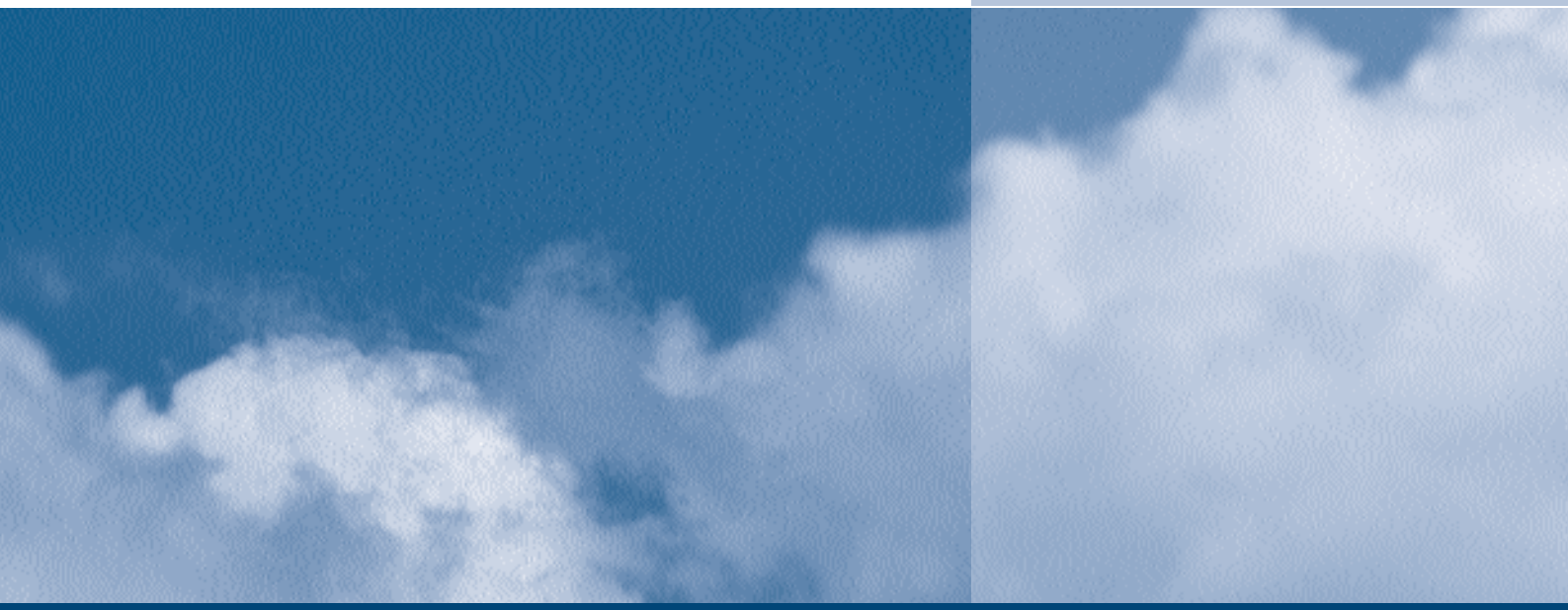

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A Review of the Toxicity and Environmental Behaviour of Hydrogen Iodide in Air

ENVIRONMENT AGENCY

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Science underpins the work of the Environment Agency, by providing an up to date understanding of the world about us, and helping us to develop monitoring tools and techniques to manage our environment as efficiently as possible.

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- **Providing advice**: To ensure that the knowledge, tools and techniques generated by the science programme are taken up by relevant decision-makers, policy makers and operational staff.

Professor Mike Depledge Head of Science

EXECUTIVE SUMMARY

Hydrogen iodide is a colourless, readily water soluble gas which dissolves to form hydroiodic acid. It is used during a number of industrial processes such as glass etching and organic chemical synthesis operations.

The major anthropogenic sources of hydrogen iodide are likely to be from the use in glass treatment and in chemical processes. It may also be present in small quantities in fuels. The major sources that report releases to the Environment Agency are coal fired power stations. There have also been discharges of iodine containing compounds from some nuclear energy related sites such as power stations, although the evidence indicates that these discharges do not contain significant proportions of hydrogen iodide. There are no estimates of the UK emissions to air of hydrogen iodide.

No UK studies relating to the measurement of hydrogen chloride have been located. While particle associated iodide has been measured since 1972 at three sites, this is an inadequate marker of hydrogen iodide levels as the iodide concentrations are likely to be dominated by marine derived iodide. Studies of radionuclides have tended to focus on detecting the radionuclide rather than the specific compounds and so little information is available from this source. However as a consequence of research into the fate of wastes from nuclear processes there is considerable information on the fate of iodide in the terrestrial and aquatic environment.

A number of measurement methods have been published for HI but while most are insufficiently sensitive to be of use in other than an occupational setting some offer the potential for short term sensitive measurements. These methods have not been used routinely and are generally regarded as research methods suitable for short-term campaigns rather than continuous measurement networks. However if cost was not a significant barrier then it is likely that these measurement methods could be so used.

The data available concerning the toxicity of hydrogen iodide is extremely limited. Inhalation of hydrogen iodide is reported to cause irritation of the upper respiratory tract, and a concentration of approximately 35 ppm (186 mg/m^3) causes irritation of the throat after short exposure. More severe exposures result in pulmonary oedema, and often in laryngeal oedema. However, no further details are available. An extensive literature search revealed no toxicological studies for humans or laboratory animals.

There is supplemental intake guidance level of 0.5 mg/day (equivalent to 0.008 mg/kg body weight per day in a 60 kg adult) set by the Expert Group on Vitamins and Minerals.

The information gathered provides a very limited dataset for the assessment and recommendation of a guideline for hydrogen iodide in ambient air that is protective of human health.

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1 INTRODUCTION

The Environment Agency of England and Wales is responsible for the authorisation of releases of a wide range of chemicals from industrial processes. As part of the permitting process the Environment Agency requires soundly based information on the levels of particular substances which are likely to lead to no significant harm to human health and the natural environment. These Environmental Assessment Levels (EALs) are published by the Environment Agency in a guidance document H1 (Horizontal Guidance Note; IPPC H1: Integrated Pollution Prevention and Control: Environmental Assessment and Appraisal of BAT, Environment Agency 2003) in order to make transparent to industry and other stakeholders the values being used within the Agency and to assist applicants with judging the acceptability of alternative process options.

