HAZRUNOFF PROJECT

"Integration of sensing and modelling technologies for early detection and follow-up of hazmat and flood hazards in transitional and coastal waters"

Chemical Hazard Prioritisation Framework
Volume 1 – Methodology of Approach

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CONTENTS

INTRODUCTION 3

Background to the Problem 3

METHODOLOGY 4

Overview 4

Step 1 - Scoping of the assessment 5

Step 2 - Hazard Identification (Source) 6

Step 3 – Identifying Areas at Risk (Receptors) 7

Step 4 - Prioritisation 8

Further Assessment 10

INTRODUCTION

This report details the works undertaken by Public Health England (PHE) to develop a framework for prioritisation of chemical hazards associated with coastal and riverine industrial infrastructure under Task 4.1 of Work Package 4.

Work Package 4 aims to contribute actively to an efficient preparedness and response to floods and hazmat response in transitional waters, through the promotion of risk management tools to support effective contingency planning and decision-making.

Background to the Problem

Industrial infrastructure has always been associated with coastal and riverine locations, in view of the amenity of such locations to facilitate bulk transport of raw materials and products. Furthermore the development of population centres would often mirror industrialisation and consequently result in the need for further infrastructure such as water treatment and waste disposal, to cater for the activities of large populations.

Whilst current industrial and waste disposal activities are highly regulated in order to prevent pollution of the environment and harm to human health, this was not always the case. EU studies indicate that soil contamination in 2011 was estimated at 2.5 million potentially contaminated sites in the EU Economic Area, of which about 45 % have been identified to date (European Environment Agency website *accessed August 2018*). Studies in the UK suggest in England alone, there are approximately 20,000 historic landfills constructed without any engineered waste management with circa 1200 of these facilities located in tidal flood zones[1].

As such many coastal and riverine areas represent a legacy of hazards, with potential for ongoing pollution of land, aqueous and marine environments. Natural processes such as coastal erosion and flooding, often enhanced by climate change, further increase risks of damage to current and historical infrastructure with the potential to pose hazards as illustrated in many media articles e.g. UK coastal landfills (Guardian Newspaper, 2016) and metal mines flooding (BBC Wales, 2012).

It is impossible to plan for every eventuality when preparing contingency and response management protocols and so a framework has been developed to help prioritise hazards, based upon the industrial sites within an area and their principal pollutant hazards. The process will assist planning and inform alerting, monitoring and modelling strategies.

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[1] (Oshea et al, 2018. https://www.sciencedirect.com/science/article/pii/S0025326X17310809?via%3Dihub)

METHODOLOGY

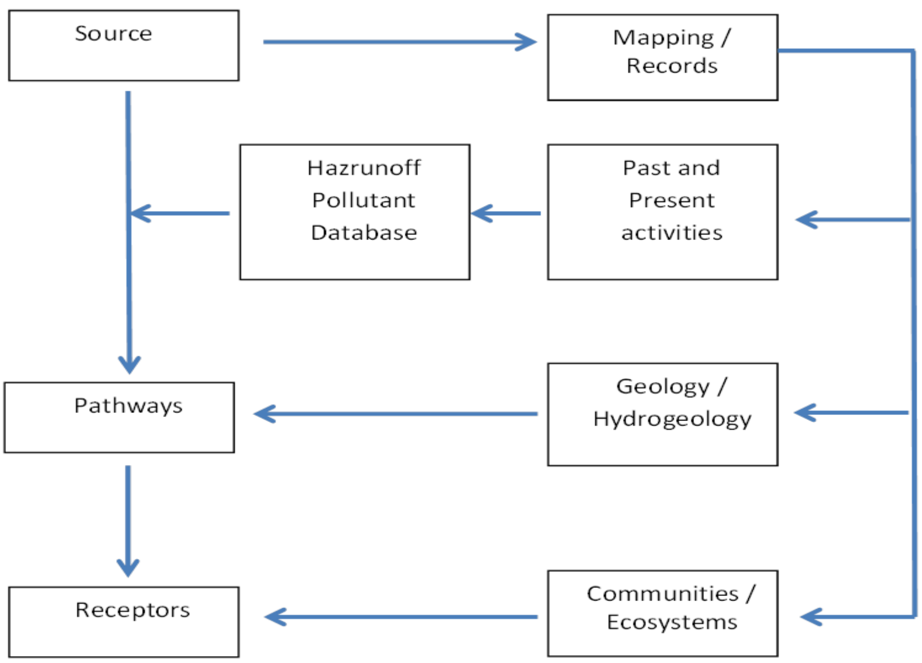
The following section details the methodology developed by PHE for the prioritisation process. A database accompanies this methodology, providing details on industrial pollutants and their hazardous properties together with worksheets to complete the prioritisation.

