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THE REDEVELOPMENT OF CONTAMINATED LAND: A SITE INVESTIGATION, RISK ASSESSMENT AND REMEDIATION SELECTION FOR A FORMER WIRE WORKS

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SUMMARY

A site investigation, risk assessment and remediation selection is carried out for an industrial site. The site contains a former wire works an iron works, and former brick and tile works, it also has a history of waste disposal.

It is found that metals, namely copper, lead, zinc, boron and nickel, contaminate the site. Arsenic is also found on the site along with polyaromatic hydrocarbons (PAH) and phenols. Sulphates were found in some areas. A hazard analysis highlights that these contaminants may be carcinogenic, toxic by ingestion, harmful to the skin and harmful to plants.

A chemical analysis of the contaminants using guidelines issued by the ICRCL and the equivalent Dutch guidelines is undertaken. The results of which show that the levels of contaminants on the site are above trigger levels. A risk assessment found that the contaminants pose unacceptable risks to the end users of the site.

Risk reduction methods are studied. Possible remediation strategies are then outlined. From the strategies a preferred strategy for a residential development, a recreational development and a retail development are discussed.

The findings are that the type of remediation depends upon the selected end use. A 'suitable for use' approach to remediation is used.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY OF CONTAMINATED LAND

Land contamination was first identified as a problem in the late 1970s and it has been estimated that 300 000 hectares of land in the UK are potentially contaminated (Ends Daily, 2000). Contamination can have occurred in the past or can still be occurring, Cairney, 1993 stated that; "The number of such sites, and hence the area of contaminated land, should diminish with time as these sites are recognised, treated and returned to use." The 'return to use' of such sites is known as remediation or which will be used to refer to the process throughout this study.

Some land could be currently being contaminated; it is however thought that the increase in such sites will be kept low with the introduction of tighter legislation. In many cases contamination has arisen through industry in the past many practices have been below today's environmental standards. Jones et al, 1997 state that; "The industrial history of the British Isles has left a legacy of contaminated land from a variety of industries and manufacturing processes." Table 1.1 highlights the major industrial practices that are likely to have been a cause to the contamination.

• **Asbestos Manufacture and use**	• **Paints and graphics**
• **Chemical Industries**	• **Pharmaceutical industries**
• **Dockyards**	• **Scrap processing industries**
• **Explosive manufacture**	• **Sewage works and farms**
• **Gas and electricity supply industries**	• **Tanning and associated trades**
	• **Transport industries**
• **Iron and steel works**	• **Use of radioactive substances**
• **Metal smelting and refining**	• **Waste disposal operations**
• **Metal treatment and finishing**	• **Wood preserving**
• **Mining and extraction**	• **Oil refining, distribution and storage**

TABLE 1.1. Industries and activities known to be associated with contaminated land. Harris & Herbert, 1995.

As shown in table 1.1 there is many industrial activities responsible for the contamination of land. "The redevelopment of these sites is becoming increasingly more common as fewer suitable greenfield sites come on to the market." (Round et al, 1999). The sources of this contamination are outlined by ICRCL, 1987 as being; “Leakage or spillage from pipes and tanks; deposition of airborne particles; storage and disposal of raw materials, unwanted wastes and residues, and the application of sewage sludge to land.” The presence of contaminants is measured in terms of the potential harm to the environment or to human health; contamination may also have detrimental effects on buildings and construction. The potential hazards of a particular site are determined by its intended use. For instance, a site that is to be developed for a car park, and thus needs only to be covered with concrete, will cause less potential hazards than a site that is to be developed for housing purposes.

Most contamination in the UK has arisen from the industrial revolution although there are some older contaminated sites; “These include sites of copper and lead workings dating back to Roman times.” (Cairney, 1993).

A problem occurs when attempting to define contaminated land. A statutory definition is given under section 78A(2) of the EPA, 1990 (as inserted by the Environment Act, 1995) and is outlined by Bell, 1997;

“Land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under land, that;

(a) Significant harm is being caused or there is significant possibility of such harm being caused; or

(b) Pollution of controlled waters is being or is likely to be, caused.”

'Contamination' has been defined by CIRIA, 1995 as; "The presence in the environment of an alien substance or agent, or energy, with a potential to cause harm."

Different countries have differing criteria for defining contaminated land and different codes of practice for clean up. For example The Netherlands has adopted an approach where the land is returned to nature reserve levels i.e. full clean up is required. The natural conditions of The Netherlands, however are different from those found in other countries.

The UK Government has adopted a 'Suitable for Use Approach' when dealing with remediation. Bell, 1997 states that; "Remedial action will only be required where the contamination poses unacceptable, actual or potential risks to the health or the environment." Land will be dealt with if it is deemed appropriate and cost effective after the intended use of the site is taken into account. Obligation is on the local authorities. They are expected to identify areas of contaminated land and to apply clean up methods where appropriate. They are required to apply the 'suitable for the use' concept to prevent unacceptable risks to human health and the environment. In the UK the Interdepartmental Committee for Redevelopment of Contaminated Land (ICRCL, 1987) has produced trigger values for use in site assessment. Risk assessment is also increasingly being used to aid remediation of contaminated sites this involves;

i. **Hazard identification**
ii. **Hazard assessment**
iii. **Risk estimation**
iv. **Risk evaluation and**
v. **Risk control**

(Harris and Herbert, 1995).

The possibility of human harm arising from contaminated and has led to the assessment of contaminated land, as simplified by Harris and Herbert, (1995). This concentrates on three key areas;

- **HAZZARD -** a property or situation that has the potential to cause harm.
- **PATHWAY -** the route by which the contaminant takes to come into contact with the target.
- **TARGET -** the entity that could be harmed through the contact with a hazard.