The present approach within H1 uses a hierarchy of values. Where accepted UK or international ambient air quality standards are available either from the UK's Expert Panel on Air Quality Standards (EPAQS), EU directives or the World Health Organization these values are used. However, the great majority of substances for which release permits are sought are not covered by these published reviews. As a result H1 presently makes use of UK occupational exposure limits (OELs) set by the HSE corrected for the longer exposure and the potential greater range of sensitivities of the wider population.

There is however a number of limitations with applying this approach uncritically. For example, some OELs may take into account technological considerations, such as levels that were achievable in industrial settings at the time the standard was derived, which are neither health-based nor relevant to ambient air concentrations. Others may not be based on the toxicological endpoint that would be the critical endpoint for the population at large, including sensitive sub-populations.

The Environment Agency has set in place a strategy of measures to improve the basis for the setting of EALs. Part of this has involved developing a work programme, in consultation with Defra and the devolved administrations, for EPAQS to develop Guidelines that may be used for the purposes of H1. EPAQS has been asked initially to look at six substances;

- hydrogen fluoride,
- hydrogen chloride,
- hydrogen bromide,
- hydrogen iodide,
- chlorine,
- bromine.

A series of six reports, one on each substance, has been produced on behalf of the Environment Agency to support the work of EPAQS. Each report reviews the sources of release to the atmosphere, a summary of monitoring methods used in the UK, UK ambient concentrations and the literature on human toxicology and health effects. The present report addresses hydrogen iodide.

Hydrogen iodide (HI: molecular weight 127.9 g/mole) is a colourless gas at environmental conditions. The CAS number for hydrogen iodide is 10034-85-2. It has a melting point of –51°C and a boiling point of –35°C. It is readily water-soluble. On dissolution in water it forms hydroiodic acid.

In order to allow comparison, conversions have been provided between the concentration value as given in the documents reviewed and either mass concentration or volume fraction as required. This conversion has been based on assumed conditions of 20 °C 101325 Pa. This may not represent the original study conditions and hence may lead to a small uncertainty in the conversion.

1.1 Anthropogenic Sources of Hydrogen Iodide

The UK's National Atmospheric Emissions Inventory does not include hydrogen iodide.

Within England and Wales, the major industries are regulated by the Environment Agency. Although hydrogen iodide is not on the list of compounds against which the Environment Agency requires companies to report estimates of their annual emissions to its Pollution Inventory, a limited amount of site-specific information is available. This indicates that in 2002 at least 150 tonnes and in 2001 at least 240 tonnes of HI were released, mainly from combustion and chemical processes. This data is incomplete as it only includes those sources that reported a release. Many of these releases are calculated from the average iodine content of the fuel. The largest reported sources, including those reported to the Scottish Environment Protection Agency, are shown in Table 1. Other possible sources include domestic coal burning, clinical waste incineration, fugitive releases from disinfectants and at least historically seaweed burning to use the ash as fertiliser.

Table 1.1 – Major Point Source Releases of Hydrogen Iodide reported to the Environment Agency and Scottish Environment Protection Agency in 2001 and 2002.

Operator	Site	Process	HI Emission 2001 Tonnes	HI Emission 2002 Tonnes	SO_2 Emission 2002 Tonnes	SO_2/HI Ratio 2002
British Energy PLC	Eggborough Power Station, Goole, North Humberside	Coal fired power station	25	25	59906	2396
Scottish Power PLC	Longannet Power Station, Kincardine-on-Forth, Fife	Coal fired power station	27 (18-40)	23 (16-39)	67100	2885 (1709-4161)
EDF Energy (Cottam Power) Ltd	Cottam Power Station, Retford, Nottinghamshire	Coal fired power station	20	22.9	70500	3079
AEP Energy Services UK Generation Ltd	Ferrybridge C Power Station, Knottingley, West Yorkshire	Coal fired power station	20	20	48144	2407
EDF Energy (West Burton Power) Ltd	West Burton Power Station, Retford, Nottinghamshire	Coal fired power station	26	20	68461	3423
AEP Energy Services UK Generation Ltd	Fiddlers Ferry Power Station, Warrington, Cheshire	Coal fired power station	23	16.5	28200	1709
Powergen UK PLC	Ironbridge Power Station, Telford, Shropshire	Coal fired power station	NR	11	31600	2873
TXU Europe Power Ltd	High Marnham Power Station, Newark, Nottinghamshire	Coal fired power station	NR	8	33290	4161
Powergen UK PLC	Ratcliffe-on-Soar Power Station, Nottingham, Nottinghamshire	Coal fired power station	NR	7.4	15924	2159
Scottish Power PLC	Cockenzie Power Station, Cockenzie, East Lothian	Coal fired power station	-	6.8 (4.7-12)	19700	2885 (1709-4161)
Powergen UK PLC	Drakelow B Power Station, Burton-on-Trent, Staffordshire	Coal fired power station	NR	6	22529	3755
Rugeley Power Ltd	Rugeley Power Station, Rugeley, Staffordshire	Coal fired power station	16	BT	34358	-

NR not reported
BT Below reporting threshold
Note 1 HI emissions for Cockenzie and Longannet power stations were calculated from the release of sulphur oxides as sulphur dioxide reported to SEPA and the average, maximum and minimum ratio of SO_2 to HI for the English power stations shown above with reported releases of both pollutants in the relevant year.

1.2 Atmospheric Chemistry of Hydrogen Iodide

It is thought likely that particle associated iodide derived from sea salt may react with acid compounds such as nitric acid to form hydrogen iodide (Moyers and Druce 1972).

1.3 Deposition Mechanisms

As hydrogen iodide is very water-soluble it is likely to have similar deposition behaviour to other hydrogen halides and hence be rapidly deposited when released to the atmosphere.

1.4 Methods of Measurement

1.4.1 Bubbler methods

The bubbler method could be used to measure gas phase iodide. Air is drawn through a membrane filter to remove particles. However any soluble iodide on particles that pass through the filters will be analysed and reported as hydrogen iodide. The air is then drawn through impingers containing a suitable adsorbing solution such as sodium hydroxide or sodium carbonate. Compounds containing water-soluble iodide will dissolve into the solution, which can then be analysed by ion chromatography or ion selective electrode methods. The latter are however susceptible to interference from bromide ions present in the solution. Typical sampling times are 24 hours to obtain sufficient sample. Longer sampling times can lead to problems in summer months with evaporation of the solution. Shorter sampling times may lead to undesirably high detection limits. Typical detection limits are around 2 $\mu g/m^3$ (0.38 ppt).