Overview

The framework adopts a source-pathway-receptor (S-P-R) approach commonly applied to risk assessment. The basic concept of the S-P-R approach is to identify the potential receptors, contaminants and pathways and therefore enable the determination of whether there is a potential risk to human health or the environment. Without all three components being present (i.e. communities / sites being or to be-exposed (receptors), contaminants (source) and a medium through which exposure can occur (e.g. air, water, soil or food; pathway) there cannot be a risk.

The framework comprises a series of simple steps involving (1) scoping of the study area / time-frame, (2) hazard identification, (3) receptor review and (4) pollutant prioritisation. Prioritisation uses the accompanying database, which has been developed with reference to previous prioritisation and assessment studies such as those undertaken by PHE / CIIMAR (ARCOPOL) (Mariner).

A case study from the Bristol Channel region of the UK (Volume 2) illustrates the process, which can be applied across all partner areas.



Step 1 - Scoping of the assessment

Before commencing any study it is important to define its scope i.e. its extent. For the hazard prioritisation framework, scoping will require establishment of boundaries for the proposed area to be assessed and the time-frame for data searches.

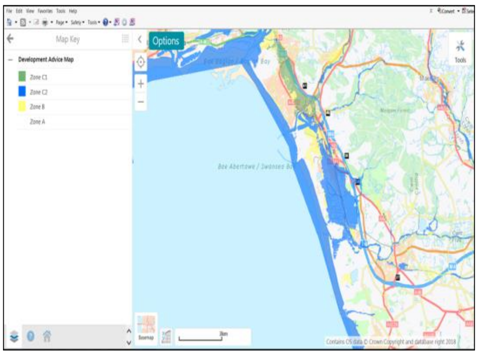
There are no defined limits to where boundaries should be set. Instead these will be determined by the assessor and based upon the underlying objectives of the study i.e. why is the study being undertaken?

Studies may be undertaken as a general review of a region or they may be in response to, or in readiness for specific events or for a specific receptor. In all cases it is recommended to scope the study area to a manageable size for assessment and if necessary use multiple prioritisation assessments for large areas e.g. assessment of an entire region.

The methodology is specifically aimed for prioritising chemical hazards from coastal or riverine infrastructure and as such it is important to define the scope of the land beyond the tidal or riverine region to be studied. This area will typically be the land susceptible to coastal or riverine effects, such as erosion, flooding, storm surges and in the longer term climate change impacts.

Again this is determined by the assessor, who may have existing knowledge of the study area. Alternatively it is possible to apply some general criteria for scoping. For example, many studies have been published, such as the Eurosion project, identifying areas at risk from coastal erosion, while the 5m contour line provides a useful scoping boundary for coastal land susceptible to sea level rise and flooding.

For rivers, a useful general criteria would be to identify areas most at risk from flooding. Flood maps are generally available from national environment agencies or regional authorities, while partners within the Hazrunoff project have also developed detailed flood models for a number of EU regions.



Temporal scoping is similarly user defined and dependent upon the aims of the assessment, but will also be determined by available data epochs for the area (This is discussed further in Step 2).

Step 2 - Hazard Identification (Source)

This step involves the identification of past and current industrial facilities for the study area defined in Step 1. As industrial processes can range considerably in scale it is recommended that searches focus on those facilities meeting criteria for regulatory management such as Seveso sites, licensed waste facilities, regulated power generation plants etc. A list of key industrial facilities is provided within the prioritisation database (See Step 4).

Current industrial facilities can be determined with reference to existing maps for the area and to records available from regulatory bodies. For example, in Wales the environmental regulator, Natural Resources Wales provide web based interactive mapping identifying licensed waste facilities. Similarly the UK Health and Safety Executive who regulate Seveso (Control of Major Accident Hazards (COMAH) Regulations) provide a database of sites searchable by postcode.

Past industrial activity within the search area can be identified using historical maps. In the UK historical mapping extends back to the late 18th Century, although the most relevant editions, produced by Ordnance Survey, start from the mid to late 19th Century.