Figure 1.1 shows the likely pathways by which a contaminant may come into contact with a target.

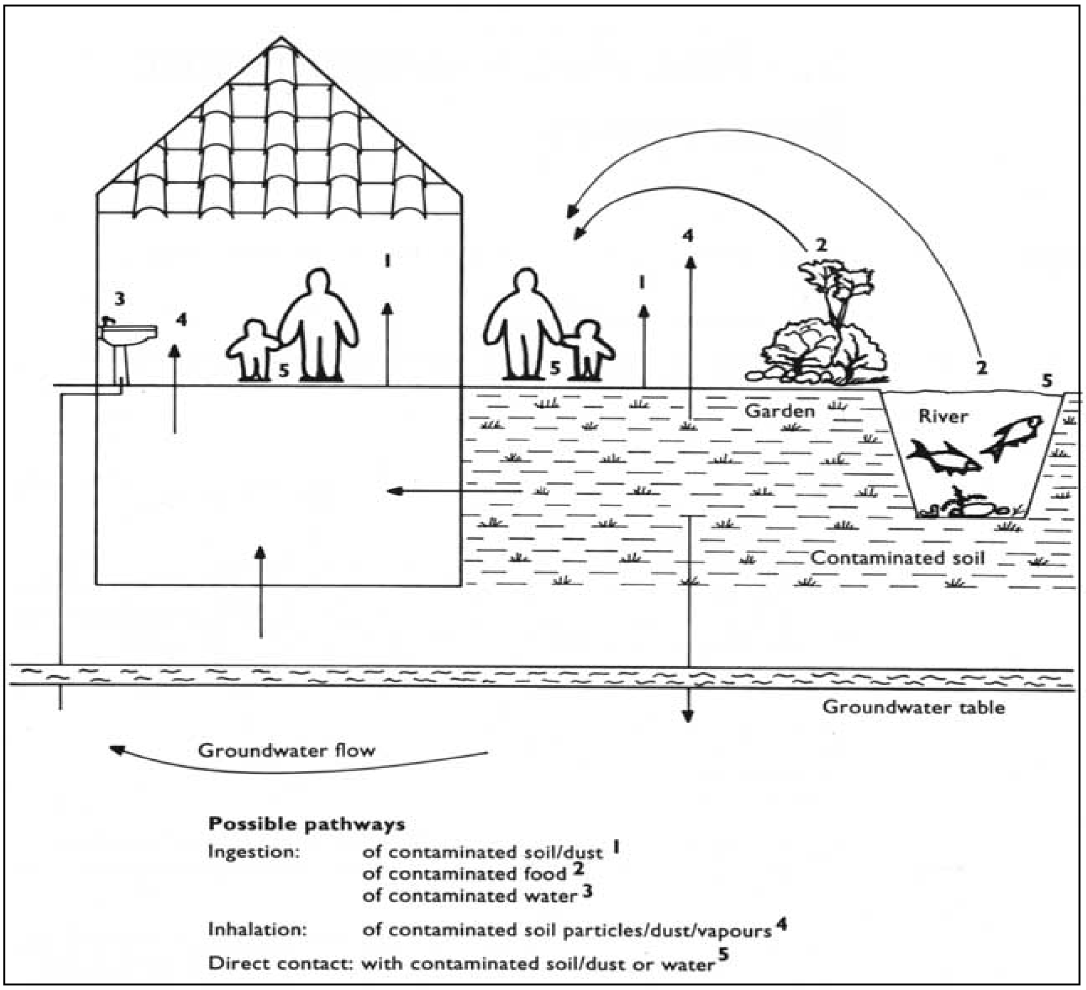

FIGURE 1.1 Hazard/Pathway/Target relationships in the investigation of contaminated land (Harris and Herbert, 1995).

Detailed studies on the subject of contaminated land have been undertaken since the problem was first identified. Forde et al, 1992 state that "prior to the 1980s land reclamation was focused on the removal of eyesores. Since then it has been directed towards projects with commercial use." Smith, (1991), looked at contaminated land in terms of "land which might currently, or in the future pose a threat to (a) human welfare (b) the environment and (c) natural resources." The approach to contaminated land investigation has gradually changed over the years with the move towards sustainable development and the introduction of legislation covering contaminated land issues. In particular the 'Statutory Guidance on Contaminated Land' has been introduced. "This will underpin section 57 of the Environmental Protection Act 1995, and enable enforcement of part IIA of the EPA (1990)." (DETR, 2000). This provides for the first time, "An explicit definition of contaminated land focusing on risks arising in the context of current use and circumstances of land." (DETR, 2000). The enforcement of this legislation, "Will require local authorities to undertake an audit of contaminated land within their boundaries and to establish an action plan for implementation of measures to mitigate health and environmental risks which are acceptable with respect to statutory guidelines." (Kelly & Lunn, 1999).

"For many years the standard approach for site assessment has involved the use of generic trigger values proposed by the Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL)." (Hines and Failey, 1997). These guidelines have meant that some contaminants have been overlooked because they are not contained within the guidelines. Hines and Failey, go on to say that, "If we can determine how pollutants behave in the environment and the mechanisms by which they cause potential exposure to the site end user, then we can be more specific on the likely consequences from such exposure and the probability of the consequences occurring." The process now increasingly being used is risk assessment. Together with risk reduction this comprises the overall process of risk management (Harris and Herbert, 1995). Risk management is defined by Hines and Failey, 1997 as; "The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probabilities of occurrence." The use of a risk management framework has come to be the major tool in assessing a contaminated site. One reason for this is the redevelopment of brownfield sites as outlined by Round et al, 1999; "The development of sites with a previous use, the so called brownfield sites, is becoming increasingly more common as fewer suitable greenfield sites come onto the market." The government has stated that by 2016, 60% of all new homes are to be built on brownfield sites (Evans et al, 1999).