1.4.2 Denuder methods

The denuder method used for the Defra nitric acid network operated by the Centre for Ecology and Hydrology is not presently used for hydrogen iodide determination. The method is probably easily adaptable to hydrogen iodide. Accuracy and precision data however are not available.

1.4.3 Diffusion tube

There are not at present diffusion tubes marketed for the measurement of hydrogen iodide. However it is likely that the tubes presently available for bromide would work equally well for iodide measurement. As with other adsorptive methods there are possible interferences from iodide forming compounds that react with the adsorbent. Hence false positives may be obtained.

1.4.4 DIAL

Differential Adsorption LIDAR uses a laser to shine two nearby wavelengths into the air. The wavelengths are selected so that one is adsorbed actively by the species of interest and the other is not. The backscattered light is measured at the two frequencies and the difference between them represents the adsorption by the component of interest. The technique suffers when high aerosol concentrations decrease the intensity of the backscattered light returned to the detector. The technique can give rapid sensitive concentration measurements across a section of the atmosphere. Evidence has not been found of this technique being used for HI.

1.4.5 DOAS

Differential Optical Absorption Spectroscopy uses a light emitter to project a beam of light with wavelengths between visible and ultra violet. The light beam passes through a known distance to a receiver. The monitoring path is usually between 300 and 800 metres. As the beam of light passes through the air different the molecules absorb different wavelengths dependant on their spectra. The light is then returned through a fibre optic cable to a spectrometer. The spectrometer measures the intensity of the different wavelengths compared this to the original beam and then calculates the air concentrations of the particular gases. No detection limit was quoted for HI.

1.4.6 DLSIOS

Diode laser single ion optical spectroscopy is a high-resolution spectroscopy technique that can detect HI in the parts per million range. Response times are reported to be as low as 1 second.

1.5 UK Measurements

No measurements of hydrogen iodide in the UK have been identified. Enquires have been made with the Environment Agency, Northern Ireland Department of the Environment and the Scottish Environment Protection Agency as well as through literature searches.

Quarterly measurements of particle bound iodide have been made at three rural locations since 1972. The results from the first few years and from more recently in 1996-2001 are shown in Figures 1 and 2 and Table 2 below. The sample was collected by passing air over a filter. The filters have been analysed by instrumental neutron activation analysis. It is possible by analogy with hydrogen chloride that at these locations any hydrogen iodide would have reacted with basic compounds such as ammonia in the atmosphere and become associated with particles. There is some evidence for seasonal behaviour. There is little evidence that concentrations have declined greatly between the early 1970s and recent years.

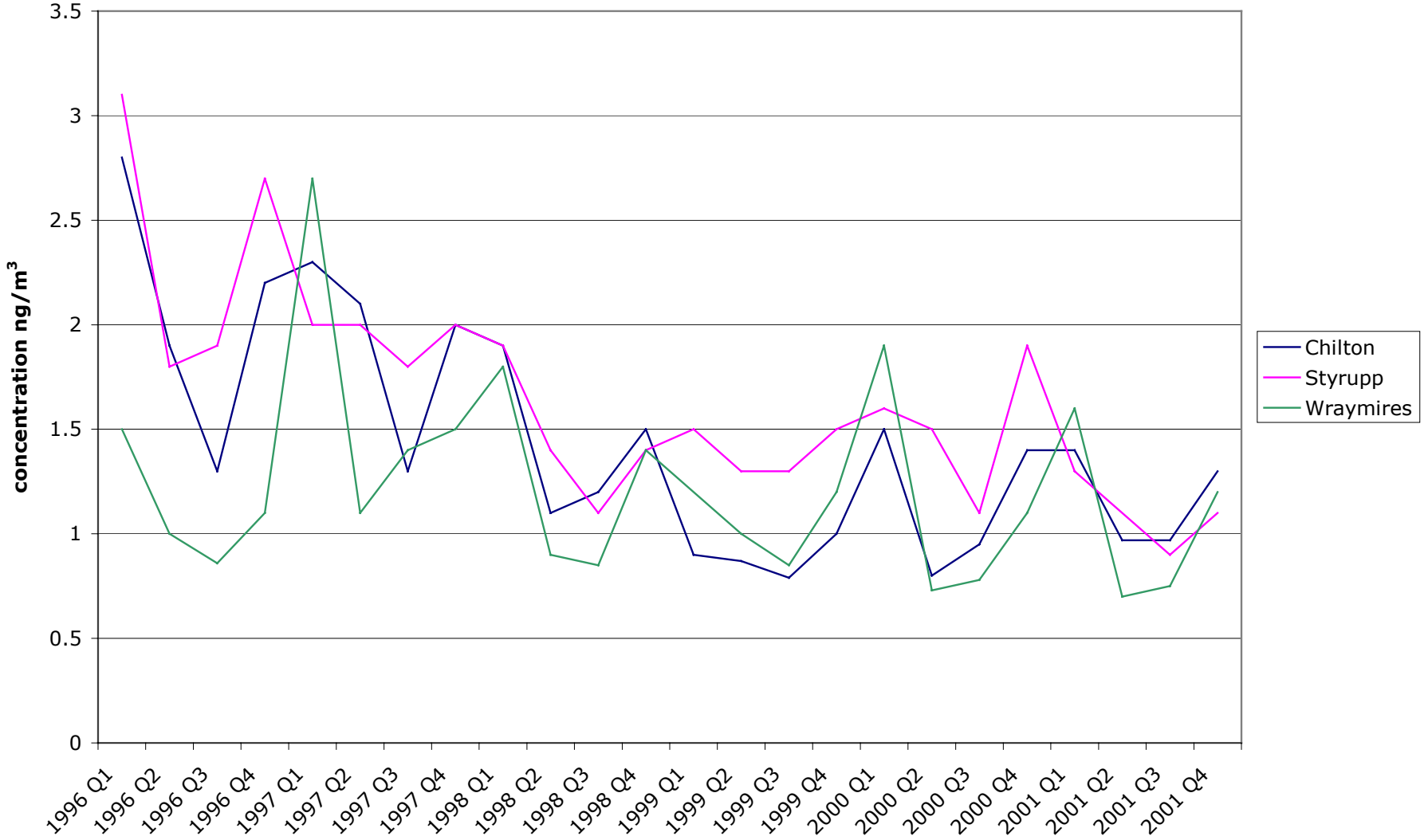

Figure 1.1 - Quarterly mean air concentrations of particle associated iodide (ng/m^3) at three rural sites in the Defra Rural Trace Elements Network