Paper maps can typically be accessed from local libraries or can be purchased from national mapping agencies. Historical maps may also be available on line via national archives, such as that provided by National Library of Scotland, which offers an interactive map finder for the entire UK.

In addition to publicly available maps and records, data may also be available via local and regional authorities. For example, in the UK local authorities are required to undertake searches of their boroughs under contaminated land regulations and will produce maps detailing potential past polluting activities.

Finally, search services may also be available from commercial companies such as Envirocheck. Such searches are commonly used for planning and development purposes and will collate the current and historical data described above as well as receptor data outlined in Step 3. Such searches however are typically performed around a single location with a defined buffer of 1 to 2 km and incur financial charge.

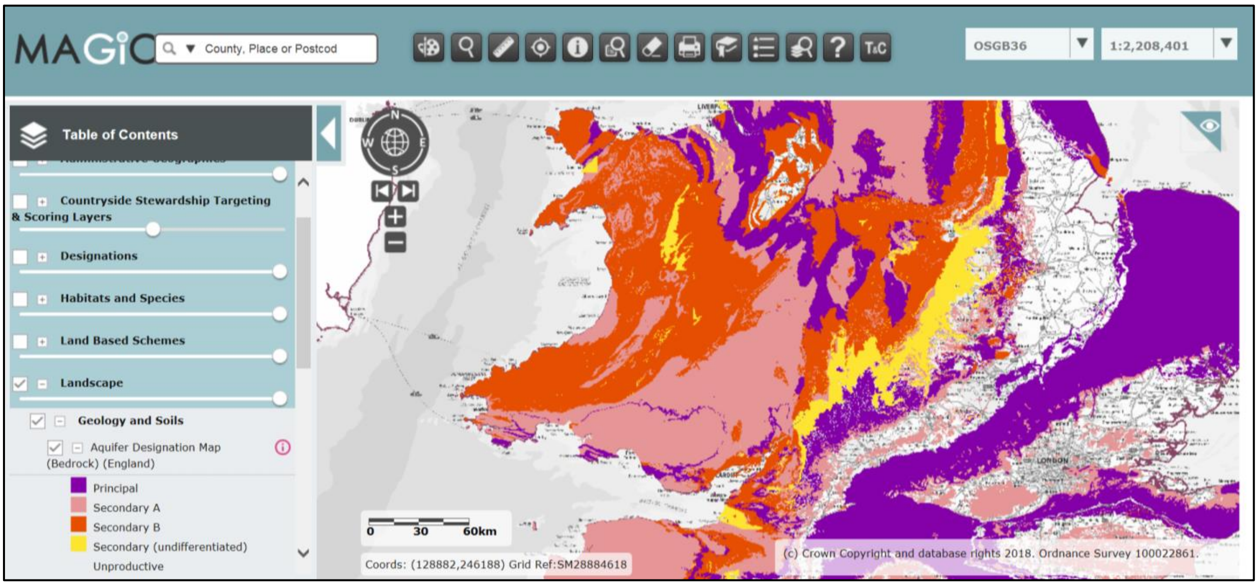
Once past and present industrial sites have been identified it is possible to move onto the next step in the process.

Step 3 – Identifying Areas at Risk (Receptors)

This is not an essential step (as it can be assumed that both human and ecological receptors will be present) but it will help to inform the subsequent prioritisation by identifying the the most relevant pollutant toxicity and behaviour parameters to be used in the assessment. For example if it is known that the main receptors are the aqueous environment and associated commercial shell fish beds then pollutants that sink and persist and with high aqueous toxicity will be most significant. In contrast if the main receptors are nearby population centres then airborne releases of toxic gases and vapours are likely to be of most concern. Key receptors to consider will include

- **Human Health** - population centres including vulnerable populations (hospitals, care homes, schools etc), amenities (bathing waters and outdoor recreational facilities e.g. boating, angling)
- **Socio-economic** – transport infrastructure, industry, agriculture / aquaculture, housing
- **Environmental** – surface water bodies, abstractions, aquifers, source protection zones
- **Ecological** - sensitive habitats / species (RAMSAR), protected sites and sites of scientific interest (Special Areas of Conservation SACs, Sites of Special Scientific Interest SSSIs,)

Identification of potential receptors will again involve review of current maps and regulatory sources. Local, regional and national regulatory and protection bodies will often make data freely available on line for example the Welsh Government Lle site provides environmental mapping data for Wales, while the Magic site has similar for England. Hydrogeological maps showing key aquifers are also often available on line via government or regional agencies. In the UK the British Geological Survey (BGS) have on line mapping data for drift and solid geology, while Magic has data for UK bedrock aquifers.