A risk management approach to contaminated land can greatly reduce the amount of contaminated soil going to landfill. One reason for this and for the rapid increase in risk management approaches is thought to be related to the introduction of the landfill tax as described by Jones et al, 1997. "In terms of remediation, the advent of the landfill tax (October, 1996) has prompted developers to consider alternatives to the excavation of contaminated materials and disposal to landfill."

Round et al, 1999 have developed an integration strategy where remediation is integrated into the redevelopment of brownfield sites. It is stated that "Although such sites are often a valuable resource, their redevelopment is often perceived as being problematic due to the time and costs involved in implementing the remediation works and the constraints associated with the subsequent development, operation and financing scheme." This approach is also described by Hodges et al, 1997, as being beneficial, and Round et al, 1999 state; "By effectively integrating the remediation into the rest of the works, site redevelopment can be made cost effective."

Many previous studies have focused on the most successful methods for remediation and most have found that site specific remediation is the most effective. Barker et al, 1999 have studied 'In Groundwater Treatment of Polluted Ground' on former military sites. It was concluded that; "The main polluting substances of the geo-environment are oil products and technogenical solutions." Remediation using soil mix technologies is discussed by Evans and Al-Tabbaa, 1999.

Some sites require testing for specific contaminants, Ruby, et al, 1996 describe a site investigation where the "bioavailability of lead and arsenic were estimated using a physiologically based extraction test." The tests are based on ingestion of soils by children and the likelihood of lead and arsenic being absorbed by the body. A study on metal contaminated soils has been undertaken by Mulligan et al, in a study presented in 1999. Several remediation techniques are discussed and it is concluded that; "Since metals are considered relatively immobile, methods for metal contamination have focused on solid phase processes such as solidification/stabilisation and vitrification.

Risk assessment requires accurate sampling techniques to be undertaken. Board, 2000 states that; "Increasingly sophisticated lab tests are being developed for analysing soils, water or gas samples from contaminated sites." The report goes on to say; "Complex lab equipment may as well be consigned to the dustbin if sampling is not carried out correctly."

Gas has been identified as a major problem on contaminated sites, Wilson, 1999 states; "In response to incidents of methane explosions in the mid 1980s guidance documents were produced in the UK for both planning authorities and the construction industry." And then goes on to describe "A rational method for classifying gassing sites in terms of the risks posed by the presence of gas and various protection measures that can be incorporated into the remediation of contaminated land."

From evaluation of the above references this report is going to identify the contaminants present on the former industrial site being studied. A risk assessment is then going to be pursued which will incorporate the use of published guidelines in order to identify the risks of the contaminants to the end users of the site.

1.2 AIMS OF THE STUDY

The aims of this project are to;

- Undertake a detailed site investigation and risk assessment
- Determine the types, amounts and distribution of contaminants on the site
- Evaluate remediation options available, and
- Choose the best option available.

The site being studied is to be demolished and cleared for the erection of non-food retail units, a storage compound, service area and car parking, with landscaping and retaining structures. In addition, as part of this investigation, the site will also be looked at in terms of residential and recreational developments.

The investigation is being carried out by a group of Consulting Engineers on behalf of the site developers who are both to remain anonymous. This study is based on the data supplied by the Consulting Engineers and by access to the site where appropriate.

The risk assessment is designed to provide information related to the levels, types and distribution of contaminants present on the site. The development proposals for the site may be affected if the contaminants are found to be particularly harmful or abundant. This also may affect the way in which the buildings are constructed as certain contaminants may effect the structures over a given time period. Information gained will help decide on the type of remediation to be used. Remediation options are reviewed and the most effective method in terms of risk reduction are short listed with a view to recommending the Best Practical Environmental Option (BPEO) in terms of protecting human health and the environment.

It is proposed that the existing buildings will be demolished and used for fill during the redevelopment of the site. On many industrial sites the building fabric can become contaminated, and questions may be posed here as to whether the material will be safe to use, or whether the crushing of it is likely to release harmful contaminants. ICRCL trigger values (ICRCL, 1987) are used to determine the levels of contaminants present on the site in relation to the end use (appendix 1), Dutch Guidelines are used to assess the levels of groundwater contamination (appendix 2). Gas levels are examined and compared with Waste Management Paper 27 (DOE, 1989) (appendix 3).

CHAPTER 2: SITE INVESTIGATION

2.1 INTRODUCTION

The site investigation presented is undertaken as a desk study. Data has been compiled from historical and recent maps, aerial photographs, local authority, local newspapers, the Coal Authority, British Geological Survey, The Environment Agency, Department of Environment, Transport and Regions and the internet. The resources are used to compile a detailed survey of the past uses and industrial practices, as there is a need to understand the history and previous uses of the site. Geological and hydrological data gives important information on the ways that any contaminants may migrate once they are in contact with the surface or groundwater. The collection of data by the Consulting Engineers is contracted out to an exploration group. The data has been collected using ten cable percussive boreholes, twenty-nine mechanically excavated trial pits, three hand excavated trial pits and twelve window sample holes together with in-situ testing. The samples give detailed information on the contaminants present on the site in the soil, rocks and surface/groundwater.

2.2 SITE INVESTIGATION

2.2.1 Location of the Site

The location of the site being investigated is to be kept confidential as requested by the site developers.

