^{-01}	5.43×10^{-01}	7.37×10^{-01}
Fenitrothion (µg/l)		24	<LOD	$3.8 \times 10^{+00}$	5.55×10^{-01}	$1.11 \times 10^{+00}$	$2.04 \times 10^{+00}$
Pirimiphos methyl (µg/l)		26	<LOD	$2.0 \times 10^{+00}$	1.86×10^{-01}	4.21×10^{-01}	8.67×10^{-01}
Chlorpyrifos (µg/l)	0.1	10	<LOD	**4.3×10^{-01}**	4.71×10^{-02}	8.44×10^{-02}	1.42×10^{-01}
Di(2-ethylhexyl) phthalate (DEHP) (µg/l)	1.3[1]	25	<LOD	**$6.2 \times 10^{+00}$**	5.77×10^{-01}	$1.11 \times 10^{+00}$	$1.76 \times 10^{+00}$

[1]No MAC EQS value available so taken as annual average EQS (AA EQS) for this compound.
<LOD, below limit of detection.

Table 2.7. Inductively coupled plasma mass spectrometry results for samples collected at Ringsend Wastewater Treatment Plant. Values in bold indicate levels above environmental quality standard (EQS) values.

Parameter	Target EQS	Frequency	Range		Percentile		
		n = 34	Min.	Max.	50	75	90
Boron (µg/l)		34	$8.00 \times 10^{+01}$	$2.52\times 10^{+02}$	$1.32 \times 10^{+02}$	$1.67 \times 10^{+02}$	$1.95 \times 10^{+02}$
Vanadium (µg/l)		12	$1.06 \times 10^{+00}$	$2.88 \times 10^{+00}$	$1.63 \times 10^{+00}$	$1.88 \times 10^{+00}$	$1.98 \times 10^{+00}$
Chromium (µg/l)	0.6–4.7	23	$1.10 \times 10^{+00}$	**$1.24 \times 10^{+01}$**	$1.82 \times 10^{+00}$	$2.89 \times 10^{+00}$	$5.38 \times 10^{+00}$
Cobalt (µg/l)		5	$1.04 \times 10^{+00}$	$2.36 \times 10^{+00}$	$2.03 \times 10^{+00}$	$2.04 \times 10^{+00}$	$2.23 \times 10^{+00}$
Nickel (µg/l)	20	34	$1.88 \times 10^{+00}$	**$4.45 \times 10^{+01}$**	$3.50 \times 10^{+00}$	$4.66 \times 10^{+00}$	$8.53 \times 10^{+00}$
Copper (µg/l)	5.0–30	34	$4.25 \times 10^{+00}$	**$1.24 \times 10^{+02}$**	$1.58 \times 10^{+01}$	$2.69 \times 10^{+01}$	$3.90 \times 10^{+01}$
Zinc (µg/l)	8–100	34	$2.48 \times 10^{+01}$	**$6.86 \times 10^{+02}$**	$5.73 \times 10^{+01}$	$8.86 \times 10^{+01}$	$1.23 \times 10^{+02}$
Arsenic (µg/l)	20–25	32	$1.01 \times 10^{+00}$	$3.81 \times 10^{+00}$	$1.53 \times 10^{+00}$	$1.99 \times 10^{+00}$	$2.50 \times 10^{+00}$
Selenium (µg/l)		12	$1.01 \times 10^{+00}$	$2.86 \times 10^{+00}$	$1.25 \times 10^{+00}$	$1.50 \times 10^{+00}$	$2.01 \times 10^{+00}$
Molybdenum (µg/l)		34	$1.68 \times 10^{+00}$	$1.11 \times 10^{+01}$	$3.04 \times 10^{+00}$	$4.36 \times 10^{+00}$	$6.54 \times 10^{+00}$
Cadmium (µg/l)	0.08–0.25						
Tin (µg/l)	0.0002	20	$1.02 \times 10^{+00}$	**$5.94 \times 10^{+00}$**	$1.48 \times 10^{+00}$	$1.83 \times 10^{+00}$	$3.15 \times 10^{+00}$
Antimony (µg/l)		10	$1.02 \times 10^{+00}$	$1.77 \times 10^{+00}$	$1.31 \times 10^{+00}$	$1.66 \times 10^{+00}$	$1.77 \times 10^{+00}$
Barium (µg/l)		34	$9.66 \times 10^{+00}$	$6.88 \times 10^{+01}$	$1.84 \times 10^{+01}$	$2.45 \times 10^{+01}$	$3.18 \times 10^{+01}$
Lead (µg/l)	7.2	19	$1.01 \times 10^{+00}$	$6.71 \times 10^{+00}$	$1.83 \times 10^{+00}$	$3.19 \times 10^{+00}$	$5.73 \times 10^{+00}$

Table 2.6 summarises the occurrence and detected levels of each of the pesticides in the wastewater effluent samples collected and analysed. The results are compared with the EQS levels applicable to the respective pesticides, where available.

Table 2.6 shows that 11 of the priority pesticides were detected in samples from Ringsend WWTP. The EQS limits for alachlor, chlorfenvinphos, diuron, chlorpyrifos and DEHP were exceeded (marked in bold in Table 2.6). Of the 36 samples collected at this site, only diuron was found to occur in all samples.

Of the 34 samples collected at Ringsend WWTP, all were shown to contain some levels of priority metals as shown in Table 2.7. It can be seen from the table that highest detected levels were determined for copper, zinc, boron, barium and molybdenum.

At this site, many of the metals were found to occur at a high frequency, with five of the metals detected at levels above EQS values (marked in bold).

2.3 Development of a Risk-Based Model

2.3.1 Model inputs, development, description and population

In order to determine the most suitable approach to adopt when preparing a model for the monitoring of emission factors for priority and hazardous substances, it is first necessary to evaluate some of the potential routes available. In a study by Ahlman and Svensson (2005), a simple geographic information system (GIS)-based model (SEWSYS) is presented that uses basic process parameters (deposition rates, accumulation time, flushing rates during rainfall) to predict storm water PS concentrations. It focuses on land use, including roof area and material type, road area, and traffic volume. This model attributes most heavy metal and PAH loadings to traffic (brake dust, tyre wear, exhaust and road surface wear). While this model provided valuable information on the type of data required and steps in establishing a basic working model, there were, however, many limitations which would have to be overcome. The SEWSYS model is

based on the MATLAB program, and the aim of the current study was to develop the model in a more accessible program, such as Microsoft Office Excel. Compared with the large number of pollutants required for monitoring by the WFD, the study by Ahlman and Svensson (2005) contains only 20 different substances (some organic pollutants, heavy metals and nutrients). As a much larger pollutant set with more varying physico-chemical characteristics and emission sources was looked at in this study, the SEWSYS model, while being a good stepping stone, needs more work before being suitable for the purposes of this project.

Throughout this project much information was obtained through verbal communication with the technicians on-site. In order for this study to be representative for the rest of Ireland, it is necessary to make information available so that the model can be fully populated for every location, thereby being more comprehensive. 13. From this work it was found that inspections were carried out by agencies, but information on the details of chemical usage or holding are not recorded, as it is not a requirement. Chemicals used in such unreported activities were found to occur in samples analysed in this project.

In order to design a model allowing for the determination of risk factors for PS emission in various catchment types, it was necessary to first identify all sources of background information for the population of the model. Figure 2.5 shows the range of data sources that were consulted in order to develop and populate the risk-based model.

In the context of this project:

- Historical data refer to all information collected from a wide variety of sources such as reports (e.g. Annual Environmental Reports (AERs)) and data collected by other parties (e.g. rainfall);
- Analytical data refer to the PS composition of samples analysed in this project;
- Data used to populate and adjust the theoretical model refer to the historical information; and
- Data for validation of the model are taken from the analytical information gained from sample analysis. The analytical data are used to validate the model by confirming the theoretically assigned risk of each site in the project.

The data sources shown in Fig. 2.5 were combined to populate the model, allowing for the development of the final risk-based model. The latter is used for predicting the risk of occurrence of specific PPs in wastewater effluent during different conditions.

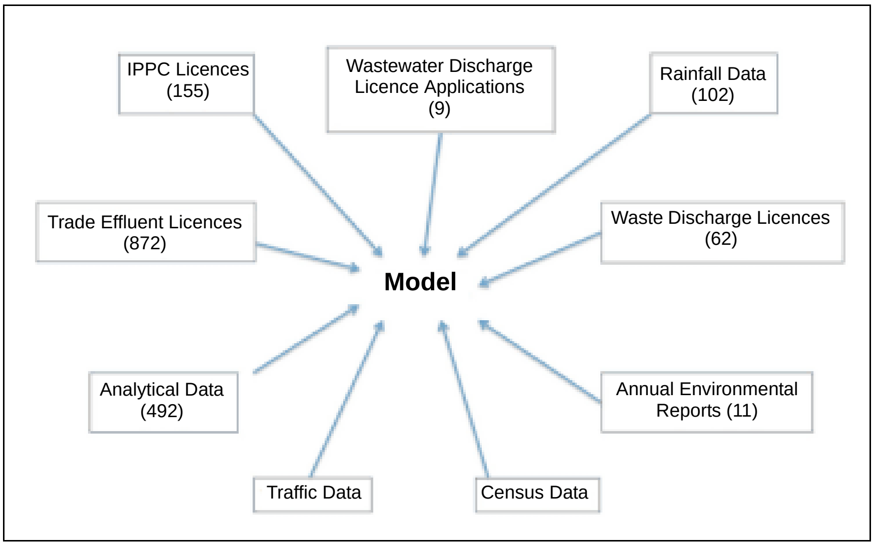

Figure 2.5. Sources and types of data used to populate the risk-based model. Numbers in parentheses indicate the number of sources accessed and used in the model development. IPPC, Integrated Pollution Prevention and Control.

Analytical data referred to in Fig. 2.5 are the data obtained from the analysis of samples of WWTP effluent collected over the project duration. The samples were analysed for the occurrence and level of PSs.

Figure 2.6 shows a schematic diagram of the final model, showing the relationship between the data collected and their place in the overall model.

The steps involved in development of the model were:

1. **Collating the variables of the model:** (see Sections 2.3.4–2.3.8) as listed in Fig. 2.5;

2. **Populating the model:** this provides predicted risk of occurrence of specific groups of pollutants under both wet and dry weather conditions;

3. **Comparison and adjustment of the model with measured levels of PSs in effluent** (i.e. the analytical data from two sites (Ballincollig and Ringsend) are used to optimise the modelled risk); and

4. **Validation of the model** (i.e. predicted risks of occurrence) by comparing the predicted risks of occurrence with estimated risk calculated from the analytical data sets.