UK bedrock aquifers (Courtesy of Magic Map, DEFRA, UK)

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Step 4 - Prioritisation

Once source data (and receptors if completed) have been collated the next step is to prioritise the potential pollutants present. This is completed using the prioritisation tool. The tool can be accessed here. Once downloaded, read the instructions on the introduction sheet. A prioritisation can then be completed rapidly as below:

The tool contains an industry profile worksheet, which lists key pollutants for a range of major industrial processes based upon UK industry profiles. This worksheet is used to identify the relevant industrial pollutants associated with the industries identified in the study area as illustrated below.

B	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
Industry	Coal tar PAH	PCB	Dioxins	BTEX	Oils	Phenols	Pesticides	Chlorinated Solvents	Alcohols	TBT / organo tin	Ethylene Glycols	ethyl lead	Methane	Faecal / Coliforms	UXO Ordnance
Docks	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(++)					(+)
Gasworks, Coke Works Coal Carbonisation	(++)			(++)		(++)									
Aggregates / Cement	(++)		(++)		(+)										(+)
Iron and steel making	(++)	(++)	(++)	(++)	(++)	(+)									
Sewage Works						(+)	(++)						(++)	(++)	
Mining													(++)		
Military Facilities		(++)		(++)	(++)		(+)				(++)	(++)			(++)
Chemical Works (General)*	(+)	(+)		(++)	(++)	(+)	(+)	(+)	(+)		(+)		(+)		
Metal works - Finishing		(+)		(++)	(++)			(++)	(+)						
Electrical Substations		(++)			(+)		(+)								
Timber Treatment	(++)	(+)		(+)	(+)	(++)	(++)								

Those pollutants marked ++ represent chemicals directly linked to the industrial processes and thus most likely to be present. Those marked + represent pollutants that may have been used for ancillary purposes such as site maintenance etc. with only the potential to be present.

Once the principal pollutants have been identified for an industrial process, the chemical pollutant sheets (inorganic and organic pollutants) can be consulted to access hazard information.

					Indicative Hazard Ratings (GESAMP)							NFP Ratings		
					Human Health -			Ecological						
	Chemical Name	CAS No	Physical State	Behaviour	Acute 0-4	Chronic 0 or 4	Health Score	Aquatic Toxicity 0-4	Bioconcentration 0-4	Persistence 0- 4	Eco Score	Flammability 0 - 3	Reactivity 0-3	Flammable / Reactive Hazard
4														
5	Benzene	71-43-2	L	E	4	4	8	2	1	1	4	3	0	F
6	Toluene	108-88-3	L	E	2	0	2	2	1	1	4	3	0	F
7	Ethyl benzene	100-41-4	L	E	2	0	2	2	1	0	3	3	0	F
8	Xylenes	1330-20-7	L	E	2	0	2	2	1	1	4	3	1	F
9	Total PAH (Coal Tar)	NA	S	S	2	4	6	4	3	2	9	2	0	F
10	Naphthalene	91-20-3	S	D	2	0	2	4	3	0	7	2	0	F
11	Benzo(a)pyrene [B(a)P]	50-32-8	L	S	0	4	4	3	4	2	9	0	0	0
12	Petrol / Aliphatic TPH (as n-Hexane)	110-54-3	L	E	0	0	0	4	3	0	7	3	0	F
13	Kerosene Aliphatic TPH (as Cyclohexane)	110-82-7	L	E	1	0	1	3	3	0	6	3	0	F
14	Diesel /Aromatic TPH (see Napthalene)	91-20-3	S	S	2	0	2	4	3	0	7	2	0	F
15	Total PCB Congeners (as	1336-36-3	L	S	0	4	4	3	4	4	11	1	0	0
16	Arochlors as 1254	11097-69-1	L	S	0	4	4	3	4	4	11	1	0	0
17	Total Dioxins / Furans	NA	S	S	0	4	4	4	4	4	12	0	0	0
18	Total Pesticides	NA	S/L	S	4	4	8	4	4	3	11	0	0	0
19	Aldrin	309-00-2	S	S	4	4	8	4	4	3	11	0	0	0
20	Parathion	56-38-2	L	S	4	4	8	4	3	2	9	0	0	0
21	Glyphosate	1071-83-6	S	S	3	4	7	2	1	2	5	0	0	0
22	Phenol	108-95-2	S	D	4	0	4	3	1	0	4	2	0	F

Inorganic Pollutants | Organic Pollutants | Worksheet (Health) | Worksheet (Ecological) | R

When selecting chemicals choose those most reflective of the industrial process being assessed. Reference to the text in the industry profile documents can assist this process (See case study also).