2.2.2 Site Description and Topography

The site is roughly rectangular in shape and is bounded to the Northeast and Southwest by roads and to the west by housing. At the east of the site lies a minor road with a refuse disposal facility to the Southeast. Factory buildings cover sixty per-cent of the site, with areas of made ground and partially vegetated ash slopes to the rear of the buildings. Other vegetation is made up of trees at the foot and the top of the ash slope and there is also a supporting wall at the foot of the ash slope. The site houses a former wire works, where production dates back to the 1870s and has also seen other industries and services, such as brick and tile works and a waste disposal site. The study site became disused in the early 1990s.

The buildings are built of a mixture of traditional stone with modern steel factory buildings and warehouses, to the front of the buildings there is an area of concrete formerly used for car parking. A disused gas-works is situated outside the site boundary to the south east with one storage tower still present. There is a small stream running parallel with the southern boundary flowing in a Southeast direction, this is a tributary to a major watercourse approximately four miles downstream.

The buildings on the site are situated on a large flat area along the southern edge leading on to the road. This is in contrast to the ash tip rising steeply towards the northern boundary. The rooms and the operations that were undertaken in them are listed in table 2.1, and the layout of the rooms (and room numbers) can be seen in figure 2.1.

Room No.	Room Name	Operations, Processes and Facilities
1	Feed Stock for Wet Drawing Department	Storage of raw material, oil storage tanks.
2	Inspection and Despatch	Inspection of wire prior to despatch.
3	Wet Drawing Dept.	Wire drawn out to fine diameters, soap lubricant used.
4	Electro-Galvanising Dept. and Wire Storage Area	Electroplating , wire storage chemicals used; sulphuric acid, hydrochloric acid, zinc sulphate, caustic soda, zinc.
5	Offices	Offices and first aid room
6	Material Storage Area	Raw material storage
7	Three Stories: Ground floor - Operating Supplies and Water Recovery. 1st floor- Machine Room. 2nd floor - Canteen	Storage of paper bags, chemical storage. Wire drawing, water pipes.
8	Water Treatment	Water used to rinse acid from the wire the water was then recirculated.
9	Effluent Plant	Storage of caustic soda (liquid).
10	Engineering and Maintenance	Engineering processes (no chemicals stored)
11	Engineering and Maintenance	As above.
12	Engineering and Maintenance	As above
13	Test House and Despatch	Laboratory operations, quality control

Room no. continued	Room name continued	Operations, processes and facilities, continued
14	Wire Cleaning Dept.	Cleaning and coating of raw material (wire rod), storage tanks containing; borax, nitrite, phosphate, zinc phosphate, water, hydrochloric acid (all empty)
15	Patenting and Heavy Galvanising	Heat treatment of the wire, coating of the wire using; hydrochloric acid, zinc phosphate, borax, zinc ammonium chloride, molten lead, cyanide and zinc.
16	Galvanising	As above.
16a	Galvanising	Wire drawing area, storage tanks for hydrochloric acid (empty) and diesel (empty)
17	Galvanising	As above.
18	Dry Wire Drawing	Wire drawing.
19	Despatch	Despatch of medium to thick wires.
-	Yard	Storage of raw material.

TABLE 2.1. The rooms found in the wire works and their former functions.

2.2.3 History of the Site

Prior to the stated industrial history of the site it was designated as gardens and allotments in an area of greenbelt. Figure 2.2 shows the site as it was in 1842 before industrial work began. The road running parallel to the southern boundary of the site (figure 2.2) was built in 1863, and shortly after this the wire works were built. The site was used primarily for this purpose until the early 1990s.

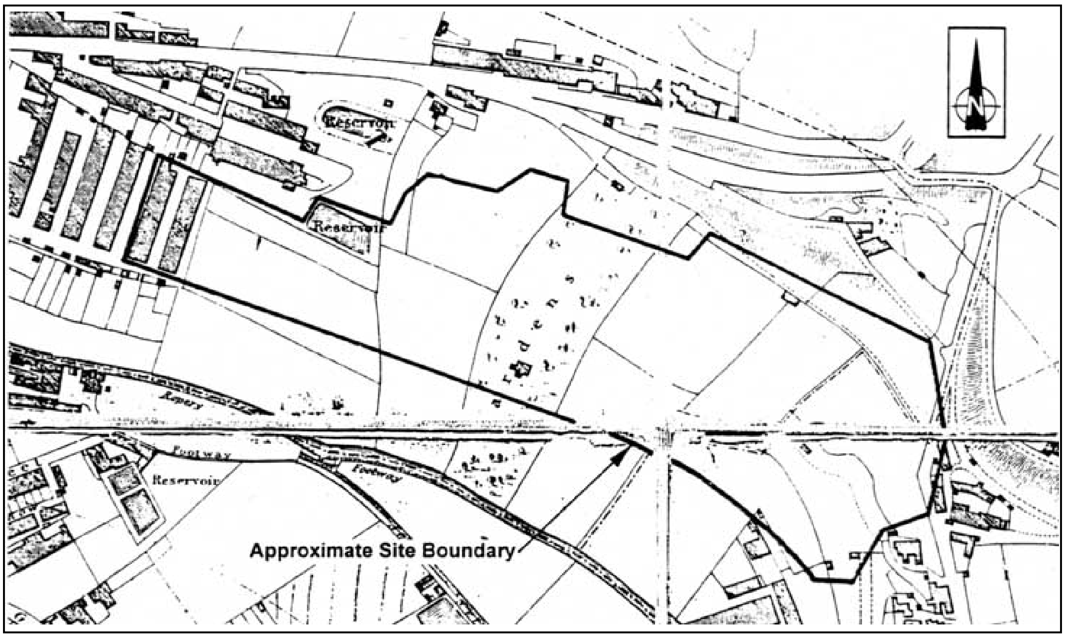

FIGURE 2.2. The site in 1842 shows the position of the gardens and allotments and the lack of industry in the area