2.3.2 *Risk rankings*

Risk rankings (as shown in Table 2.8) were developed to enable the categorisation of various emission factors of PSs according to the associated risk of loading attributed to each of those factors. The risk rankings were assigned based on collated data from a

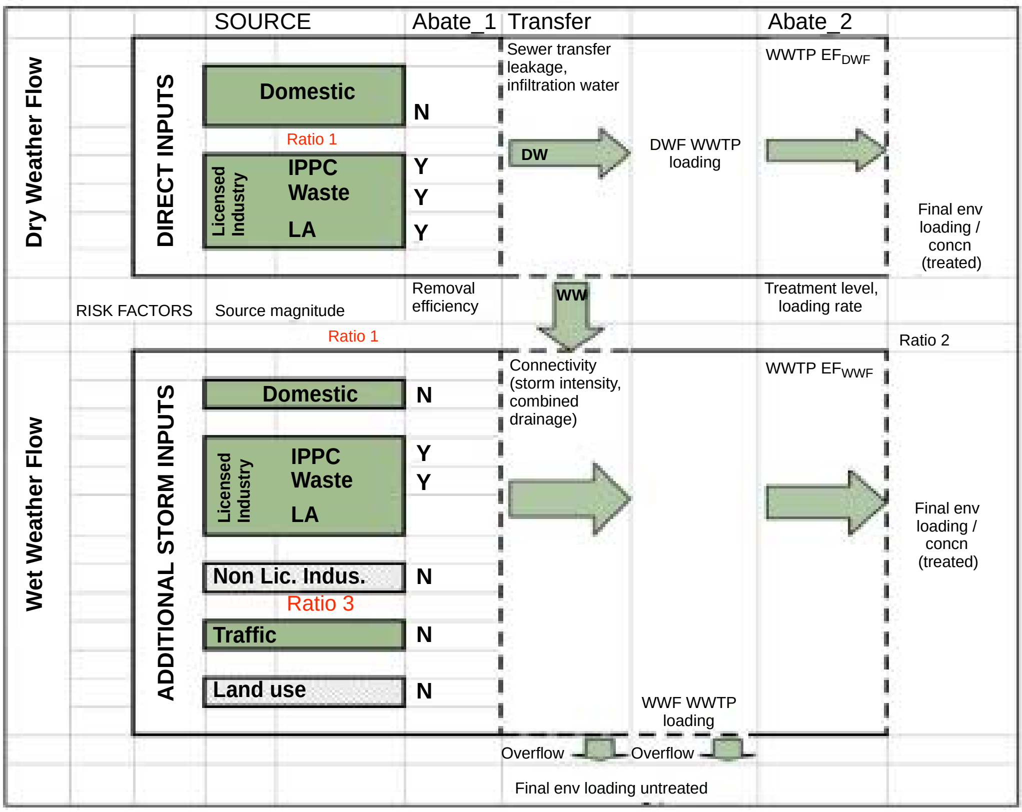

Figure 2.6. Overview of the information required to populate the model and how this information is related. LA, local authority; N, no; Y, yes; DW, dry weather; WW, wet weather; env, environmental; EF_{WWF}, effluent factor for wet weather flow; EF_{DWF}, effluent factor for dry weather flow; Non-Lic Indus., non-licensed industry. Note: DWF refers to flow in a sewerage system during periods of dry weather in which the system is under minimum influence of inflow and infiltration. WWF is DWF combined with storm water introduced into a combined sewer system, and DWF combined with infiltration/inflow in a separate sewer. IPPC, Integrated Pollution Prevention and Control; WWTP, wastewater treatment plant.

Table 2.8. Risk ranking scale applied to the data for the model.

Risk ranking	Description
0	No loading[1]
1	Light loading[2]
2	Significant loading
3	Substantial loading
4	Heavy loading[3]

[1]Either no data available or no suspected source of pollutants to this catchment from industry (e.g. sport, office).
[2]Industry with little emission of relevant pollutants (e.g. hotel).
[3]High number of relevant industry sources of PSs in the catchment resulting in a direct input or run-off risk (e.g. chemical, landfill).

number of sources (Fig. 2.5) in conjunction with the analytical results of the sampling campaign at each of the sites included in the study.

It was possible to validate the risk rankings assigned within the model, or indeed re-evaluate an assigned rank by confirmation with the analytical results obtained.

For the purpose of this project, Microsoft Office Excel was chosen as the platform for this model due to its simple user interface, widespread availability and use, and because it is a low-cost program that would be receptive to large volumes of data.

2.3.3 Selecting and characterising the agglomeration

The nine sampling sites were chosen on the basis that a spread of PEs, levels and types of treatment, and input to the treatment plants would best support a broad framework of knowledge from which to construct a model. Therefore counties Dublin and Cork were chosen to best represent these requirements. In order to prepare a valuable tool to assist PS monitoring for this study, it was necessary to collect any available information on each site in order to build complete data sets. Included in the wastewater discharge licence applications for each of the treatment plants is an agglomeration map. Figure 2.7 shows the steps involved in establishing the agglomeration map for each location.

Using this information it was possible to geo-reference each catchment map to a Google hybrid layer (Fig. 2.8). The catchment borders were plotted and conversions carried out in order to relate map distances to actual areas. This was carried out using a Google map distance measuring tool as illustrated in Fig. 2.7. In order to convert this map to a usable map from which the catchment area can be calculated, it

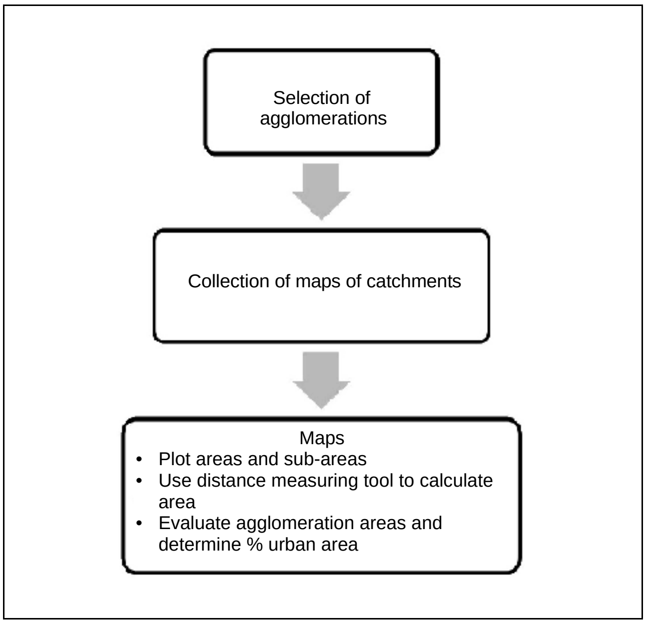

Figure 2.7. Preliminary data obtained from agglomeration mapping.

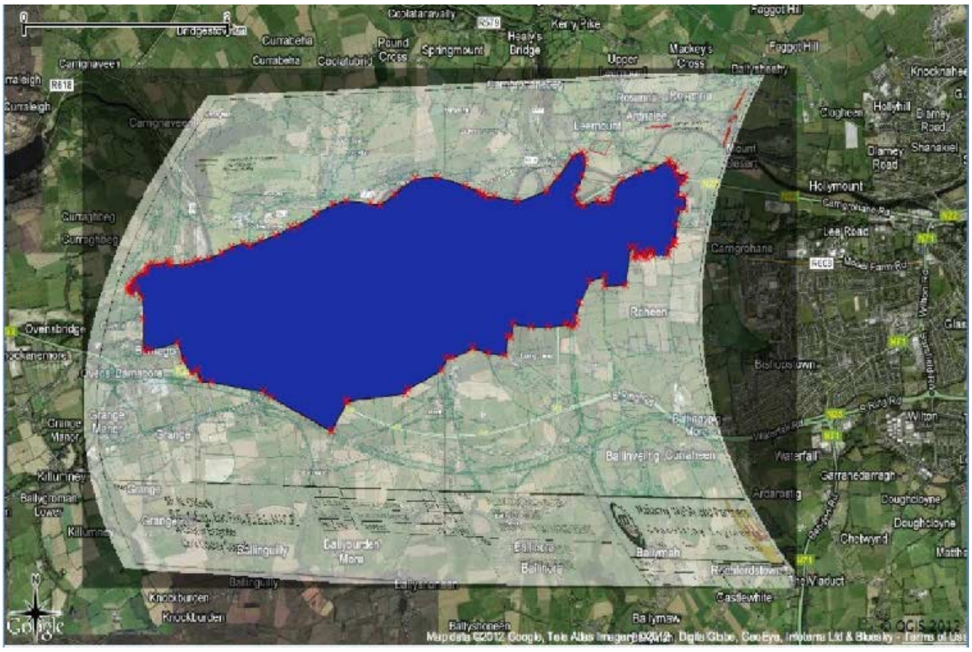

Figure 2.8. Quantum GIS mapping of Ballincollig agglomeration.

was necessary to perform a geo-referencing step. This refers to the selection of several points along the catchment border and direct referencing to the same point on a hybrid map canvas. As well as an overall catchment map, the licence applications can often also include maps of sub-areas to the catchment, as in the case of Ringaskiddy, and maps showing sampling points are referred to within the application. Each agglomeration was evaluated using the catchment maps along with census data from the Central Statistics Office (CSO) to provide the percentage urban area for each catchment.

Table 2.9 shows the steps taken in the calculation of the total areas of each catchment. From the Google hybrid map (Fig. 2.8), an appropriate scale was

Table 2.9. Calculation of the total areas of each catchment.

Name abbreviation	Sub-catchment	Length			Sub-area (ha)			
		km	cm	km per cm	1	2	3	Total area
BG	Ballincollig	4.902	23.7	0.207	760			760
BN	Bandon	3.541	17.3	0.205	458			458
CE	Charleville	2.96	21.5	0.138	172	58	44	274
CY	Town North of town Inchydoney	3.662 1.347 1.79	20.5 9.5 14.2	0.179 0.142 0.126	499 72 178			499 72 178
FY	Fermoy	3.434	25.1	0.137	394			394
MW	Mallow	4.211	19.1	0.220	595			595
RY	Carrigaline Crosshaven Ringaskiddy	8.908	13.1	0.680	444 83 246	194		638 83 246
RD	Ringsend	32.82	32.4	1.013	1,228	565	24934	26,728
SD	Swords	9.706	25.3	0.384	2,236	437		2,673

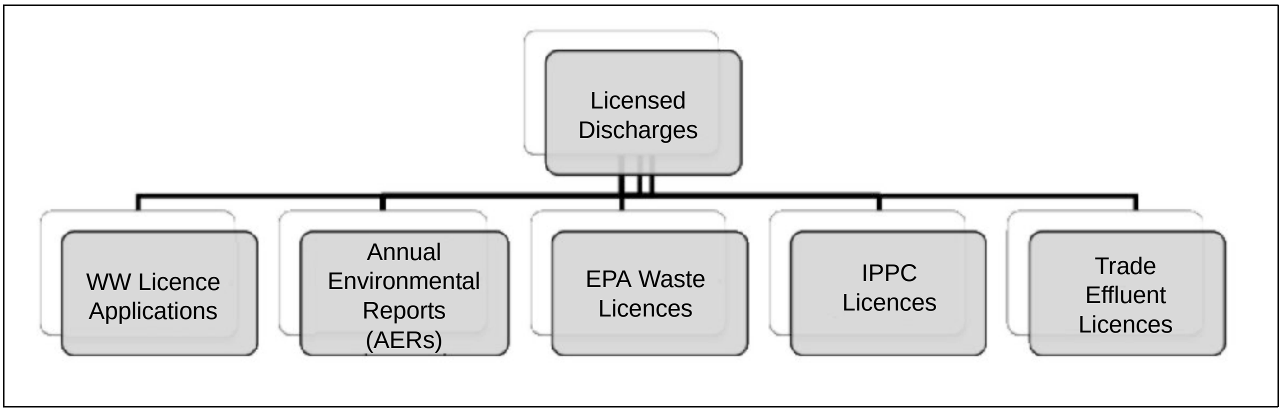

Figure 2.9. Overview of licensed discharges used as sources of data for populating the model. WW, wastewater; EPA, Environmental Protection Agency; IPPC, Integrated Pollution Prevention and Control.

available which allowed for transformation of the original map into an exact catchment area calculation.