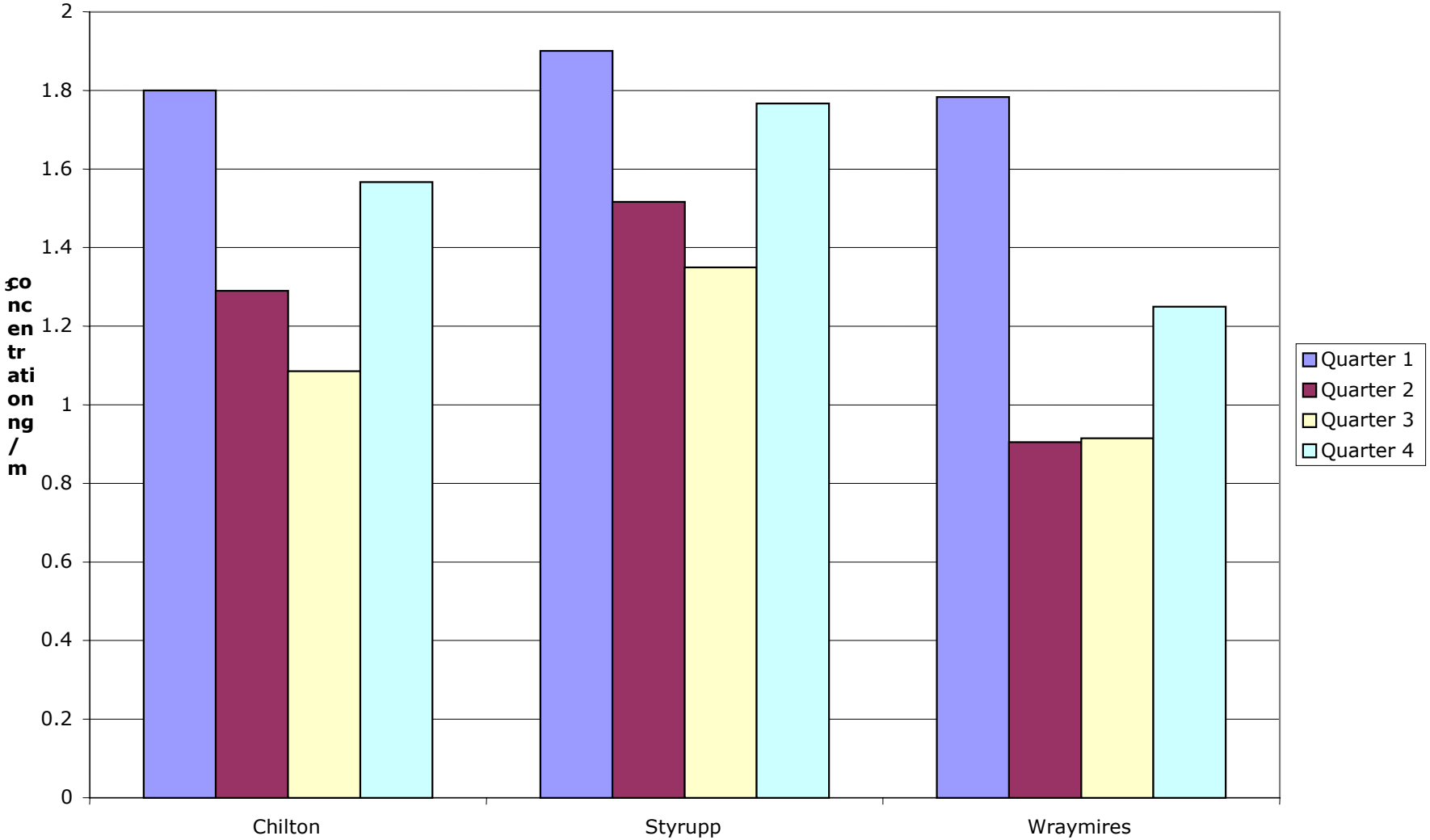

Figure 1.2 - Mean Concentration of particle associated iodide (ng/m^3) averaged over each quarter 1996-2001

Table 1.2 - Annual mean air concentrations of particle associated iodide (ng/m^3) at three rural sites in the Defra Rural Trace Elements Network 1972-74 and 1996 to 2002.

	Chilton	Styrupp	Wraymires
1972	<2.4	<8.4	<1.2
1973	<3.6	<7.2	<2.4
1974	<2.4	<8.4	<1.2
1996	1.8	2.4	1.1
1997	1.9	2	1.7
1998	1.4	1.5	1.2
1999	0.89	1.4	1.1
2000	1.2	1.5	1.1
2001	1.2	1.1	1.1
2002	1.1	1.2	0.9

2 TOXICOLOGY

The data available concerning the toxicity of hydrogen iodide are extremely limited. Inhalation of hydrogen iodide is reported to cause irritation of the upper respiratory tract, and a concentration of about 35 ppm (186 mg/m^3) causes irritation of the throat after short exposure. More severe exposures result in pulmonary oedema, and often in laryngeal oedema (HSDB 2003). However, no further details are available. An extensive literature search revealed no toxicological studies for humans or laboratory animals exposed to hydrogen iodide.

There is however, extensive literature available on the toxicity of iodine and iodide salts, which are known to both enhance and depress thyroid activity dependent on relative concentrations. The Joint FAO/WHO Committee on Food Additives (JECFA, 1988) and the UK Expert Group on Vitamins and Minerals (EVM, 2003) have reviewed the toxicity of iodine.

Iodine is an essential dietary element which is required for synthesis of the thyroid hormones, thyroxine (T4) and triiodothyronine (T3). T4 and T3, which are iodinated molecules of the essential amino acid tyrosine, regulate cellular oxidation and hence effect calorigenesis, thermoregulation, and intermediary metabolism. These hormones are necessary for protein synthesis, and they promote nitrogen retention, glycogenolysis, intestinal absorption of glucose and galactose, lipolysis, and uptake of glucose by adipocytes. Dietary deficiency of iodine can lead to thyroid enlargement, goitre. As a result, iodine supplementation programs have been developed in many countries to prevent endemic goitre. This has been done by adding iodine salts to common salt (JECFA 1988).