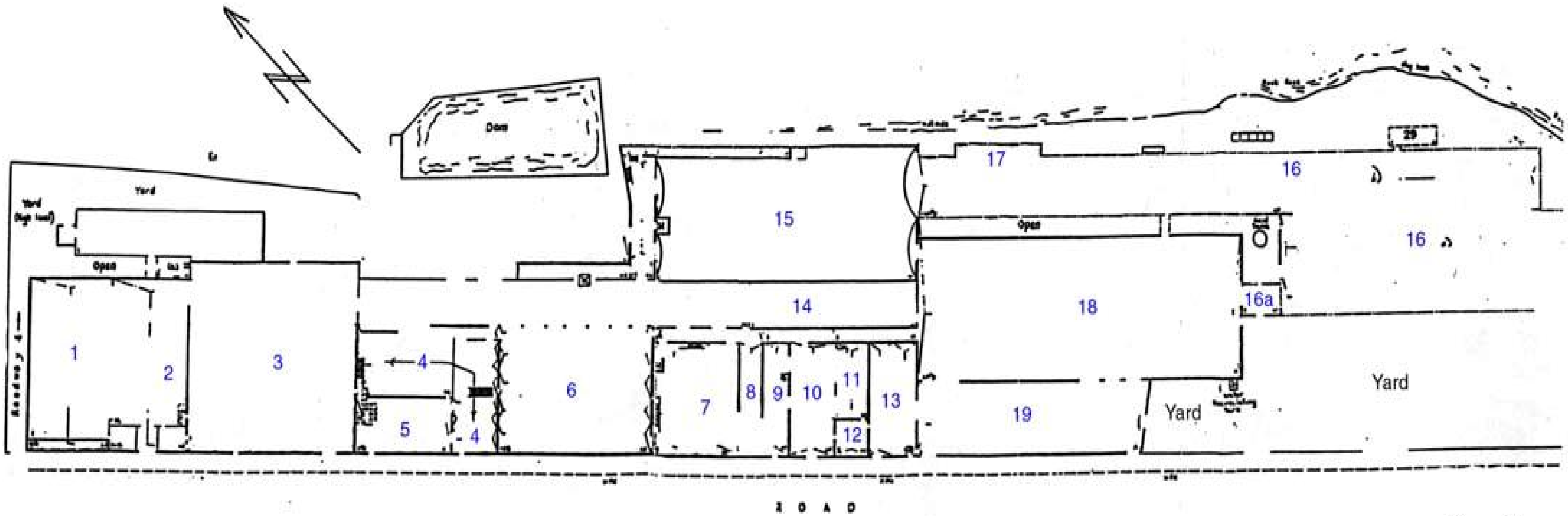
Dam
Yard
Yard (high level)
Open
Roadway
1
2
3
4
4
5
6
7
8
9
10
11
12
13
14
15
16
16
16a
17
18
19
Open
Yard
Yard
ROAD

Figure 2.1

In 1890 the site was also home to a brick and tile works to the east, there was also a quarry, it is thought this may have supplied raw materials to the brick and tile works (figure 2.3). There were two millponds north of the wire works, these were most probably used for cooling and supply purposes and there is evidence that the ponds were present before the wire works were in operation (figure 2.2), today one of the ponds remains and the other is thought to have been covered before 1963.

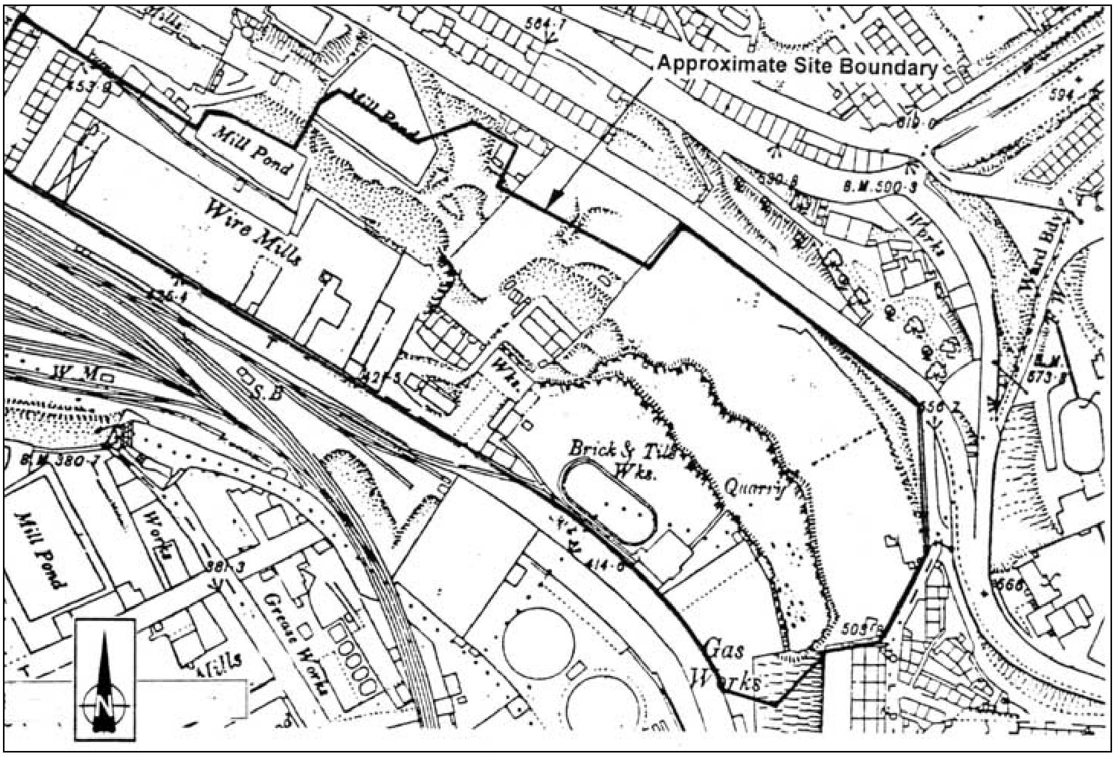

FIGURE 2.3 The site in 1892 shows the brick and tile works to the east of the site.