Each agglomeration was then evaluated using the catchment maps along with census data to provide the percentage urban area for each catchment.

2.3.4 Licensed discharges

Having characterised the respective agglomerations, an evaluation into the significant sources of PSs in each, beginning with licensed emissions, was carried out. These emissions are broken down in Fig. 2.9.

From the research, it was found that not all businesses in the agglomeration have applied for trade effluent licences. This probably excludes a larger proportion of businesses in the small agglomerations, where sites may not be linked to the sewer network. Such sites (e.g. garages) may still contribute to sewer PS loading via surface run-off (Note: Some of these are represented by surface run-off rankings). Sewer loading of PSs from licensed installations was separated into direct sewer inputs and potential surface run-off inputs via combined drainage. This can be a problem with other unlicensed sources such as car washes, bed and breakfasts, shops, pubs, sporting facilities, etc., which are not taken into account. In 2008, it was reported that pollution loads arising from commercial sources were underestimated in the design of the Ringsend WWTP. The same report estimated the actual contributed PE from these commercial sources to be 190,000 on top of the pollution load arriving at the Ringsend WWTP.

While the maps are an important source of background information for the model, one of the greatest sources of large volumes of data required for populating the model are the wastewater effluent discharge licence applications and the AERs for each of the plants. Where available, these documents provided a wealth of information, as depicted in Fig. 2.10.

Basic information on the WWTPs and the agglomerations they serve is provided in applications for Waste Water Discharge Licences submitted to the EPA (http://www.epa.ie), as summarised in Table 2.10.

Three critical factors were derived from available WWTP operational data to estimate the equivalent level of treatment achieved by each WWTP under DWF and WWF conditions:

1. Level of treatment under normal operating conditions;
2. DWF load factor; and
3. WWF load factor.

As well as grid reference values and sampling dates, wastewater treatment licence applications and AERs provided information on the PE of the agglomeration which is broken down into domestic and licensed contributions. This allowed the characterisation of the loading factors to the plant to be carried out. The biological and hydraulic capacity of each plant was also included. However, the flow data were of the most value as these facilitated later calculations of base flow through each plant, allowing for the distinction of WWF

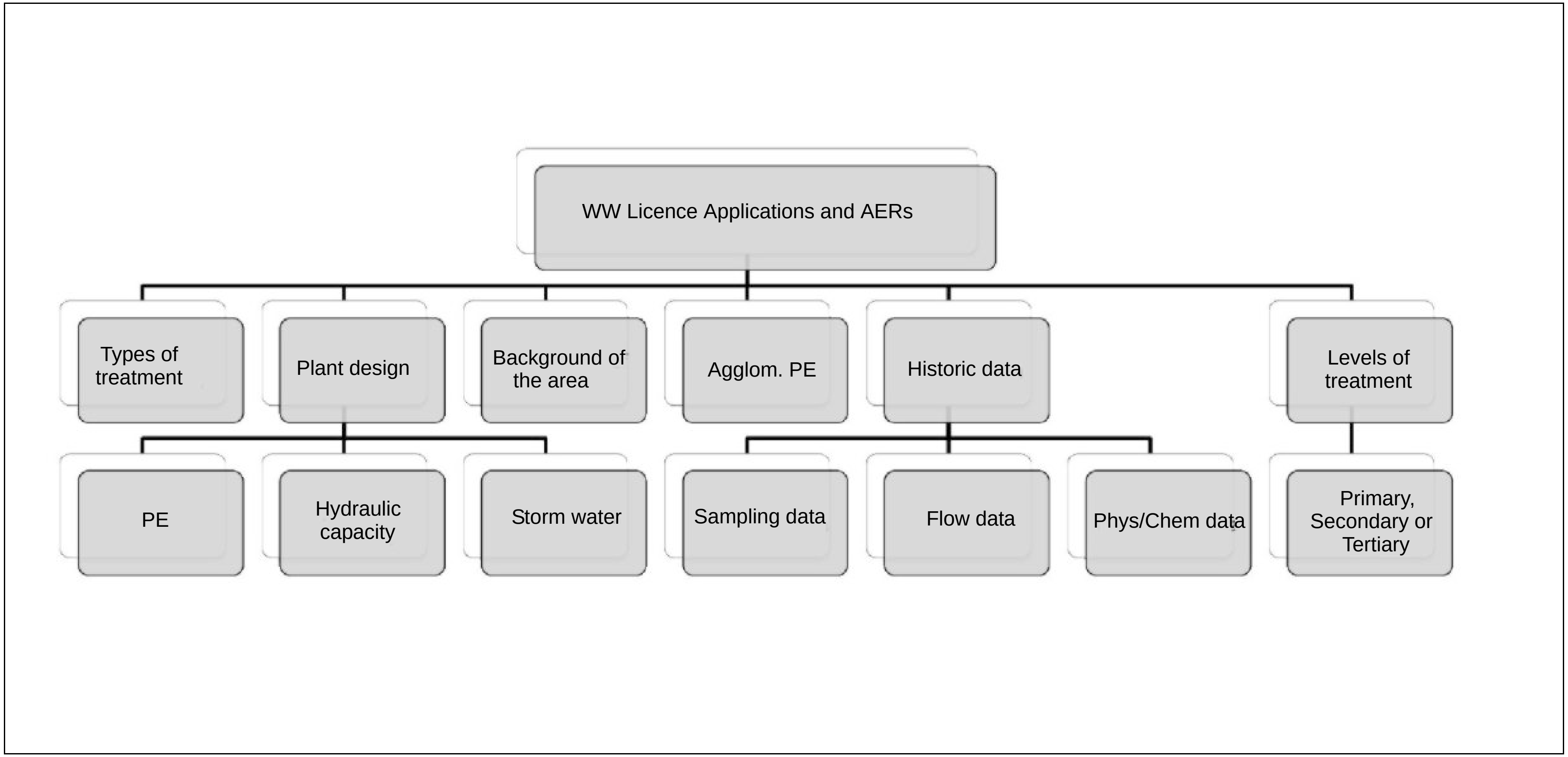

Figure 2.10. Information included in the wastewater treatment plant effluent discharge licence applications and Annual Environmental Reports (AERs); PE, population equivalent; WW, wastewater.

Table 2.10. Wastewater treatment plant (WWTP) and agglomeration characteristics, from wastewater effluent discharge licence applications.

WWTP	Treatment	Capacity PE	Agglomeration population	Area (ha)[1]	Receiving waters
Ballincollig (BG)	Secondary	26,000	16,339	760	Freshwater – river
Bandon (BN)	Secondary	20,000	6,200	458	Freshwater – river
Charleville (CE)	Secondary	15,000	2,984	274	Freshwater – river
Clonakilty (CY)	Secondary	6,067	7,500–15,000	750	Estuarine
Fermoy (FY)	Secondary, NR	20,000	5,800	394	Freshwater – river
Mallow (MW)	Secondary, NR	18,000	7,091	595	Freshwater – river
Ringaskiddy (RY)	None	0	14,864	967	Estuarine
Ringsend (RD)	Tertiary	1,640,000	1,200,000	26,728	Estuarine
Swords (SD)	Secondary, NR	60,000	50,000	2,673	Estuarine

[1]From the study calculations.
PE, population equivalent; NR, nutrient removal.

and DWF conditions in relation to specific sampling results. The flow data also aided in the calculation of loading factors and evaluation of the performance of a specific plant especially when it is operating above capacity.

2.3.5 Rainfall data

Rainfall in an area leads to increased flow through a WWTP, as water runs off buildings and roads and enters the sewerage system before eventually making its way to the plant. This creates a flushing effect at the plant, as this rainwater brings with it many pollutants that had been present as street dust, pesticides on grass and fields, and airborne particulates. During these periods of rainfall, an increased flow reaches the plant, often pushing a plant above capacity, and the stream is diverted to storm water overflow where the water can be released, untreated, back into the effluent stream. Met Éireann provided an extensive list of rainfall monitoring stations nationwide, including grid references, which allowed for their mapping. The rainfall data were used to assess the dry periods, rain intensity and rain duration and the effect of meteorological conditions at the time of sampling. Over 100 rainfall monitoring stations were plotted on a Google map in relation to each of the WWTPs. Pearson correlation coefficient values were used to assess the statistical significance of the data collected. For this purpose, each station within a 5-km radius of a WWTP was evaluated with regard to rainfall and flow within the plant. Correlation between stations was assessed for significance using the Pearson correlation values. Figure 2.11 shows rainfall monitoring stations mapped in the Dublin area. A similar process was carried out in the case of the Cork sites.

2.3.6 Traffic data

Traffic data obtained from the National Roads Authority (NRA), as well as the CSO, were used in conjunction with QGIS mapping techniques (refer to the End of Project Report), which allowed for the determination of average road usage in each catchment.

Traffic-induced loading to WWTPs (PAH, volatile organic compounds (VOCs), heavy metals (HMs)) should be largely proportional to traffic volume within agglomeration combined drainage areas, as measured by vehicle kilometres travelled (VKT). Relevant available statistics are traffic flow on national roads in the vicinity of study agglomerations, total VKT for different vehicle types and national VKT for six major road types (National Primary, National Secondary, Regional, Local Primary, Local Secondary, and Local Tertiary). Traffic was divided into two components: local traffic and through traffic. Local traffic was considered to be a function of agglomeration

Figure 2.11. Google map showing rainfall monitoring stations in the Dublin area. Wastewater treatment plants (WWTPs) are marked in red, with Swords WWTP to the north and Ringsend WWTP in the centre.

population, and was calculated based on the national average VKT per car on Regional and Local roads[2] estimated to occur within urbanised (i.e. WWTP agglomeration) areas – it was assumed that national average car ownership data (CSO, 2009) translated into a ratio of 0.4 cars per capita in Dublin City, and 0.5 cars per capita elsewhere in Ireland.

Local VKT within agglomerations was taken to equal the standard VKT per car (2,359 km per area unit; 2,949 km per area unit in Dublin), or twice the agglomeration length if this was smaller (to bound traffic volume by catchment size for smaller catchments). Local heavy commercial vehicle (HCV) traffic (lorries and buses) was calculated as a fixed ratio to car traffic based on CSO (2009) data. A weighting factor of 3 was applied to HCV traffic to generate car-equivalent VKTs that reflect higher PS deposition from HCVs (e.g. greater road wear and generation of brake dust, higher fuel use). The estimated proportional area under combined drainage was multiplied by agglomeration VKT to estimate the traffic-loading index for the catchment.

Through-road traffic was assumed to occur on N roads[3] within agglomeration boundaries. National road traffic count data for points on N roads in the vicinity of agglomerations (NRA, 2010) were multiplied by the length of the N road within agglomeration boundaries to generate N road VKT for each agglomeration. N roads were classified as peripheral (e.g. bypass roads) and central to the agglomeration. Peripheral roads were assumed to have independent drainage systems, whilst central roads were assumed to have combined drainage according to individual agglomeration proportional combined drainage estimates. For Dublin, where N roads radiate out of the centre and carry most commuter traffic to and from the city, through traffic was assumed equal to traffic on the radial M50 motorway. NRA data are reported as annual average daily traffic (AADT) and percentage HCV, enabling car equivalent VKT to be calculated for each N road.