Iodine occurs in foods mainly as inorganic iodide, which is readily and completely absorbed from the gastrointestinal tract. Other forms of iodine in foods are reduced to iodide before absorption. Absorbed iodide is distributed throughout the body via the circulatory system. A proportion (approximately 30%) is removed by the thyroid for hormonal synthesis. By analogy with the other hydrogen halides, it is expected that exposure to hydrogen iodide will, upon dissolution in water, result in exposure to the iodide anion.

In summary, food is the major route of human exposure to iodine for the general population and estimated UK dietary intakes are well in excess of the amount recommended for adequate nutrition. Mineral supplements or other iodine-containing drugs can also represent a substantial source of iodine intake for consumers of such products.

In addition to dietary sources, various mineral supplements and medical preparations can further increase iodine intake to a significant extent. The major sources of iodine that have caused adverse effects are iodine-containing pharmaceuticals. Iodine-containing drugs (most commonly potassium iodide solutions) have been prescribed for respiratory problems such as asthma, bronchitis, cystic fibrosis, and chronic obstructive pulmonary disease. These iodine-containing drugs are usually prescribed for their expectorant action. Potassium iodide and other iodine solutions have also been prescribed in the treatment of goitre and hyperthyroidism.

Whether iodine is administered topically or systemically, iodine and iodides can give rise to allergic reactions, therefore there is likely to be a sub-population that is at higher risk to the effects of inhalation exposure due to sensitisation to iodine and iodides.

The JECFA Committee concluded that while individual human exposure to iodine may vary, an iodine intake of 1 mg per day or less is probably safe for the majority of the population, but may cause adverse effects for some individuals, e.g., people with thyroid disorders or people who are particularly sensitive to iodine. WHO has recommended a dietary allowance of iodine of 0.10 to 0.14 mg/day per adult. For purposes of safety, the Committee set a provisional maximum tolerable daily intake of 140 mg iodine/day (0.017 mg/kg body weight) (sic) from all sources. However, 0.017 mg/kg body weight gives a daily intake of approximately 1mg iodine/day for a 60 kg adult, more in line with the JECFA figure. Exposure to hydrogen iodide in the environment is likely to present only a small contribution to the overall intake of iodine.

In May 2003, the Expert Group on Vitamins and Minerals (EVM, 2003) established a supplemental intake guidance level of 0.5 mg/day (equivalent to 0.008 mg/kg body weight per day in a 60 kg adult). This level as a supplement to the iodine present in the diet was considered not to result in any significant adverse effects in adults.

In the absence of any other relevant data, these figures could be used to derive a inhalation guideline using a conservative estimate for the daily intake of hydrogen iodide in air.

3 EVALUATIONS AND RECOMMENDATIONS BY OTHER ORGANISATIONS

The USEPA Office of Pollution Prevention and Toxics proposed Acute Exposure Guideline Levels (AEGLs) for hydrogen iodide in 2000. There are three types of guidelines: AEGL-1, AEGL-2 and AEGL-3. The definitions of these provided in the public draft document for hydrogen iodide are:

AEGL-1 is the airborne concentration (expressed as ppm or mg/m3) of a substance at or above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain sub-clinical non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m3) of a substance at or above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m3) of a substance at or above which it is predicted that the general population, including susceptible individuals, could experience life threatening health effects or death.

For the purposes of this evaluation it is considered that AEGL-1 is the most appropriate guideline to consider. Further details for the derivation of AEGL-2 and AEGL-3 are available in the USEPA (2000) reference. The values derived for hydrogen iodide were based on hydrogen bromide as USEPA considered that there was insufficient information on hydrogen iodide.

AEGL-1 VALUES FOR HYDROGEN IODIDE

Time	AEGL-1 Value
10 minutes	1 ppm (5.3 mg/m^3)
30 minutes	1 ppm (5.3 mg/m^3)
1 hour	1 ppm (5.3 mg/m^3)
4 hours	1 ppm (5.3 mg/m^3)
8 hours	1 ppm (5.3 mg/m^3)

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Appendix A – Literature Search Strategy

The search of the scientific literature was performed in several stages. Initially a primary search of the full literature to April 2003 was conducted and assessed for content. The search was then refined to look for reviews. Following this, a further search was performed to look for reviews in the time period 01/01/1995 – 30/04/2003. A final search to include the search term toxicity was also made.

The initial search included the following literature sources;

A primary search of PubMed with search term 'Hydrogen AND iodide
World Health Organisation Environmental Health Criteria
INCHEM – WHO database of documents
IARC – International Agency for Research on Cancer
EURAR – European Union Risk Assessment reports
USEPA Integrated Risk Information System
USEPA (2000) Office of Pollution Prevention and Toxics. Acute Exposure Guideline Levels
American Conference of Governmental Industrial Hygienists
Agency for Toxic Substances and Diseases Registry
Occupational Safety and Health Administration
National Institute for Occupational Safety and Health
Office of Environmental Health Hazard Assessment
Health and Safety Executive
Toxicology Excellence for Risk Assessment
Health Canada
NAS (National Academy of Sciences)
International Uniform Chemical Information Database (2000)
Google Search Hydrogen Iodide
Toxnet search Hydrogen Iodide

The later searches looked at the following;

Search with search term 'Hydrogen AND iodide and limited to reviews
Search with search term 'Hydrogen AND iodide and limited to reviews and 01/01/1995 – 30/04/2003
Search of PubMed with search term 'Hydrogen AND iodide and limited to reviews with search terms Hydrogen and Iodide and toxicity