In 1913 a flood destroyed the tubing galvanising department of the wire works, this area was quickly rebuilt and production continued. By 1922 the brick and tile works had ceased production but the buildings and chimney remained, the quarry also became disused. Also in 1922 an iron works had been built on the northern boundary of the site (figure 2.4). At this stage it appears that ash was tipped into the area to the north of the brick and tile works, the ash forms a steep slope rising to the northern boundary of the site. It is not clear where the ash came from though there is a possibility that it is waste from former fireclay works to the north of the site, waste from the iron works or from the wire works. Figure 2.4 shows the site in 1922.

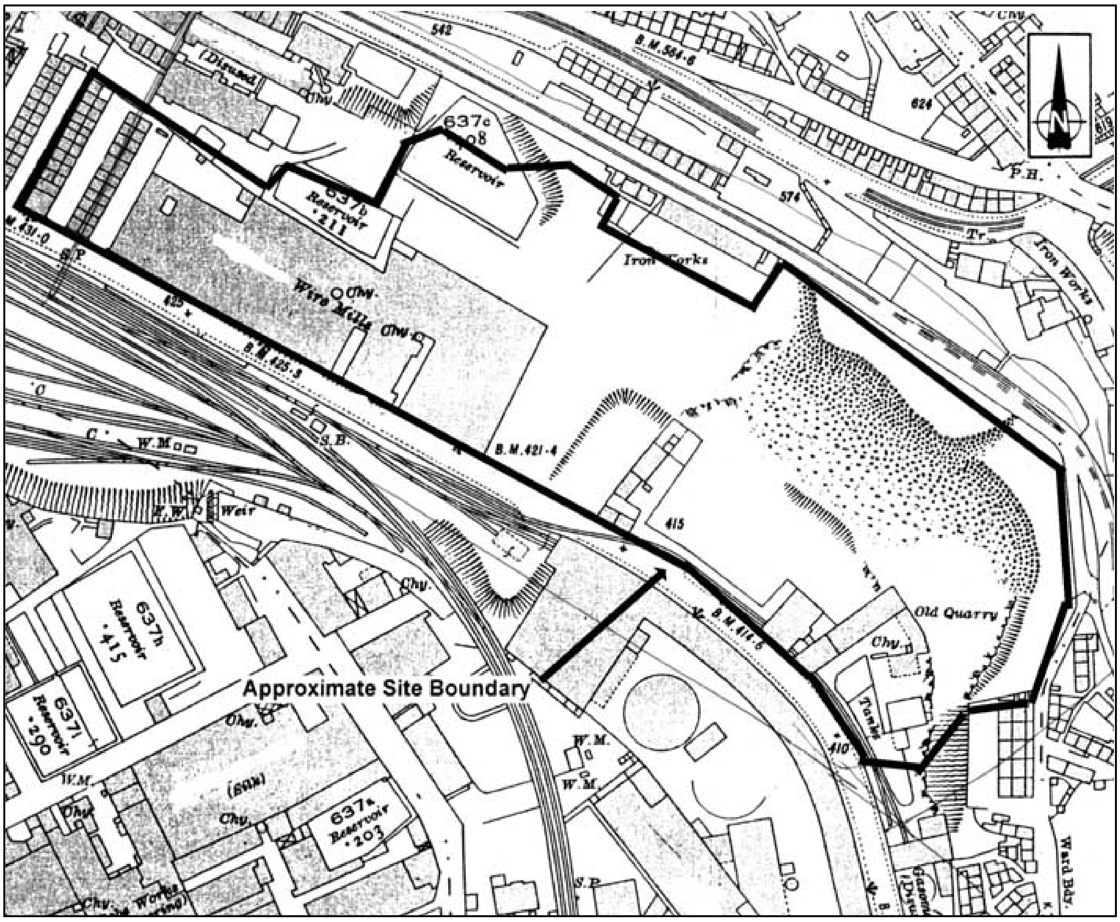

FIGURE 2.4. The site in 1922 showing the position of the iron works.

The site remained this way until a Local Corporation Cleansing Department Refuse Disposal Works opened in 1952 this was situated in the buildings formerly used for the brick and tile works. In 1963 there is evidence that some areas of the site near the refuse disposal works were being used for refuse tips (figure 2.5). The former quarry was one area being used, other areas were to the rear of the iron works, and two tips to the rear of the wire works (figure 2.5), these were worked until the early 1970s. The wire works were extended in1974 towards the east of the site at which time walls were built to retain the ash slope. In 1988 fire destroyed the wire works but the factory was quickly rebuilt and construction continued. In December 1992 a tanker delivering hydrochloric acid spilled its load, the spill was quickly dealt with by the local fire service that used lime and water to neutralise it.