Each chemical entry has been populated with defined hazard scores, based upon GESAMP ratings as well as reference to current (recognised) health and environmental standards and potential monitoring and detection methods.

Chemical behaviour characteristics have also been assigned scores with reference to standard European classifications[2] as indicated below.

Behaviour	**Human Health**	**Ecological**
Gas / Evaporator	4	1
Floater	3	2
Dissolver	2	3
Sinker	1	4

The tool has 2 worksheets (health and ecologocal) where the prioritisation calculations are undertaken. Select each chemical to be prioritised from the drop-down list. This will automatically populate all relevant fields in the worksheet. Repeat for all chemicals identified for prioritisation. Repeat these steps for both sheets.

Entry	Chemical Name	CAS No	Physical State	Behaviour	Acute 0-4	Chronic 0 or 4	Health Score	ic Toxicity 0-4	Bioconcentration 0-4	Persistence 0- 4	Eco Score	Flammability 0 - 3	Reactivity 0-3	le / Reactive Hazard	Total Score (Eco)	Behaviour Score (1 - 4)	Reactivity Score (1 or 0)	Weighting (Optional)
1	Asbestos	1332-21-4	S	S	0	4	4	0	0	4	4	0	0	0	8	4	0	1
2	Arsenic	7440-38-2	S	S	2	4	6	2	0	4	6	0	0	0	10	4	0	1
3	Chromium (III)	7440-47-3	S	S	2	0	2	3	0	4	7	0	0	0	11	4	0	1
4	Copper	7440-50-8	S	S	1	0	1	3	0	4	7	0	0	0	11	4	0	1
5	Iron	7439-89-6	S	S	1	0	1	1	0	4	5	0	1	0	9	4	0	1
6	Lead	7439-92-1	S	S	1	4	5	3	0	4	7	0	0	0	11	4	0	1
7	Tin	7440-31-5	S	S	1	0	1	0	0	4	4	0	0	0	8	4	0	1
8	Zinc	7440-66-6	S	S	2	2	2	3	0	3	6	0	2	R	11	4	1	1
9	Ammonia (/Ammonium ion)	7664-41-7	L	E	4	0	4	2	0	1	3	1	0	0	3	0	0	1
10	Cyanides (as sodium salt	143-33-9	S	E	4	0	4	4	0	1	5	0	0	0	5	0	0	1
11	Acids (inorganic as HCl)	7647-01-0	L	D	4	0	4	4	0	0	4	0	3	R	8	3	1	1
12	Benzene	71-43-2	L	E	4	4	8	2	1	1	4	3	0	F	5	0	1	1
13	Total PAH (Coal Tar)	NA	S	S	2	4	6	4	3	2	9	2	0	F	14	4	1	1
14	Kerosene AliphaticTPH (as Cyclohexane)	110-82-7	L	E	1	0	1	3	3	0	6	3	0	F	7	0	1	1
15	Total PCB Congeners (as 118)	1336-36-3	L	S	0	4	4	3	4	4	11	1	0	0	15	4	0	1
16	Total Dioxins / Furans	NA	S	S	0	4	4	4	4	4	12	0	0	0	16	4	0	1
17	Total Pesticides	NA	S/L	S	4	4	8	4	4	3	11	0	0	0	15	4	0	1
18	Phenol	108-95-2	S	D	4	0	4	3	1	0	4	2	0	F	8	3	1	1
19	Trichloroethylene (TCE)	79-01-6	L	S	2	4	6	2	2	1	5	1	0	0	9	4	0	1
20	Methane (LNG)	74-82-8	G	E	2	0	2	1	0	0	1	3	0	F	2	0	1	1

Prioritisation - Hazard to Environment

Inorganic Pollutants | Organic Pollutants | Worksheet (Health) | **Worksheet (Ecological)** | R

The worksheets will automatically calculate relative hazard, based upon the scoring criteria and plot the results to provide a rapid visual assessment of those most hazardous for each receptor type.