Appendix B – Medical Glossary

adenoma	a benign tumour of *epithelial origin that is derived from glandular tissue or exhibits clearly defined glandular structures; may undergo malignant change.
atelactasis	failure of part of the lung to expand
barbiturates	a group of drugs, derived from barbituric acid that depress activity of the central nervous system and formally used as sedatives.
blepharospasm	involuntary tight contraction of the eyelids
bronchiolitis obliterans	also known as BOOP (bronchiolitis obliterans organising pneumonia); a disease entity characterised by a flu-like illness with cough, fever, shortness of breath and late inspiratory crackles
bronchopneumonia	pneumonia infection which starts in a number of small bronchi and spreads in a patchy manner into the alveoli.
cardiovascular system	the circulatory system – the heart together with the two networks of blood vessels
cheilitis	inflammation on the lips
chorioamnionitis	Infection, of the chorionic and amniotic membranes caused by bacteria. These membranes enclose the amniotic fluid and when infection is present in the membranes, the mother and foetus are at increased risk for severe infection.
choliangiocarcinoma	a malignant tumour of the bile ducts
chromatolysis	the dispersal or disintegration of the microscopic structures within the nerve cells that normally produce proteins (part of the cell's response to injury)
cilia	hair-like structures, large numbers of which found on certain epithelial cells; particularly characteristic of the epithelium that lines the upper respiratory tract, where their beating serves to remove particles of dust and other foreign material
clastogen/clastogenic	causing chromosomal aberrations
cyanosis	a bluish discoloration of the skin and mucous membranes resulting from an inadequate amount of oxygen in the blood
desquamation	the process where the outer layer of the epidermis of the skin is removed by scaling
diuresis	increased secretion of urine by the kidneys
emphysema (related to the lung)	a disease where the air sacs of the lungs are enlarged and damaged, which reduces the surface area for the exchange of oxygen and carbon dioxide
endomitotic	chromosome replication without mitosis, leading to polyploidy.
epithelium	the tissue that covers the external surface of the body and lines hollow structures.
erythrocyte	blood cell containing the red pigment haemoglobin, the principal function of which is the transport of oxygen
fenestration	creation on an opening (surgical or due to disease)
fibrin	the final product of the process of blood coagulation,

	produced by the action of the enzyme thrombin on a soluble precursor *fibrinogen
fibrinogen	a substance present in blood plasma, that is acted upon by the enzyme thrombin to produce the insoluble protein *fibrin in the final stage of blood coagulation
tracheitis	inflammation of the trachea
follicle-stimulating hormone (FSH)	a hormone synthesised and released by the pituitary gland; stimulates ripening of the follicles in the ovary and formation of sperm in the testes
goblet cell	a column shaped secretory cell found in the epithelium of the respiratory and intestinal tracts; secretes the principal constituents of mucous
haemorrhage	bleeding: the escape of blood from a ruptured blood vessel, externally or internally
hepatic	relating to the liver
hepatocyte	the principle cell type in the liver; a large cell with metabolic functions
hilar	refers to the area where nerves and blood vessels attach to an organ
histology (histological)	study of the structure of tissues by means of special staining techniques combined with light and electron microscopy
hyaline membrane disease	also known as respiratory distress syndrome. the condition in a newborn infant in which the lungs are imperfectly expanded
hypercapnia	the presence in the blood of an abnormally high concentration of carbon dioxide
hyperplasia	the increased production and growth of normal cells in a tissue or organ; the infected part becomes larger but retains its normal form.
hypertension	high blood pressure
hypertrophy	increase in the size of a tissue or organ brought about by the enlargement of its cells rather than by cell multiplication (i.e. muscles undergo this change in response to increased work).
hypotension	where arterial blood pressure is abnormally low
hypotonia	a state of reduced tension in muscle
hypoxaemia	reduction of the oxygen concentration in the arterial blood, recognised clinically by the presence of central and peripheral *cyanosis
hypoxia	a deficiency of oxygen in the tissues
lacrimation	the production of excess tears; crying
lesion	a zone of tissue with impaired function as a result of damage by disease or wounding
leucopoiesis	the process of production of white blood cells (leucocytes)
luteinising hormone (LH)	a hormone synthesised and released by the pituitary gland that stimulates ovulation, corpus luteum formation, progesterone synthesis by the ovary and androgen synthesis by the interstitial cells of the testes
macrophage	a large scavenger cell present in connective tissue and major organs and tissues

meatus	a passage or opening
acidosis	a condition in which the acidity of body fluids and tissues is abnormally high
mediastinum	area at the centre of the chest which contains the heart, windpipe (trachea), gullet (oesophagus) large main blood vessels and the lymph nodes that surround the heart.
metaplasia	an abnormal change in the nature of a tissue
microphthalmia	a congenitally small eye, usually associated with a small eye socket
mucosa	also known as mucous membrane; the moist membrane lining many tubular structures and cavities, including the nasal sinuses, respiratory tract, gastrointestinal tract, biliary and pancreatic systems.
myocardium	the middle of the three layers forming the wall of the heart
dystrophy	a disorder of an organ or tissue, usually muscle, due to an impaired nourishment of the affected part
nares	the nasalis muscles (nares) are used as accessory muscles of respiration during times of respiratory distress; they are partially responsible for 'nasal flaring'.
nasopharynx	the part of the *pharynx that lies above the soft palate
necropsy	autopsy
necrosis	the death of some or all of the cells in an organ or tissue
ocular	related to the eye and vision
oedema	excessive accumulation of fluid in the body tissues
olfactory	relating to the sense of smell and nose
oligozoospermia	condition where the sperm concentration is low, less than 20 million per ml.
parenchyma	the functional part of an organ, as opposed to the supporting tissue (*stroma*)
pathology	study of disease processes with the aim of understanding their nature and causes
peritoneal mesothelioma	a tumour of the *peritonium
peritoneum	the *serous membrane of the abdominal cavity
pharyngitis	inflammation of the part of the throat behind the soft palate; produces a sore throat and associated with tonsillitis
pharynx	the muscular tube, lined with mucosa, that extends from the beginning of the oesophagus up to the base of the skull.
plethysmograph	a record of the changes in the volume of a limb caused by alterations on blood pressure
pneumomediastatinum	air in the mediastinum
pneumonitis	inflammation of the lung that is confined to the walls of the air sacs
polymorphonuclear leucocyte	same as polymorph and neutrophil – variety of white blood cell that is capable of ingesting and killing bacteria and provides an important defence against infection.
proteinuria	the presence of protein in the urine; may indicate the presence of damage or disease of the kidneys
pseudomembrane	a false membrane, consisting of a layer of exudate on the surface of the skin or mucous membrane

pulmonary	relating to the lung
renal	relating to the kidneys
rhinitis	inflammation of the mucous membrane of the nose
rhinorrhea	a persistent watery mucous discharge from the nose, as in the common cold
septal	partition between the left and right halves of the chest
serous membrane	a smooth transparent membrane, consisting of mesothelium and underlying elastic fibrous connective tissue lining certain large cavities of the body
squamous cell	an epithelial cell that is flat like a plate and forms a single layer of epithelial tissue
squamous metaplasia	a change in the nature of tissue into *squamous epithelium; may be an early sign of malignant change
submucosa	the layer of loose connective tissue underlying a mucous membrane
synctial	made up of a mass of *protoplasm containing several nuclei, e.g, muscle fibres are *synctia*
tachypneoa	rapid breathing
thrombosis	a condition in which the blood changes from a liquid to a solid state and produces a blood clot
protoplasm	the material of which living cells are made, which includes the cytoplasm and nucleus
trigeminal nerve	the fifth and largest cranial nerve; controls the muscles involved in chewing and relaying information about temperature, pain and touch from the whole frond half of the head
turbinate bone	any of the three thin scroll-like bones that form the sides of the nasal cavity (also known as nasal concha)

Appendix C – Glossary of Terms and Acronyms

Acceptable Daily Intake (ADI): The amount of a chemical a person can be exposed to on a daily basis over an extended period of time (usually a lifetime) without suffering deleterious effects.