2. From NRA (2003) data, extrapolated to 2008 based on the increase in national VKT between 2001 and 2008 (CSO, 2009).

3. National Primary and National Secondary roads.

2.3.7 WWTP removal efficiencies

WWTPs can be major point source inputs of PSs to surface waters, and while many studies show that wastewater treatment removes 90–95% of pollutants, this removal efficiency depends on a number of factors. In order to calculate the loading of PSs attributed to the WWTPs, it was first necessary to determine approximate removal efficiencies for each of the pollutants within the respective plants. This was obtained from literature review and AERs. The values recorded are directly related to the operations at the plant, the input to the plant, the treatment levels/types received by the water at each site. Taking the removal efficiencies, based on literature review and statistical weighting (see End of Project Report) for the four main groups of PSs (PAHs, pesticides, metals and volatiles), it was possible to compile all data collected (licensed information, rainfall and traffic data and removal data) into a functional model.

2.3.8 Conceptual modelling

The conceptual model is devised to identify key risk indicators of PS loadings applicable under DWF and WWF conditions. To convert the risk factors assigned into estimated loading factors for each WWTP for populating the risk model, loading was considered to be exponentially related to the four risk factors (as clarified in Section 2.3.9). This reflects the wide range of loading expected from different licensed sources, with large Integrated Pollution Prevention and Control (IPPC) sites, for example, discharging up to 100 times the volume of commercial sites.

WWTP load factors were calculated as a ratio of agglomeration PE loading to WWTP PE capacity. For Clonakilty WWTP, with a calculated load factor of 2.2, DWF removal factors were based on the assumption that half the flow received secondary treatment, and half received primary treatment only. For WWTPs working in excess of or close to capacity, wastewater removal factors were based on the assumption that overall removal efficiencies under high loading conditions were equivalent to primary treatment removal efficiencies. Removal factors were inversed into effluent factors (EFs) for direct multiplication with loading factors.

Loading to the environment from each WWTP under DWF can be expressed as DWF domestic loading (population size) plus DWF industrial loading (total agglomeration PE), multiplied by EF_{DWF}.

Risk of elevated DWF PS conc. =
$(Industry_{DWF} / Pop) \times EF_{DWF}$ (Eqn 2.1)

Equation 2.1 can be further expanded as below:

Risk of elevated DWF PS conc. =
$((Agg\_Ind_{DWF} / Nat\_Ind_{DWF}) / (Agg\_Pop / Nat\_Pop)) \times EF_{DWF}$ (Eqn 2.2)

where Agg_Ind_{DWF} is the total industrial contributions from the agglomeration under DWF conditions (taken from number of industrial licensed inputs in each agglomeration); Nat_Ind_{DWF} is the total national industrial contributions under DWF conditions (taken from total number of industrial licensed inputs nationwide); Agg_Pop is the total population loading for the agglomeration – this represents domestic inputs; Nat_Pop is the total national population loading; and EF_{DWF} is the effluent factor under DWF conditions.

Under WWF, WWTP loading is a function of DWF loading, plus WWF domestic loading, plus WWF industrial loading, plus WWF traffic loading, plus WWF land-use loading, all multiplied by EF_{WWF}. Assuming that industry and transport sources are major contributors to WWTP PS loading, then the risk of elevated PS concentrations can be simplified thus:

Risk of elevated WWF PS conc. =
$(Industry_{DWF} / Pop) + (Industry_{CD} / Area_{CD}) + (Traffic_{CD} / Area_{CD}) \times PDP \times EF_{WWF}$ (Eqn 2.3)

where PDP is the preceding dry period (should be linearly related to loading); $Industry_{DWF}$ is the total industrial loading under DWF conditions; Pop is the domestic population of the agglomeration; $Industry_{CD}$ is the total industrial loading in the combined drainage area; $Area_{CD}$ is the total combined drainage area; $Traffic_{CD}$ is the traffic loading in the combined drainage area; and EF_{WWF} is the effluent factor under WWF conditions.

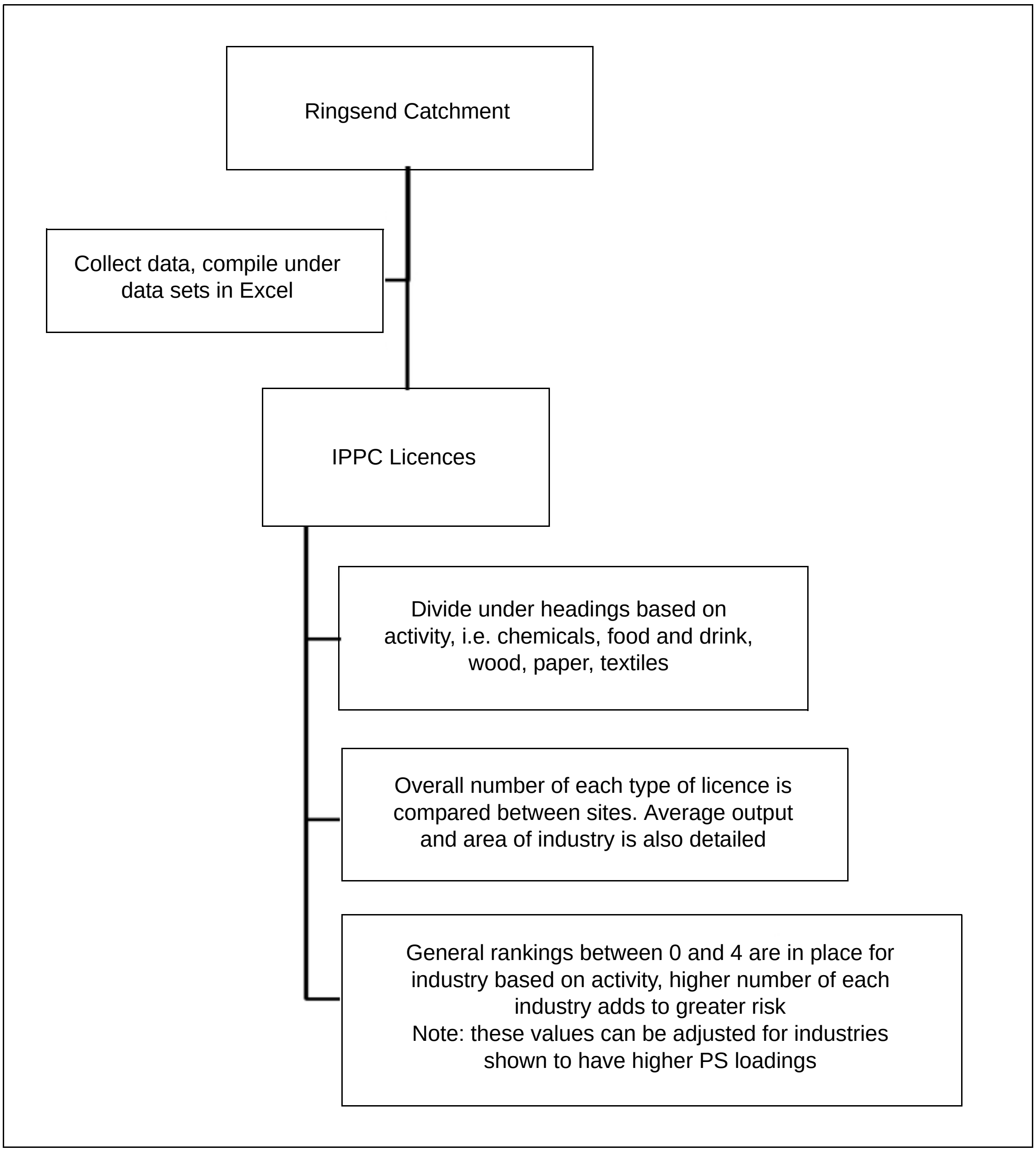

Figure 2.12. Overview of procedures involved in assigning risk factors using Integrated Pollution Prevention and Control (IPPC) licences as a sample source from the Ringsend catchment. PS, priority substance.

2.3.9 Assigning risk

Assigning risk values for different PSs under different conditions follows the procedure outlined in Fig. 2.12 and is used along with the conceptual modelling described previously.

This is expanded upon in Fig. 2.13. using another example to illustrate assigning of risk values to the different catchments for the Ballincollig site.

To give a more specific example, Fig. 2.14 tracks a single trade effluent licence, for a petrol station, from collection of the licence to the assignment of a risk factor.

The risk factor determined for the site described in Fig. 2.14 is a single risk for a single site. For a single petrol station, the risk of PAH, VOC and metals occurrence is 2 (per group) while pesticides are risked as 0. When all trade effluent licences for Ballincollig

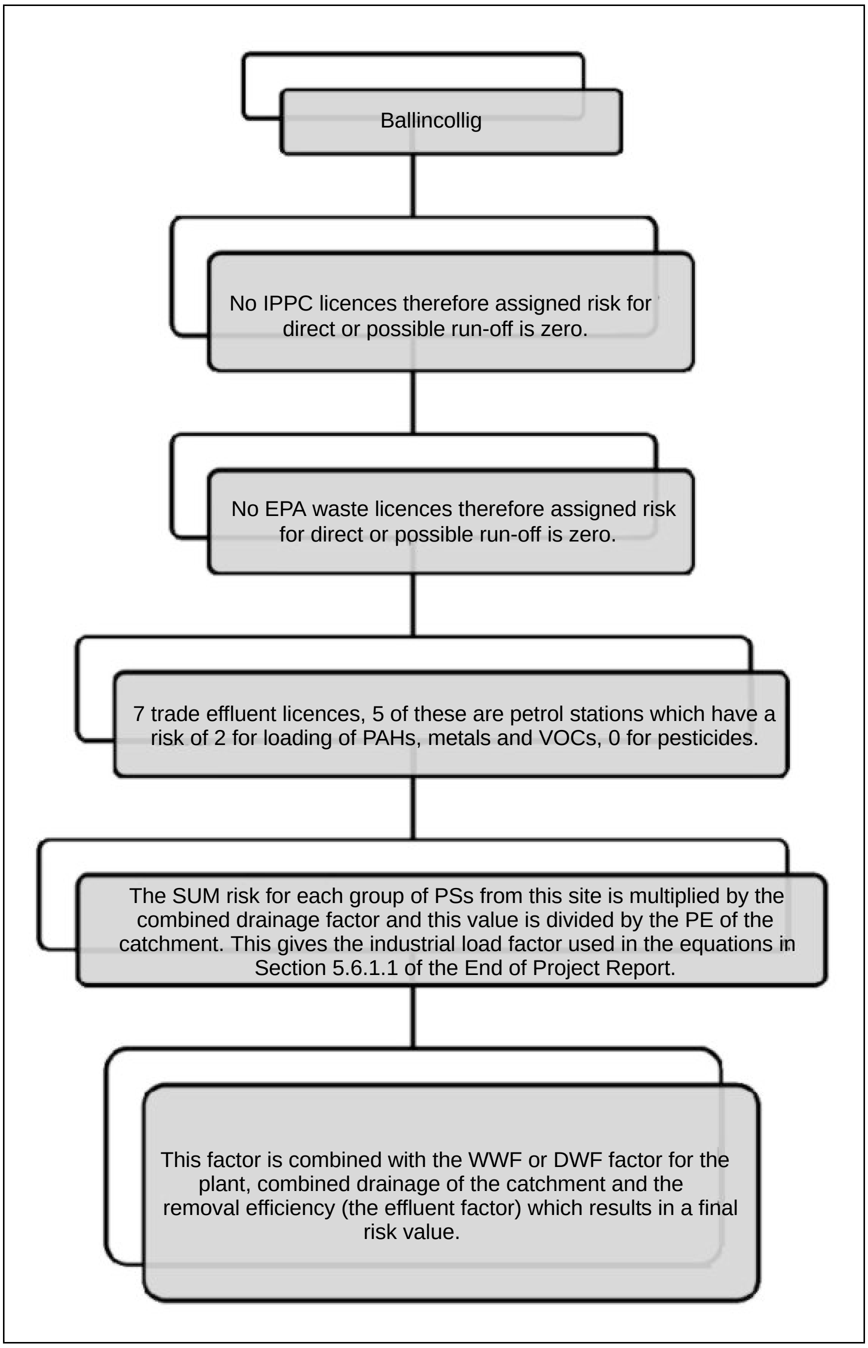

Figure 2.13. Outline for assigning risk based on Integrated Pollution Prevention and Control (IPPC) licences in Ballincollig. EPA, Environmental Protection Agency; PAH, polycyclic aromatic hydrocarbon; VOC, volatile organic compound; PS, priority substance; PE, population equivalent; WWF, wet weather flow; DWF, dry weather flow.

have been evaluated in this manner, the same procedure is carried out for waste discharge licences and IPPC licences. As Ballincollig had no licences other than trade effluent, this was the simplest site to model. The SUM risk for each group of pollutants assigned from the seven trade effluent licences was used to calculate the final risk. For example, the SUM PAH risk for Ballincollig of 38 shows how this number relates to the final DWF risk for PAHs in Ballincollig. Taking Ballincollig as an example, and focusing on PAHs during DWF, Table 2.11 sets out how the final risk factor is achieved.