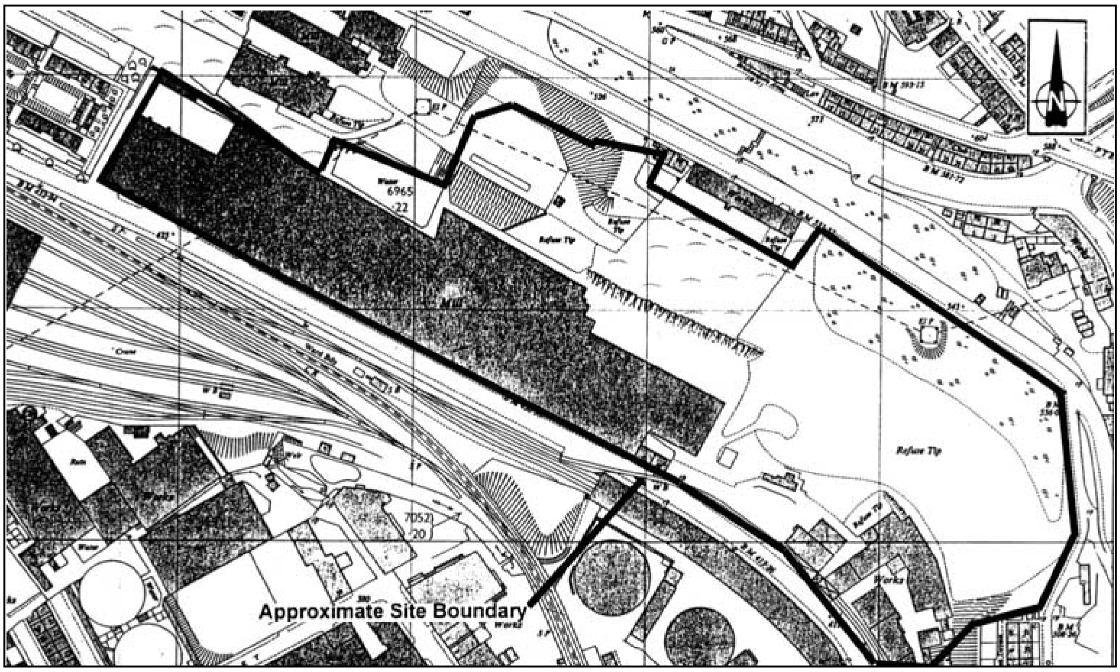

FIGURE 2.5. The site in 1963 showing the position of the waste disposal sites.

The wire works ceased production in the early 1990s, the buildings remain to the present day. Figure 2.6 shows the site as it is today, the buildings are still present but production has ceased.

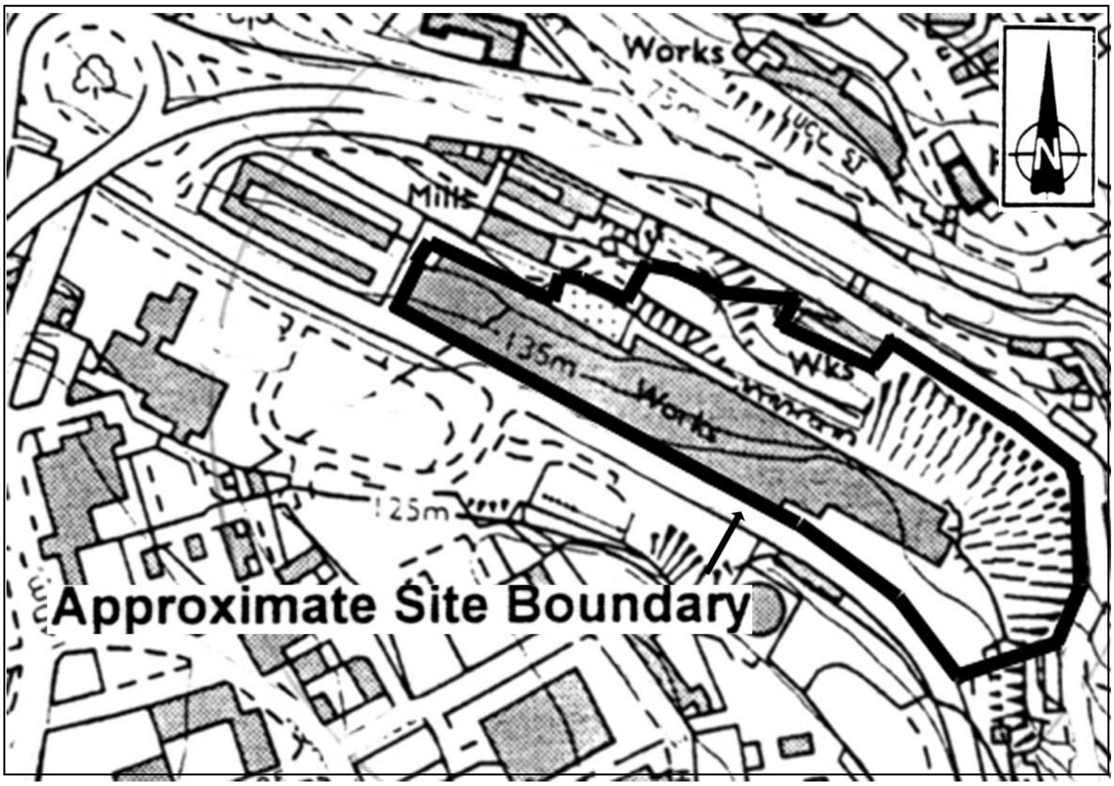

FIGURE 2.6. The site as it was in 1989 and as it remains to present day.