Ambient Air Level Goals (AALGs): The term used by Calabrese and Kenyon to describe the numerical values derived using their methodology. The values are described as goals because the values are based only on health effects and do not include consideration of technical, economic, and analytical feasibility or any other issues that are within the realm of risk management.

Average Daily Dose (ADD): Dose rate averaged over a pathway-specific period of exposure expressed as a daily dose on a per-unit-body-weight basis. The ADD is usually expressed in terms of mg/kg-day or other mass-time units.

Benchmark Dose (BMD) or Concentration (BMC): A statistical lower confidence limit on the dose that produces a predetermined change in response rate of an adverse effect (called the benchmark response or BMR) compared to background.

Best Available Techniques (BAT): The meaning of this term can depend on the context within which it is used. When used in the context of IPPC or PPC it is defined as the most effective and advanced technique for the prevention, or where that is not practicable, the minimisation of emissions and impact on the environment as a whole. It includes consideration of the availability of the technique for the type of process concerned and cost. However, the term BAT may also be applied in the context of the IPC regime where it has a similar meaning to that under IPPC or PPC except that costs are not taken into consideration. See also Integrated Pollution Prevention and Control, Integrated Pollution Control and Pollution Prevention and Control.

Best Practicable Environmental Option (BPEO): The Royal Commission on Environmental Pollution (RCEP) in their Twelfth Report defined the BPEO as;

"the option which provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as the short term."

The determination of the BPEO was intended to be wide ranging and include assessment of, for example, alternative ways of undertaking the activity in different locations. Impacts were also to be considered broadly and include not only the direct impact of a process on the natural environment or human health but also issues such as visual intrusion, the effects of additional traffic or the production and delivery of raw materials. The term was also applied to the Integrated Pollution and Control regime, which required operators to use the Best Available Techniques Not Entailing Excessive Cost to achieve the Best Practical Environmental Option *in relation to releases from the process*. This definition, therefore, prescribes the scope of the BPEO when used in the context of IPC and specifically excludes consideration of effects other than those arising directly from the process releases. The term BPEO is not specifically mentioned in Integrated Pollution Prevention and Control. However, the directive does refer to the need to protect the environment as a whole, which is taken to be a similar concept to BPEO.

Carcinogen: An agent capable of inducing cancer.

Carcinogenesis: The origin or production of a benign or malignant tumour. The carcinogenic event modifies the genome and/or other molecular control mechanisms of the target cells, giving rise to a population of altered cells.

Case-control study: An epidemiological study contrasting those with the disease of interest (cases) to those without the disease (controls). The groups are then compared with respect to exposure history, to ascertain whether they differ in the proportion exposed to the chemical(s) under investigation.

Chronic Exposure: Multiple exposures occurring over an extended period of time, or a significant fraction of the animal's or the individual's lifetime.

Chronic Study: A toxicity study designed to measure the (toxic) effects of chronic exposure to a chemical.

Chronic Toxicity: The capacity of a substance to cause adverse human health effects as a result of chronic exposure.

Cohort Study (or Prospective Study): An epidemiological study comparing those with an exposure of interest to those without the exposure. These two cohorts are then followed over time to determine the differences in the rates of disease between the exposure subjects.

Confounder (or Confounding Factor): A condition or variable that is both a risk factor for disease and associated with an exposure of interest. This association between the exposure of interest and the confounder (a true risk factor for disease) may make it falsely appear that the exposure of interest is associated with disease.

Control Group (or Reference Group): A group used as the baseline for comparison in epidemiological studies or laboratory studies. This group is selected because it either lacks the disease of interest (case-control group) or lacks the exposure of concern (cohort study).

Dose-Response Relationship: The relationship between a quantified exposure (dose), and the proportion of subjects demonstrating specific, biological changes (response).

Environmental Assessment Level: Environmental Assessment Levels (EALs) are benchmarks in a particular environmental media which denote the concentration of a chemical that should have no adverse effects on the natural environment or human health. By comparison with the predicted environmental concentrations arising from releases, they are intended to enable the significance of releases to be assessed, the need for further pathway modelling to be determined and the relative impact of pollutants released to different environmental media to be compared.

Horizontal Guidance Note (H1): The name of the guidance note issued by the Environment Agency which describes how operators should assess the environmental impact of processes and appraise the Best Available Techniques when applying for a permit under the Pollution Prevention and Control (PPC) regime. The term 'Horizontal' refers to the fact that the guidance can be applied across all the sectors covered by PPC.

Indicative Occupational Exposure Limit Values (IOELVs): European Community limit values, which are health based and are set under the EU Chemical Agents Directive (98/24/EC) (earlier Directives referred to the as ILVs). They indicate levels of exposure to hazardous substances considered to provide protection from ill health caused by work. IOELVs are similar to the British OELs system under COSHH.

Integrated Pollution Control (IPC): Prior to the PPC regulations coming into force, many industrial sectors covered by the IPPC Directive were regulated under Part I of the Environmental Protection Act 1990. This introduced the systems of Integrated Pollution Control (IPC), which controlled releases to all environmental media, and Local Air Pollution Control (LAPC), that controlled releases to air only. Processes regulated under IPC were controlled by the Environment Agency in England and Wales and were potentially the most polluting or technically complex. LAPC was operated by local authorities. Similar but separate arrangements were applied to Scotland and Northern Ireland. The objective of IPC was to use the Best Available Techniques Not Entailing Excessive Cost (BATNEEC) to prevent releases or where that was not practicable to minimise and render them harmless.