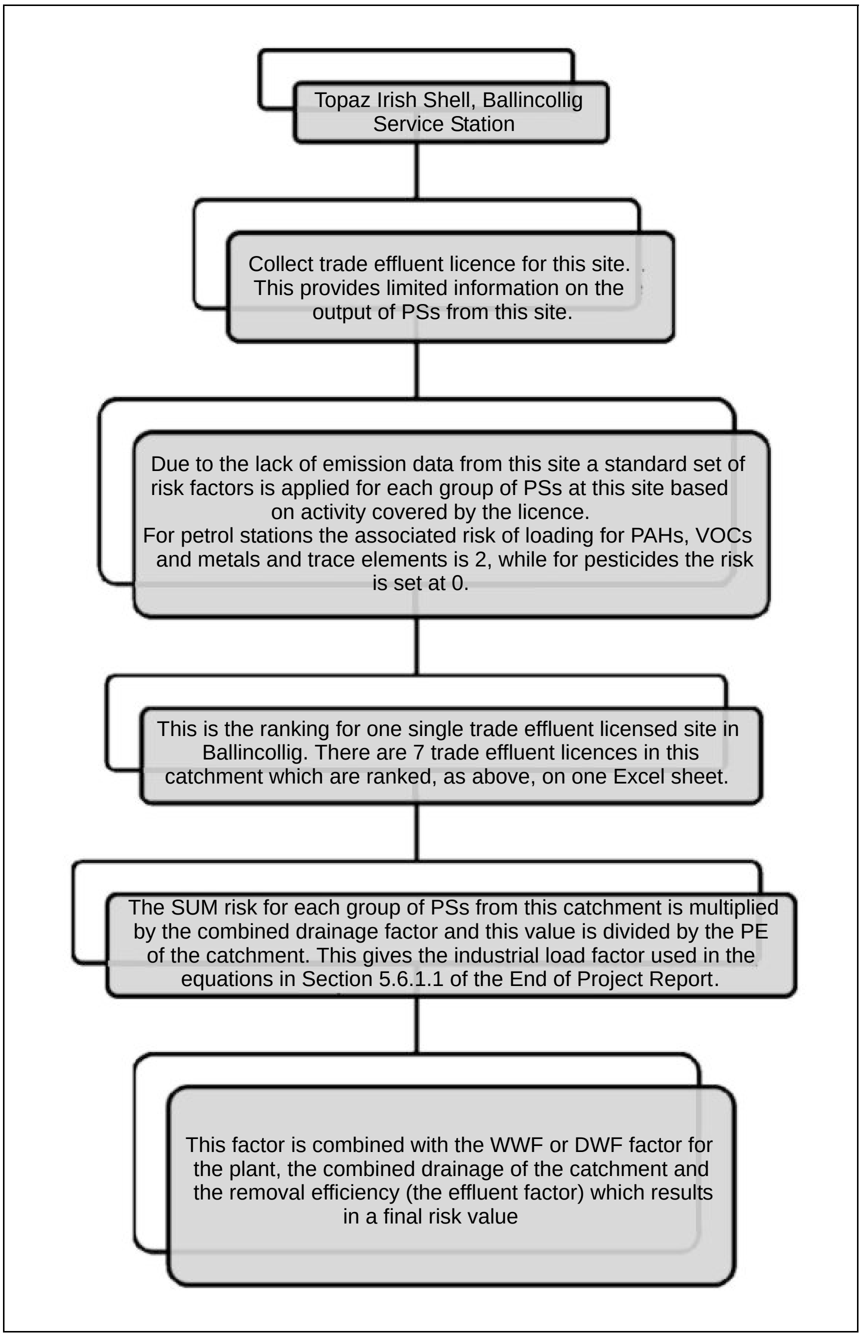

Figure 2.14. From licence to risk factor for a petrol station in Ballincollig, Cork. PS, priority substance; PAH, polycyclic aromatic hydrocarbon; VOC, volatile organic compound; PE, population equivalent; WWF, wet weather flow; DWF, dry weather flow.

Table 2.11. Final calculation of dry weather flow (DWF) risk factor for polycyclic aromatic hydrocarbons in Ballincollig.

	PE	Industrial risk factor	Effluent factor	DWF risk
Ballincollig	17,989	38	0.2	**0.09**
National	4,240,000	20,000		

PE, population equivalent.

- The PE has been gathered from WWTP licence application and census records for this catchment.
- The calculation of the industrial risk factor has been outlined above.
- The effluent factor is assigned as 0.2. This was derived from the standard removal efficiency of PAHs from secondary treatment. The effluent factor can be any value from 1 to 0, with 1 indicating no removal of the pollutant and 0 indicating 100% removal of the pollutant. The value of 0.2 here indicates 80% removal of PAHs at this site under normal operating conditions.
- The national population is under National PE.
- The national industrial risk factor is the total number of trade effluent licences.

Finally, the DWF risk is calculated:

- DWF risk for PAHs = (industrial risk divided by national industrial risk) divided by (PE divided by national PE) multiplied by the effluent factor = 0.09.

2.4 Model Population to Determine Risk Values and Validation Using Two Sites

Population of the model with analytical data could only be carried out after the sampling regime had been completed and the samples analysed. The analytical results obtained from each of the sampling sites have been used to validate the final model. Results are available in the End of Project Report.

The final step in the establishment of the risk model was the population of the model with sampling data from two sites. This includes data collected at the nine WWTPs over the 24-month (2009–2011) period for an overall sample set of 164 samples (n = 3). Samples were analysed for the presence of trace levels of eight PAHs, 14 pesticides and 15 metals. Historical information allows models to be populated with high-quality, representative data, making the final model more reliable and robust. They also identify data needs in the area. Through the sampling regime carried out in this project it is important to highlight the value of intensive sampling data. The analysis of samples for VOCs was not carried out in this work; however, it is possible to establish risk information based on the available information and literature reports.

Figure 2.15 presents an overview of the final risk factors for each group of PSs at the nine WWTPs under both WWF and DWF conditions. These data are also presented in Table 2.14. (Note: These values are predicted from the model which has been populated with historical sampling data.) For the pesticides, VOCs, metals and trace elements, there are consistently higher risks associated with WWF conditions. This is representative of the higher run-off risk loadings attributed to sources of PSs in the catchments. The PAHs were found to have higher risk of direct loading from licensed sources than from run-off, with traffic proving to be one of the largest contributors of PAHs. This would indicate that these sites should be monitored specifically for PAHs at periods of DWF when there is a greater likelihood of elevated priority substance occurrence to be detected.

By examining two of the sites more closely, Ballincollig in Cork and Ringsend in Dublin, it is possible to validate the model making it applicable to any site. As no VOC analysis was carried out that model is based entirely on historical, licence and collected data.

Ballincollig and Ringsend were chosen as the sites to be included in this model validation step as they represent both counties in the study, two different levels of treatment and removal efficiency, two different types of input to the respective plants and were the sites with the most available data for collection and population of the model. They are representative of the range of conditions evaluated in the model. Specific flow data for each of these WWTPs allowed for a clear distinction between WWF and DWF conditions, whereas a number of the other sites did not collect flow data sets and flow data were determined solely from weather conditions and historical data. These facts made Ringsend and Ballincollig the most rational choices for the validation study.

Table 2.12 provides a comparison between the Dublin and Cork sites. This table shows detected exceedance of EQS values for specific pollutants from each group of pollutants by site. The percentile of exceedance is

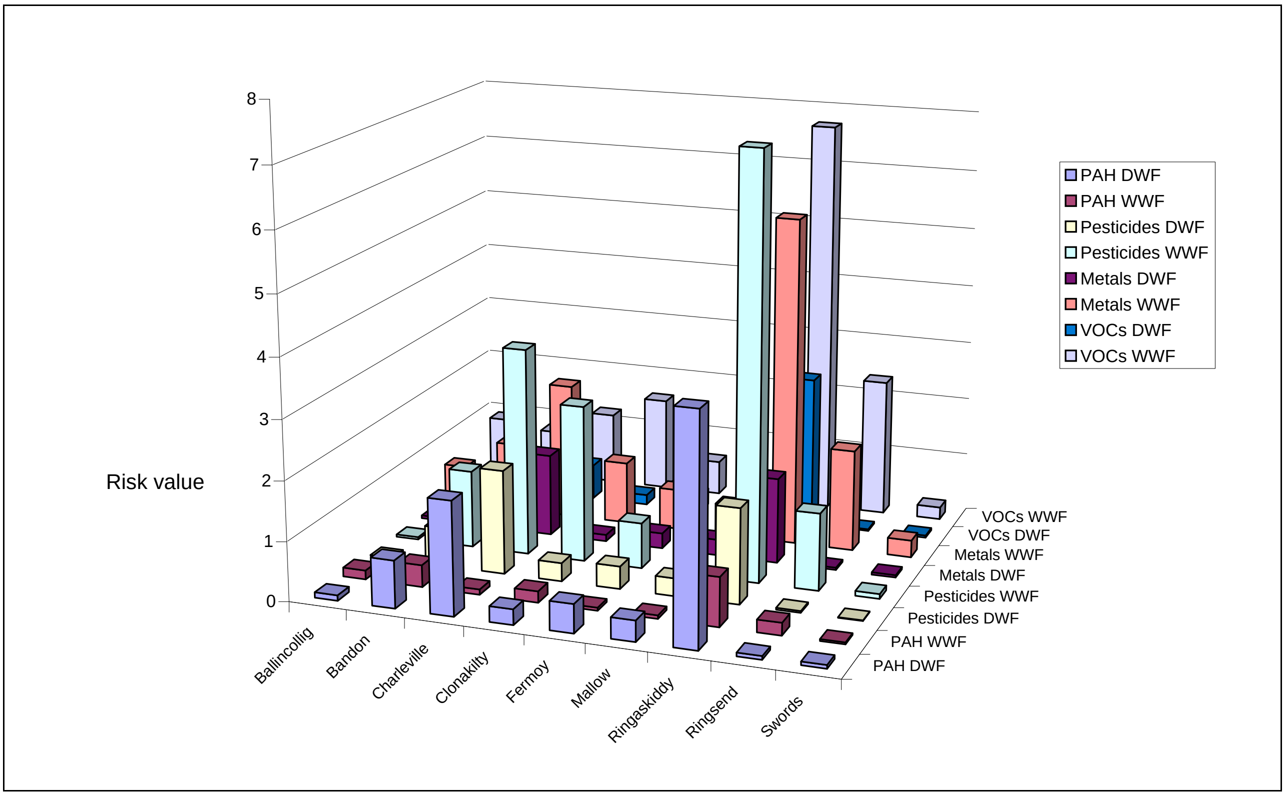

Figure 2.15. Graphical representation of final risk values assigned to each of the four main groups of priority substances during periods of both dry weather flow (DWF) and wet weather flow (WWF) for each of the sites included in this study. These values are predicted from the model based on the collection of historical data. PAH, polycyclic aromatic hydrocarbon; VOC, volatile organic compound.