An option is available for users to include a weighting to scores to "fine tune" the prioritisation. For example, weightings can be added to reflect the number of sites in which the pollutant may be present, the scale of the past or present industrial operation, or whether the pollutant is likely (++) or potential (+). The size of any weighting is user defined but scores will be multiplied by the weighting so a default score of 1 should always be included in the weighting column.

[2] Standard European Behaviour Classification (SEBC) System, Bonn Agreement, CounterPollution Manual, vol. 2, Chapter 25, pp 1-8. 1991.

Further Assessment

The prioritisation does not present an absolute hazard for a pollutant as this will depend on other site specific factors but instead presents a comparative hazard ranking for the area and scenario being assessed. As such the list provides an initial mechanism to compare and prioritise pollutants for further detailed assessment.

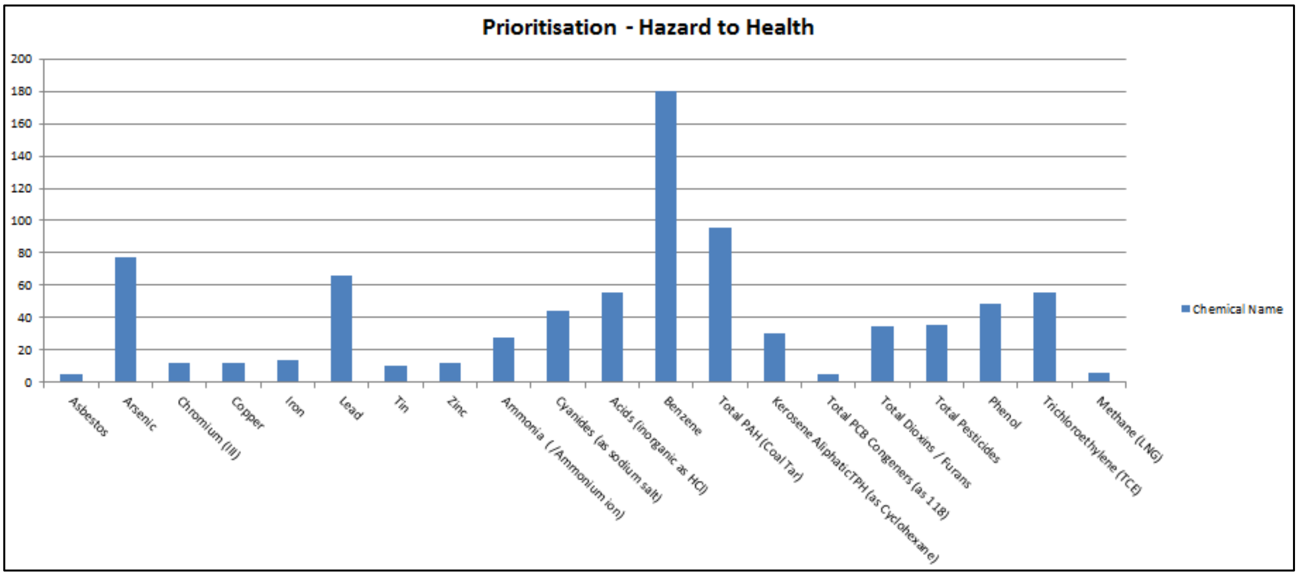

Illustration of prioritisation output (Arsenic, lead, benzene and Coal Tar would merit consideration within detailed plannig and assessment)

Once priority pollutants have been identified these can be used to inform plans detailing how pollutants will behave in the environment (modelling), how they may interact, what kinds of techniques can be used for monitoring, what standards are available to aid alerting and protecting the public and what control techniques can be applied to respond to and manage any incidents.

Further information to supplement this process can be accessed and downloaded via a range of other web based resources including; Hazardous and Noxious Substances (HNS) datasheets from European projects such as HNS-MS, Arcopol and Marpocs ; chemical profiles and incident response sheets published by Public Health England and Toxicological Profiles published by US ATSDR.

The aim of any plan is to prepare for an incident and the information can also assist in estimating the significance of impacts against various modelled *'what-if'* scenarios and help to develop risk communication strategies and exercises for specific regions. In addition, the data can be used to help prevent incidents by aiding engagement with industry and regulatory bodies helping to target further investigation and remedial works in respect of the prioritised chemical hazards identified.

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