Integrated Pollution Prevention and Control (IPPC): The system of Integrated Pollution Prevention and Control (IPPC) applies an integrated environmental approach to the regulation of certain industrial activities. This means that emissions to air, water (including discharges to sewer) and land, plus a range of other environmental effects, must be considered together. It also means that regulators must set permit conditions so as to achieve a high level of protection for the environment as a whole. These conditions are based on the use of the Best Available Techniques. (BAT), which balances the costs to the operator against the benefits to the environment. IPPC aims to prevent emissions and waste production and where that is not practicable, reduce them to acceptable levels. IPPC also takes the integrated approach beyond the initial task of permitting, through to the restoration of sites when industrial activities cease. IPPC was introduced by the European Community (EC) Directive 96/61/EC on Integrated Pollution Prevention and Control (the IPPC Directive). The Directive is implemented by the Pollution Prevention and Control (England and Wales) Regulations 2000, SI 2000/1973. Separate systems have been introduced to apply the IPPC Directive to Scotland, Northern Ireland and the offshore oil and gas industries. Industrial activities are being brought under the control of the regulations on a sector by sector basis according to a timetable set out in the regulations and the Directive will not be fully implemented until 2007. See also Pollution Prevention and Control and Integrated Pollution Control.

Integrated Risk Information System (IRIS). IRIS is an on-line database established by the US Environmental Protection Agency (EPA) which provides information related to; substance identification, chemical and physical properties, hazard identification and dose response assessments. EPA working groups then review the available studies and develop reference doses based on assessment of lifetime exposure for non-carcinogenic endpoints or unit risk estimates for carcinogenicity. Information is also given on relevant EPA regulatory actions, standards and guidelines. The data included within IRIS is extensively peer reviewed and represents EPA consensus on risk. Selected studies from the primary literature are referenced.

Maximum Exposure Limit (MEL): Maximum Exposure Limits (MELs) are one of the two types of Occupational Exposure Limits (OELs) the UK Health and Safety

Commission (HSC) sets. A MEL is proposed for substances, which may cause the most serious health effects, such as cancer and occupational asthma. These are substances for which no threshold level of exposure for the key health effect can be determined or for which exposure thresholds may be identified but at a concentration that is not yet routinely achievable in the workplace. The Control of Substances Hazardous to Health (COSHH) regulations 1999 require that exposure should be reduced as far below the MEL as reasonably practicable. See also Occupational Exposure Standard (OES).

Minimum Risk Level (MRL): An estimate of daily exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure. The ATSDR develops MRLS for acute, intermediate and chronic duration exposures by the oral and inhalation routes. The concept, definition and derivation of MRLs are consistent with those of EPA's RfC and RfD. ATSDR publishes MRLs as part of its toxicological profile documents for each substance.

No-Observed-Adverse-Effect Level (NOAEL): A highest exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effect between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered adverse, nor precursors to adverse effects.

No-Observed-Effect Level (NOEL): An exposure level at which there are no statistically or biologically significant increases in the frequency or severity of any effect between the exposed population and its appropriate control.

Occupational Exposure Level (OEL): This is the collective term used in America to describe American occupational levels; those typically referred to are Recommended Exposure Limits (RELs), Permissible Exposure Limits (PELs) and Threshold Limit Values (TLVs).

Occupational Exposure Limit (OEL): The UK Health and Safety Commission (HSC) sets occupational exposure limits (OELs) which are concentrations of substances in the air at or below which occupational exposure is considered to be adequate. The HSC sets two types of occupational exposure limits – Maximum Exposure Limits (MELs) and Occupational Exposure Standards (OES). See also Occupational Exposure Level.

Occupational Exposure Standard (OES): Occupational Exposure Standards (OES) are one of the two types Occupational Exposure Limits (OELs) the UK Health and Safety Commission (HSC) sets. An OES is proposed at a level at which based on current scientific knowledge, there is no indication of risk to the health of workers who breathe it in daily. If exposure to a substance that has an OES is reduced to at least that level, then adequate control has been achieved.

Permissible Exposure Limits (PELs). Occupational exposure limit issued by the US Occupational Safety and Health Administration (OSHA). PELs are time-weighted average concentrations that must not be exceeded during any 8 hour work shift of a 40 hour week. May consider economic and technical feasibility in addition to health effects.

Pollution Prevention and Control (PPC): The Pollution Prevention and Control (England and Wales) Regulations 2000, SI 2000/1973 implement the requirements of the European Community (EC) Directive 96/61/EC on Integrated Pollution Prevention and Control (the IPPC Directive), in so far as it relates to installations in England and Wales. Separate systems have been introduced to apply the IPPC Directive to Scotland, Northern Ireland and the offshore oil and gas industries. The regulatory regime established by the regulations is often known as the PPC regime. See also Integrated Pollution Prevention and Control and Integrated Pollution Control

Recommended Exposure Limits (RELs). Occupational exposure limit developed by the US National Institute of Occupational Safety and Health (NIOSH). RELs are time-weighted average concentrations for up to a 10-hour work day during a 40-hour work week, that should not be exceeded at any time during a work day.

Reference Concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's non-cancer health assessments.

Relative Source Contribution (RSC). The RSC is an assessment of the proportion of total exposure to a substance that may be allowed to arise from a specific exposure route, in this context inhalation. This may be calculated, where exposure routes are quantified, on the basis of the scale of exposure from other routes compared to the allowable exposure. However in many cases assumptions need to be made as to the relative importance of inhalation. In some circumstances use of an RSC may not be relevant such as where the endpoint is non-cumulative, e.g. irritation, or the adverse effect is specific to inhalation and would not occur via other routes of exposure.

Threshold Limit Values (TLVs). These values are established by the American Conference of Governmental Industrial Hygienists (ACGIH). They are the concentration in air of a substance to which, it is believed that, most workers can be exposed daily without adverse effect. Quoted as time weighted concentrations for a 7 or 8 hour workday and a 40 hour working week. For most substances the value may be exceeded, to a certain extent, provided there are compensating periods of exposure below the value during the workday, or in some cases working week. A limited number of substances are given ceiling concentrations that should never be exceeded.

Uncertainty Factor (UF): (also known as a safety factor) one of several, generally 10-fold factors, used in operationally deriving the RfD and RfC from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population, i.e., interhuman or intraspecies variability; (2) the uncertainty in extrapolating animal data to humans, i.e., interspecies variability; (3) the uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure to lifetime exposure, i.e., extrapolating from subchronic to chronic exposure; (4) the uncertainty in extrapolating from a LOAEL rather than from a NOAEL; and (5) the uncertainty associated with extrapolation from animal data when the data base is incomplete.