Table 2.12. Exceedances of priority substances at two wastewater treatment plants.

Analyte groups	Ballincollig	Ringsend
PAHs	• Benzo-b/k-fluoranthene and indeno-1,2,3cd-pyrene/benzo-ghi-perylene all exceed EQS in the 90th percentile	• Indeno-1,2,3cd-pyrene/benzo-ghi-perylene exceed EQS above the 90th percentile
Pesticides	• Chlorfenvinphos and DEHP exceed EQS in the 50th percentile	• Alachlor, DEHP, chlorfenvinphos, diuron, and chlorpyrifos exceed EQS in the 90th percentile
Metals and trace elements	• Tin and lead exceed EQS above the 50th percentile	• Chromium, copper, zinc and tin exceed EQS in the 50th percentile • Nickel exceeds EQS in the 90th percentile

PAH, polycyclic aromatic hydrocarbon; EQS, environmental quality standard; DEHP, di(2-ethylhexyl) phthalate.

also included to show the frequency of occurrence of these high levels of PSs.

Ballincollig was found to have low risk attributed to all areas even during WWF, while Ringsend was classified as at risk of high levels of both pesticides and metals under the same conditions. Breaking this down by group, it is possible to rationalise these results. First, focusing on the PAHs, the results show that Ringsend was found to have higher frequency of occurrence for the WFD priority PAHs than Ballincollig, and the WWF risk is corroborated by the maximum sum PAH concentration detected during WWF which was only 2.06×10^{-2} at Ballincollig compared with 7.56×10^{-2} at Ringsend; the same was true for mean

PAH concentrations. This result is expected when taking into account the catchment characteristics; while Ringsend has over 200 licensed sources of PSs that were evaluated for risk Ballincollig has only seven trade effluent licences, four of which are petrol stations that are considered to be sources of PAHs, making them the main licensed sources of PAHs in that catchment. Also, in conjunction with the much lower population in the Ballincollig catchment compared with the Ringsend catchment, there is a higher level of traffic contributing PAHs to Ringsend than to Ballincollig. However, when taking into account notably high levels of occurrence, Table 2.12 shows that while there was a higher frequency of occurrence of PAHs at Ringsend, there were more exceedances of EQS levels in Ballincollig.

The pesticides were risked higher at Ringsend than Ballincollig for both WWF and DWF. While results show higher percentage occurrence of most pesticides at Ringsend, results gave both higher maximum sum pesticide concentration and average sum pesticide concentration at WWF for Ballincollig. Table 2.12 shows that while Ballincollig has a higher level of EQS exceedance for two pesticides, Ringsend has a greater range of pesticides exceeding EQS values in the 90th percentile of samples. Ballincollig, although covering a much smaller area than Ringsend, has both a higher combined drainage factor and a higher percentage non-urban area than Ringsend (30% compared with 25%).

The issue with pesticide loading factors can be attributed to data gaps in this area, specifically usage data and unlicensed sources. Large comprehensive data sets are needed that would cover the usage statistics, import and purchasing of PSs, especially pesticides, as there are currently unexplained levels of banned substances occurring in Irish wastewaters. For example, pesticides, such as atrazine and simazine, were found to be present in a number of samples collected at sites in both Dublin and Cork, substances which have been banned for several years. Other pesticides, such as alachlor and aldrin, were also detected even though these substances would have to be sourced from African or Mediterranean countries and would not be expected to be found here in Ireland. It is discoveries such as these that lead the authors to recommend that banned and obscure pollutants are not removed completely from current and future monitoring programmes as their continued presence in water systems must be noted and steps to remediation taken. There are also potentially large sources of pesticides that are unlicensed, for example golf courses apply pesticides but are not required to report usage of, account for disposal of or potential run-off of pesticides from their greens, leading to official loading factors of zero. Through the development of this model, it is observations such as these that will facilitate the success of future monitoring programmes.

The metal and trace element risk assessments met expectations, with Ringsend ranked as a higher risk than Ballincollig. Ringsend shows both higher percentage frequency of occurrence for the metals and trace elements, but also a wider variety of these substances than Ballincollig. Table 2.12 shows results in agreement with the model, with a number of metals found to exceed EQS levels at a higher percentage occurrence in Ringsend than for Ballincollig. Ringsend also covers a much larger catchment, with a higher percentage urban area than Ballincollig (75% compared with 70%). This catchment included 36 waste licences, 66 IPPC licences and 253 trade effluent licences, many of which are for laboratories, construction and machinery companies, the transport industry and other sources that are highly ranked for loading of PSs.

Through the comparison of these sites, the model predictions have been found to be in line with analytical results. This correlation arises from a strict sampling regime based on a large data set of licences, AERs and historic data. The model can be further adapted and is receptive to unlimited amounts of data making it amenable to continuous updating.

2.4.1 Summary of observations

Table 2.13 shows a ranking system converting risk factors to a scale of risk of PS occurrence under different conditions of DWF and WWF.

In order to summarise the overall observations of the study, Table 2.13 shows a final risk ranking for every site under conditions of DWF and WWF for each of the four PS groups. VOCs were not analysed in this project, but based on historical data available (see End

Table 2.13. Ranking system converting risk factors to scale of risk of priority substance occurrence under different conditions.

Scale	PAHs		Pesticides		Metals		VOCs	
	DWF	WWF	DWF	WWF	DWF	WWF	DWF	WWF
<0.05	LR	LR	LR	LR	LR	LR	LR	LR
0.06–0.1	LR	LR–SR	SR	LR	LR–SR	LR	LR	LR
0.11–0.5	SR–MR	MR	MR	LR	SR–HR	LR–SR	SR–MR	LR–SR
0.51–1	MR–HR	HR–VHR	HR	SR–MR	HR–VHR	SR–MR	MR–HR	SR–MR
1.1–1.5	HR	VHR	HR–VHR	MR–HR	VHR	MR–HR	HR–VHR	MR–HR
>1.5	VHR	VHR	VHR	HR–VHR	VHR	HR–VHR	VHR	VHR

PAH, polycyclic aromatic hydrocarbon; VOC, volatile organic compound; DWF, dry weather flow; WWF, wet weather flow; LR, low risk; SR, some risk; MR, moderate risk; HR, high risk; VHR, very high risk.

Table 2.14. Final risk rankings attributed to each site for the four main groups of Water Framework Directive priority substances under both wet weather flow (WWF) and dry weather flow (DWF) conditions.

Site	PAHs		Pesticides		Metals		VOCs	
	DWF	WWF	DWF	WWF	DWF	WWF	DWF	WWF
Ballincollig (BG)	0.09	0.15	0.02	0.04	0.05	0.66	0.03	0.93
Bandon (BN)	0.8	0.37	0.65	1.31	0.44	1.17	0.3	0.8
Charleville (CE)	1.9	0.09	1.75	3.5	1.39	2.32	0.6	1.23
Clonakilty (CY)	0.26	0.19	0.31	2.64	0.11	1.06	0.17	1.6
Fermoy (FY)	0.48	0.05	0.38	0.77	0.26	0.69	0.28	0.58
Mallow (MW)	0.35	0.06	0.3	0.59	0.27	0.53	0.13	0.26
Ringaskiddy (RY)	3.79	0.82	1.6	7.1	1.44	5.55	2.56	6.71
Ringsend (RD)	0.06	0.21	0.03	1.3	0.04	1.72	0.03	2.34
Swords (SD)	0.06	0.03	0.01	0.08	0.04	0.29	0.04	0.21

PAH, polycyclic aromatic hydrocarbon; VOC, volatile organic compound. Dark green – low risk. Light green – some risk. Yellow – moderate risk. Orange – high risk. Red – very high risk.

of Project Report) it was possible to establish a risk of occurrence also for this group.

Table 2.14 shows the final model-predicted risks of occurrence of PSs in wastewater. The rankings applied relate to the scale of risk of occurrence of PSs. Green indicates a low risk of PS loading during certain conditions, with risk progressively increasing to a high risk of loading indicated in red. The Ringaskiddy site has been ranked as very high risk owing to the lack of treatment of the wastewater at this site.

Through the collection of data as described in the End of Project Report, it can be concluded that the same ranking system can be applied to other catchments and can be used as a guidance document for the monitoring of PSs in an area. By generating risk factors using the methods described, the scale outlined above can be used to evaluate the risks of occurrence of PSs at a site under both wet and dry weather conditions.

The results of this project indicate that a very effective risk-based model has been developed for monitoring PSs/PHSs on the basis of assessing risk of occurrence. The model uses readily available data and has been validated by analytical data collected over the duration of the 3-year project.

3 Key Project Outputs

The outputs of this project include new information on the occurrence of PSs in Irish wastewater effluents, new analytical methods, a new tool to assist the monitoring of PPs and recommendations on how monitoring might be improved. The output of the risk-based model devised in this project identifies the likely occurrence of groups of PSs based on WWTP PE and usage. This approach can be applied to other locations in Ireland and can inform a monitoring programme for WFD compliance.

The project involved the collection of data from a wide range of sources such as licences, reports and discussions with stakeholders. Some of this information is new and most of the information has never been used to develop a tool like the risk-based model from this project. All of the collected information was made available at the end of the project from the EPA Safer database (see Appendix 2 for more information on project outputs).

Analytical methods for the determination of PP pesticides and PAHs were adapted from methods described in the literature and the project team has published improvements in current methods (see End of Project Report for references). SOPs were developed for all steps in the analytical process and these were used by the team for sampling, sample treatment and analysis. A new risk-based model has been tested against the analytical data collected from the analysis of the samples from Cork and Dublin wastewaters.

Throughout the project two workshops were held and stakeholders and other researchers were invited to discuss the topic of PP monitoring. The aims of the workshops were to:

- Bring together stakeholder groups to discuss project progress at different stages in the project;
- Identify knowledge gaps in the monitoring of PSs;
- Find opportunities to inform monitoring, e.g. PRTR; and
- Provide data generated in the project that may be of value to stakeholders.

These workshops helped build awareness of the issues of monitoring PSs/PHSs and the factors affecting their occurrence in particular.

This project has provided postgraduate and postdoctoral research training opportunities, including project management training, generic research skills training and analytical skills training to four researchers in the project, building the capacity for both analytical science and environmental monitoring in Ireland. The project became an important sounding board for parallel PS/PHS projects in the EPA and local authorities.

Important relationships have been established between key stakeholders in Ireland providing the potential for future collaboration on environmental research. This, together with international engagements during this and other projects, provides the opportunity for national and EU research funding in the future.

The following project resources and outputs are also available at http://erc.epa.ie:

- PhD Thesis 1: Development of a Risk-Based Model for Use in Water Quality Monitoring. Lisa Jones;
- PhD Thesis 2: Novel LC-MS Methods for the Determination of Environmental and Food Contaminants Incorporating Analyte Confirmation Using High Resolution Mass Spectrometry. Michael Cahill;
- Raw analytical data sets; and
- The model.

The project website can be found at http://www.priority-substances.com.

4 Conclusions from Research and Future Research Needs

The need for good analytical methods is clear and as new and emerging pollutants are introduced to legislation it will be more important than ever to have monitoring programmes capable of meeting worldwide requirements. It is a model (or tools) such as this one that makes these monitoring programmes possible, by informing the monitoring approach and highlighting the areas that require the most attention. Monitoring our waters for PPs and emerging contaminants for compliance with the WFD monitoring requirements is a significant task and the information provided from this research together with a risk-based model can assist in formulating monitoring approaches in the coming years. Both licensed and unlicensed activities contribute to the input of PSs/PHSs to wastewater treatment works and the unlicensed sources play a significant role in the occurrence of certain pollutant groups.

The aim of this project was to establish risk values that relate PEs to the occurrence of PPs. The project focused on the development of analytical methods and the analysis of samples for the occurrence of PSs in order to develop a monitoring tool based on emission factors. SOPs for sample collection, handling and preparation were established and methods for sample analysis were developed. This project involved the sampling and analysis of water from two counties, Dublin and Cork, representing a variety of characteristics, loadings and practices. The sites were chosen on the basis of sources of pollutants, PEs and likely occurrence of PSs. The project revealed that information on licensed sources is valuable in developing a risk-based model. However, unlicensed sources of chemicals are significant in number and relevance to the development of a monitoring tool. This project successfully developed a risk-based model for the assessment of sites in relation to PS/PHS occurrence.

The End of Project Report provides detailed methods for the sampling and analysis of samples for pesticides, PAHs and metals in the PP list. Details on site characteristics and catchment maps are also provided in the End of Project Report together with the data available for each site relating to PE, practices in the catchment, traffic and rainfall. The report, which details and analyses these data, provides a very valuable resource for further research and use in monitoring. The technical information is of value to agencies, local authorities and other researchers and the model is now available for trial at other locations using the steps provided in the End of Project Report.

Critical research areas that should be addressed are:

- Methods for determining pesticides and emerging contaminants are still underdeveloped and require development and testing in suitable sample types.
- Methods for the determination of PSs and PHSs in biota and sediments may provide more valuable information regarding occurrence, availability and toxicity. Therefore emphasis should be placed on the development and application of passive sampling methods for determination of uptake by organisms.
- There is a need to collaborate with agencies that are already working on passive sampling in parallel to biota studies incorporating fish or shellfish. Passive sampling may provide a cost saving in terms of monitoring requirements and therefore this needs to be explored in relation to current and emerging PSs for WFD monitoring.
- Novel materials and deployment approaches for passive sampling should be developed.
- Desk studies of data collation and management would be useful to help roll out a risk-based model for monitoring.
- Continued research on the effect of rainfall, storm water and treatment efficiency is needed to establish the likelihood of pollutants entering waters.

- The project team will build on the knowledge gained and contribute to future research in a follow-up project on the role of passive sampling in the screening and monitoring of new and emerging chemicals. This project started in 2013 (https://sites.google.com/site/irishpassivesampling/).

5 Recommendations for Implementation and Uptake of Research Findings

- Prior to this project there were few historical monitoring data available to be used in order to build and test the model. Therefore the data generated by this project, while only based on two counties, provide a wealth of information on occurrence and usage of PSs and the authors strongly recommend the application of the model to other locations where adequate information is available.

- There is a need to improve the way that data are collected and provided for research and development purposes. This can be facilitated by a more streamlined approach to licence application and provision, as well as identifying operational efficiencies of potential sources of pollution.

- The project recommends that there is improved communication between agencies in order to facilitate the monitoring requirements under the WFD.

- Development of tools to facilitate monitoring should be encouraged to ensure compliance with the WFD and also to identify high-risk activities and locations.

- The data obtained in this project can be utilised to validate the current PRTR model that was designed based on data from Ringsend WWTP.

Where adequate usage data are available, these can be used to inform monitoring more effectively thereby reducing the overall cost associated with monitoring, particularly in light of the new chemicals being added to PS lists over the coming years. This model can be a valuable decision support tool in monitoring for PSs/PHSs provided the information can be made available to the decision makers.

Table 5.1. Recommendations for implementation and uptake of research findings.

Issue	Recommendations	Target	Time frame
Streamlining wastewater treatment plant (WWTP) licence processes			
	The project recommends that the process of licence application through to granting is shortened and that changes be facilitated and verified throughout the period of application. The licence application needs to identify seasonal variations in population as this can affect the performance of the WWTP. Specifically, accurate population equivalents (PEs) for the WWTPs and agglomerations must be determined by the applicant and be recorded accurately in these applications. In the data gathering process of the research, it was found that PEs vary, sometimes greatly, depending on the source of the information, i.e. licence application has different PEs than Environmental Protection Agency (EPA) reports. This leads to the need for information in applications to be verified and this should be done when an application is made, before approval. If information is verified properly there should be no PE errors. It is a further recommendation that the licences should be updated frequently, or at least at regular intervals. The EPA can improve all of the above by making the licensing procedure more efficient. Where information is being held it is desirable to ensure that licence applications include digital copies of the plans of the treatment plants.	EPA	Short term

Table 5.1 ***contd***

Issue	Recommendations	Target	Time frame
Documenting and transparency of WWTP operation			
	There is a need to monitor the efficiency of WWTP operation. This is valuable in providing information on the removal of priority substances (PSs) at each plant. This is directly related to the flow in the plant. Many of the plants visited in the study were found to have no facilities for continuous flow monitoring or recording of these data. Therefore, it was difficult to accurately determine the removal efficiencies and the effects of external sources (rainfall, etc.) on the levels of PSs at the WWTPs in the Cork location. Clearly, it would be helpful to have an indication of pharmaceutical loading contributions to wastewater in many of the catchments under study. It is the recommendation of this project that, in relation to running of the plants, records should be kept on any shutdowns, i.e. which parts of the plant were shut down or out of order. The latter would facilitate explanation of any erroneous or unusual results and the calculation of more appropriate removal efficiencies for the PSs. In the context of aiming to carry out relevant research of this nature, it is important that such information be readily available.	Local authorities	Short–medium term
Identifying sources and usage of PSs			
	A recommendation from the project is that any information collected and stored should be made available for research projects so that the outputs can be more representative and have greater ultimate value. More data should be collected on the emission sources of PSs, i.e. trade effluent discharge information, hospitals, golf courses, airports, etc., sources of pollutants and up-to-date information on their respective discharges. An issue encountered in the research relates to unlicensed sources of PSs. There were a number of contributors of PSs that are not licensed. These accounted, in as far as is possible, for those sources with very limited data. From the research, it is clear that some of those sources may have a significant impact at certain times of the year; therefore, it is recommended that these sources be regulated and monitored. Where companies currently hold a licence to discharge waste there is no obligation to reveal the nature and composition of the waste for a research project of this nature. During the research, the authors were provided with information on licences to discharge waste; however, they were not given details of quantities and specific composition. Where companies are licensed to discharge waste they are only required to meet standards in relation to biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients, etc., and information on the organic composition of the waste is not provided. Therefore, it is difficult to accurately populate a model based on usage and source data. The Department of Agriculture, Food and the Marine has information on usage and purchasing of specific pesticides for the entire country; however, this information is deemed commercially sensitive and therefore could not be supplied to the project team. This information would facilitate a more accurate determination or account of emission sources of pesticides in the catchments under study.	Departments/ Agencies	Short term
Management of water resources			
	The authors recommend that the procedures carried out by all agencies reporting to the EPA should follow standard approaches. It is clear that improved communication is necessary within organisations to facilitate timely and full data and information transfer. The authors believe that adopting a system similar to that used by the Scottish EPA would greatly improve monitoring of water quality in Ireland. The overall recommendation is to establish a mechanism whereby licences don’t need to be transferred over many agencies, local authorities, and different departments.	EPA/ Agencies	Short term

Table 5.2. Model observations and conclusions.

Observation	Conclusions	Recommendations
Assigning risk	It is only through the greater level of understanding achieved in the design of this model and the incorporation of its associated observations into future policy that more informed, targeted monitoring programmes for priority substances may be initiated. By studying the final established model, a number of conclusions can be drawn.	By assigning the same risk factors to other agglomerations based on the activities carried out in the area, it is possible to adapt this model to any area.
	The risk values that have been assigned based on collected information and analytical data are generally representative of the actual priority substance loading risks from these sources, i.e. landfill sites, hazardous waste management facilities and chemical industries are ranked higher due to the high pollutant release risks inherent in these operations, while gyms, offices and hotels are shown to be lower risk emitters.	
Unlicensed sources	It must be noted that while some activities have been assigned low-risk values due to historical and collected data, in some cases the risk values should be re-evaluated. For example, through the research it was found that golf courses have an overall risk value of 0 for pollutant loading and run-off based on previous monitoring data and statistics. However, it is known that golf courses are unlicensed sources of pesticides due to the nature of their activities and therefore should be assessed on that basis.	Information populating of a model such as this one remains a dynamic process. Continuous updating of information will only improve the validity of the overall model.
Occurrence of PAHs	From the analytical results, it was found that there was a higher frequency of occurrence of polycyclic aromatic hydrocarbons (PAHs) in samples from Dublin than in those collected from Cork. The expected exception is Ringaskiddy, which provides no wastewater treatment. This higher occurrence is due to the higher volumes of traffic through a greater area, with larger national roads and motorways catering to a higher population and more heavy goods vehicles than would be encountered in the Cork areas.	Traffic data and road network information is important in identifying sources of PAHs.
	It was also found that while the frequency of occurrence was higher in Dublin, there were more instances of environmental quality standard (EQS) exceedances at higher levels in Cork than in Dublin. This can be attributed to the better removal efficiencies in the Dublin sites compared with the Cork sites.	WWTP efficiency is important in PAH removal.
Occurrence of pesticides	In this project, as Cork is a more agricultural area than Dublin, higher levels of pesticides would be expected in samples collected from the Cork sites; however, through this study's analytical results, it was found that Dublin samples showed both higher frequency and levels of pesticides, phenomena that should be taken into consideration when designing new monitoring programmes. These results can be explained by agricultural activities in the Swords area, and in parts of Meath, which are linked to the Ringsend wastewater treatment system. Also, pesticides are applied to the footpaths and roads in the city annually and these contribute to pesticide loadings in wastewater during periods of rainfall.	Assess and document pesticide applications outside agricultural sources.

Table 5.2 *contd*

Observation	Conclusions	Recommendations
Occurrence of metals	Dublin has many more sources of industrial input than Cork, explaining the higher frequency and levels of metals in samples from Dublin. The Cork sites generally have lower frequencies except for Ringaskiddy, which is to be expected due to the lack of treatment there.	
Effect of rainfall	From this study's intensive sampling, specifically for PAHs, it is possible to demonstrate the flushing effect and run-off effects attributed to the higher levels of rainfall. For future monitoring programmes the 'lag' effect must also be taken into account as, for example samples taken at Swords WWTP on the day of a heavy rainfall are not representative of the normal weather conditions. At that site, it was found that a 24-h delay between increased rainfall and increased flow was characteristic.	It is important to take account of dry weather and wet weather flow when monitoring for priority substances/priority hazardous substances.

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Acronyms and Annotations

AA	Annual average
AADT	Annual average daily traffic
AERs	Annual Environmental Reports
CIT	Cork Institute of Technology
CMA	Centre for Microscopic Analysis
CSO	Central Statistics Office
DCU	Dublin City University
DEHP	Di(2-ethylhexyl) phthalate
DWF	Dry weather flow
EC	European Commission
EF	Effluent factor
EPA	Environmental Protection Agency
EPER	European Pollutant Emission Register
E-PRTR	European Pollutant Release and Transfer Register
EQS	Environmental quality standard
EU	European Union
GCMS	Gas chromatography mass spectrometry
GIS	Geographic information system
HCV	Heavy commercial vehicle
HMs	Heavy metal
ICPMS	Inductively coupled plasma mass spectrometry
IPPC	Integrated Pollution Prevention and Control
MAC	Maximum allowable concentration
NRA	National Roads Authority
PAH	Polycyclic aromatic hydrocarbon
PE	Population equivalent
PHS	Priority hazardous substance
PP	Priority pollutants
PS	Priority substance
SOP	Standard operating procedure

SPE-LC-MS/MS	Solid phase extraction liquid chromatography tandem mass spectrometry
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound
WFD	Water Framework Directive
WWF	Wet weather flow
WWTP	Wastewater treatment plant

Appendix 1 List of Priority Substances

In October 2006, the Irish EPA published Version 1.0 of a Water Framework Directive Monitoring Programme (EPA, 2006). This document contained an appendix (Appendix 2.1, Surface Water Parameters and Groundwater Parameters for Dangerous Substances Monitoring) where the list of PSs was expanded to contain a total of 66 priority and hazardous substances and locally relevant pollutants, shown in Table A1.1.

Table A1.1. List of priority and priority hazardous substances in the field of water policy (European Parliament, 2000) and relevant pollutants (EPA, 2006).

	Name of priority substance	CAS number
(1)	Alachlor	15972-60-8
(2)	Anthracene	120-12-7
(3)	Atrazine	1912-24-9
(4)	Benzene	71-43-2
(5)	Brominated diphenylethers	N/A
(6)	Cadmium and its compounds	7440-43-9
(7)	$C_{10,13}$-chloralkanes	85535-84-8
(8)	Chlorfenvinphos	470-90-6
(9)	Chlorpyrifos	2921-88-2
(10)	1,2-Dichloroethane	107-06-2
(11)	Dichloromethane	75-09-2
(12)	Di(2-ethylhexyl)phthalate (DEHP)	117-81-7
(13)	Diuron	330-54-1
(14)	Endosulfan	115-29-7
	(alpha-Endosulfan)	959-98-8
(15)	Fluoranthene	206-44-0
(16)	Hexachlorobenzene	118-74-1
(17)	Hexachlorobutadiene	87-68-3
(18)	Hexachlorocyclohexane	608-73-1
	(gamma-isomer, Lindane)	58-89-9
(19)	Isoproturon	34123-59-6
(20)	Lead	7439-92-1
(21)	Mercury	7439-97-6
(22)	Naphthalene	91-20-3
(23)	Nickel	7440-02-0
(24)	Nonylphenols	25154-52-3
	(4-(para)-nonylphenol)	104-40-5

Table A1.1 *contd*

	Name of priority substance	CAS number
(25)	Octylphenols	1806-26-4
	(para-tert-octylphenol)	140-66-9
(26)	Pentachlorobenzene	608-93-5
(27)	Pentachlorophenol	87-86-5
(28)	Polyaromatic hydrocarbons	N/a
	(Benzo(a)pyrene),	50-32-8
	(Benzo(b)Fluoranthene),	205-99-2
	(Benzo(g,h,i)perylene),	191-24-2
	(Benzo(k)Fluoranthene),	207-08-9
	(Indeno(1,2,3-cd)pyrene)	193-39-5
(29)	Simazine	122-34-9
(30)	Tributyltin	688-73-3
	(Tributyltin-cation)	36643-28-4
(31)	Trichlorobenzenes	12002-48-1
	(1,2,4-Trichlorobenzene)	120-82-1
(32)	Trichloromethane (Chloroform)	67-66-3
(33)	Trifluralin	1582-09-8
(34)	DDT total	N/a
	para-para DDT	50-29-3
(35)	Aldrin	309-00-2
(36)	Endrin	60-57-1
(37)	Dieldrin	72-20-8
(38)	Isodrin	465-73-6
(39)	Carbon tetrachloride	56-23-5
(40)	Tetrachloroethylene	127-18-4
(41)	Trichloroethylene	79-01-6
(42)	Epichlorohydrin	106-89-8
(43)	Mecoprop	96-65-2
(44)	Pirimiphos-methyl	29232-93-7
(45)	Fenitrothion	122-14-5
(46)	Malathion	121-75-5
(47)	Epoxiconazole	135319-73-2
(48)	Glyphosate	1071-83-6
(49)	Nonylphenol ethoxylates	37340-60-6
(50)	Arsenic	7440-38-2
(51)	Zinc	7440-66-6

Table A1.1 *contd*

	Name of priority substance	CAS number
(52)	Copper	7440-50-8
(53)	Chromium	7440-47-3
(54)	Selenium	7782-49-2
(55)	Antimony	7440-36-0
(56)	Molybdenum	7439-98-7
(57)	Tin	7440-31-5
(58)	Barium	7440-39-3
(59)	Boron	7440-42-8
(60)	Vanadium	7440-62-2
(61)	Cobalt	7440-48-4
(62)	Fluoride	16984-48-8
(63)	Maneb	124727-38-2
(64)	Thiram	137-26-8
(65)	Mancozeb	8018'-01-7
(66)	Zineb	12122-67-7

Appendix 2 Current Outputs of Project

Table A2.1. Conference presentations – oral presentations.

Event	Contributors	Title
Environ, Limerick, Ireland 2010	L. Jones and F. Regan	Analysis of Priority PAHs in Wastewater using GC-MS using LC-DAD and GC-MS
Workshop: Challenges of Monitoring Priority Pollutants in the Environment, DCU 2011	L. Jones, B. Kinsella, A. Furey and F. Regan	Analytical Method Development Protocols for Priority Substance Analysis
Workshop: Challenges of Monitoring Priority Pollutants in the Environment, DCU 2011	L. Jones, B. Kinsella, A. Furey and F. Regan	Occurrences of Priority Substances in Selected Catchments
Conference in Analytical Sciences, Dublin, Feb. 2011	L. Jones and F. Regan	Monitoring Priority Pollutant PAHs in Irish Waste Waters
Euroanalysis, Belgrade, Serbia July 2011	L. Jones, D. Styles, A. Lawlor and F. Regan	Monitoring and Modelling of Priority Pollutants in Irish Wastewaters

Table A2.2. Conference presentations – poster presentations.

Event	Authors	Title
Environ, Waterford, Ireland Feb. 2009	L. Jones and F. Regan	Review of Methods used in Priority Pollutant Analysis
Analytical Research Forum, UK July 2009	L. Jones and F. Regan	SPE-LC-DAD Method for PAH Analysis
IUPAC, Glasgow, Scotland August 2009	L. Jones and F. Regan	Analysis of Emerging Pollutants in Wastewater using LC-DAD and GC-MS
EPA Research Seminar, Dublin Nov. 2009	L. Jones and F. Regan	Monitoring Criteria for Priority Pollutants leading to Emission Factors: PAHs in Wastewater
Analytical Research Forum, UK July 2010	L. Jones and F. Regan	Occurrence of PAHs in Water Following Wastewater Treatment
EPA Research Seminar, Dublin Nov. 2010	L. Jones and F. Regan	Monitoring of PAHs in Wastewater using SPE followed by GCMS
Workshop: Challenges of Monitoring Priority Pollutants in the Environment, DCU 2011	L. Jones and F. Regan	Priority and Hazardous Substances Legislation Controlling the Emission of Priority Pollutants
Pittcon, Atlanta, Georgia, USA March 2011	L. Jones, A. Lawlor, D. Styles and F. Regan	Monitoring and Modelling the Occurrence of Priority Substances in Wastewater
Euroanalysis, Belgrade, Serbia July 2011	L. Jones and F. Regan	Monitoring Priority Pollutant Metals and Trace Elements in Irish Wastewaters
HPLC, Budapest, Hungary June 2011	L. Jones and F. Regan	Determination of Priority Substances in Wastewater using SPE, LCMS and GCMS
38th International Symposium on High Performance Liquid Phase Separations and Related Techniques, 16th–21st June 2012, Anaheim Marriott, Anaheim, California, USA P-007-Mon, p. 51	B. Kinsella, L. Jones, A. Lawlor, F. Regan, J. Chapman and A. Furey	Development of a Polymeric Solid-Phase Extraction Method for the Confirmation of Pesticide Residues in Wastewater Using Liquid Chromatography-Tandem Mass Spectrometry Analysis

Table A2.2 *contd*

Event	Authors	Title
HTC-11 Feb. 2010 Bruges, Belgium	M.G. Cahill, G. Caprioli, M. Stack, S. Vittori and K.J. James	Development of an On-line LC-MS/ MS method for the of Basic Pesticides in wastewaters
HTC-11 Feb. 2010 Bruges, Belgium	M.G. Cahill, G. Caprioli, M. Stack, S. Vittori and K.J. James	Semi-automated liquid chromatography - mass spectrometry (LC-MS/MS) method for basic pesticides in wastewater effluents with analyte confirmation using nanoelectrospray high resolution MS

Table A2.3. Journal publications.

Journal	Contributors	Title
The Column (online) 2012	L. Jones, B. Kinsella, A. Furey and F. Regan	Monitoring Water Framework Directive Priority Substances in Wastewater
Journal of Environmental Monitoring 2012, DOI: 10.1039/C2EM30605K	L. Jones, B. Kinsella, A. Furey and F. Regan	Monitoring the Occurrence of PAHs in Irish Wastewater Effluent
Analytical and Bioanalytical Chemistry, under review	L. Jones and F. Regan	Analytical Methods for Priority Substances in Wastewaters
Environmental Science, Processes and Impacts, in preparation	L. Jones, B. Kinsella, A. Furey and F. Regan	The relationship between traffic and industry on metals in Irish wastewaters
Water Research, in preparation	L. Jones, D. Styles, B. Kinsella, A. Furey and F. Regan	A risk-based model for use in water quality monitoring
Journal of Mass Spectrometry 2010 **45(9):** 1019–1025	M.G. Cahill, G. Caprioli, M. Stack, S. Vittori and K.J. James	Elucidation of the mass fragmentation pathways of potato glycoalkaloids and aglycons using Orbitrap mass spectrometry
Analytical Bioanalytical Chemistry 2011 **400(2):** 587–594	M.G. Cahill, G. Caprioli, M. Stack, S. Vittori and K.J. James	Semi-automated liquid chromatography - mass spectrometry (LC-MS/MS) method for basic pesticides in wastewater effluents

Table A2.4. Thesis submissions.

Degree	Author	Thesis title	Date
PhD	M. Cahill	Novel LC-MS Methods for the Determination of Environmental and Food Contaminants Incorporating Analyte Confirmation Using High Resolution Mass Spectrometry	2011
PhD	L. Jones	Development of a Risk Model for use in Water Quality Monitoring	2012

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce;
- dumpáil mara.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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SSTI
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Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government