2.2.4 Geology and Mining History

The site is situated on the Carboniferous Coal Measures (figure 2.7) and the whole of the site has layers of made ground. The made ground is found in thicknesses up to 4.5 metres and consists in most cases of either asphalt, reinforced concrete or concrete slab overlying loose, red to brown clayey sand. The sand contains gravels and cobbles, the content of which is as follows; sandstone, shale, mudstone, brick, concrete, occasional wood fragments, metal fragments and cobbles, plastic, glass, paper, asbestos sheeting, plastic pipe, tar fragments and fabric. The made ground lies on top of beds of shale, mudstone, clay and sandstone. The shale is found at depths up to 6 metres and is highly weathered and fissile. Mudstone bands are found at depths up to 8 metres and is light green to dark grey, orange mottled, thinly laminated and highly weathered. The clay is also found to depths of 8 metres and thickly laminated and firm with fragments of gravel. In some of the boreholes sandstone was found to an unknown depth, this was light green to grey, thickly laminated and highly weathered. There is a dip of 10° to the east (figure 2.7). Three coal bands run through the site as shown in figure 1.3, and there is a history of mining in the area. However there has been no mining on the site the bands were most probably unproductive, there are no shafts running underneath. Faulting to the north east of the site has formed a steep slope; this is seen on the cross section in figure 2.7.

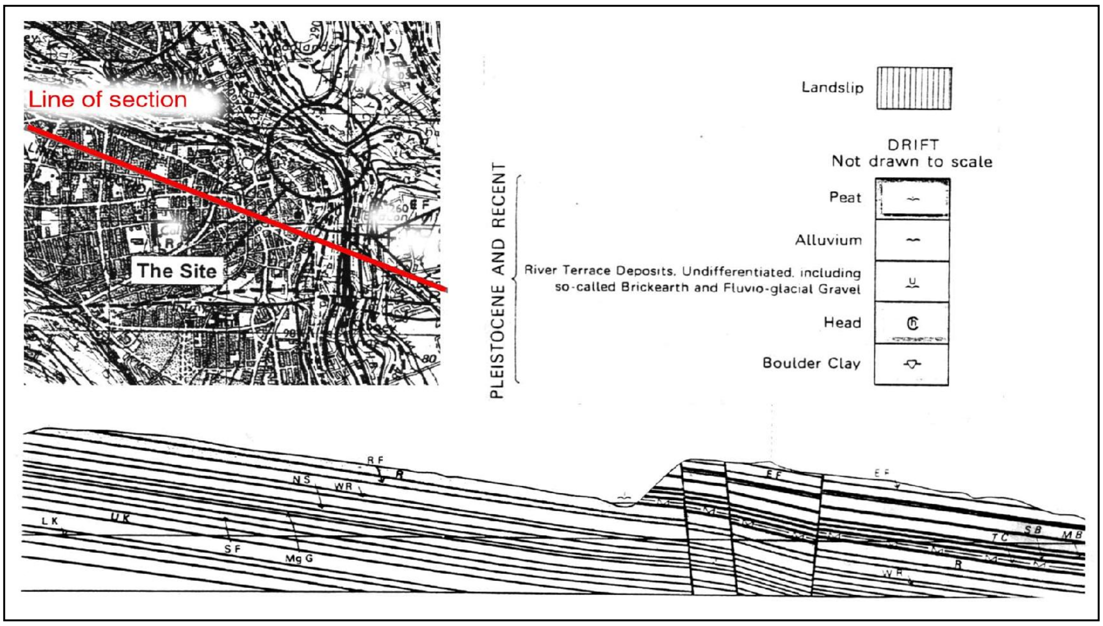

FIGURE 2.7. Geology of the site, note the steeply rising section found to the north of the site, this area contains the ash slope.

2.2.5 Hydrology

Surface water is not found on the site, the nearest water course to the south of the site in the form of a small river, which flows in a north - south direction. Groundwater has been found on the site in a number of boreholes and window samples at various depths. Water extracted from a borehole to the rear of the buildings at the east of the site was used in the wire works for wire cleaning purposes. This borehole did not supply drinking water to the site. In the area of study there are no major aquifers used for supply purposes.

2.2.6 Potential Contaminants Found on the Site

From analysing the former uses of the site, the contaminants associated with these uses can be determined. This process is only preliminary and is undertaken prior to the chemical analysis of the site. This is useful in determining the most beneficial sampling points to be used. As stated by the Health and Safety Executive (HSE, 1991), the likely contaminants to be encountered on a metal processing works are the metals, especially iron, copper, nickel, chromium, zinc, cadmium, and lead. Asbestos is also likely to be present. A number of chemicals have been used on the site as shown in table 2.1. These chemicals may be responsible for a number of the contaminants present.

The galvanising areas of the wire works are likely to be the areas of highest concentrations of contaminants. Here a variety of chemicals were used including; sulphuric acid, hydrochloric acid, zinc phosphate, borax, ammonium chloride, caustic soda and cyanide. Molten lead and zinc were also used. In addition to these nitrite was also used wire cleaning purposes. A likely result of the use of molten lead and zinc is high levels of these metals in the buildings, soils and water. The use of sulphuric acid can produce sulphates; these may be in a solid form and would need disposing of. The disposal areas on the site may have been used for this purpose. The use of borax in the galvanising process will produce boron contaminants in the areas related to room14 (figure 2.1). Zinc will also be present from the use of zinc phosphate and molten zinc. Caustic soda used in the cleaning process may break down to form hydroxides or chlorides.

The burning of fossil fuels on the site in the furnaces of the wire works and the brick works may have resulted in the production of polyaromatic hydrocarbons (PAHs) and phenols. These form when "The smoke from burning wood or coal is not completely converted to CO or CO_2" (Baird, 1995). The PAHs and phenols form relatively heavy particles therefore would settle out relatively quickly from the smoke and remain in the soil. The areas of settlement would be inside the chimneys and on the ground throughout the site most probably concentrated in the areas where the smoke was blown by the prevailing wind (i.e. to the eastern and northern parts of the site).

The waste disposal sites are likely to contain a range of contaminants depending upon the types of waste deposited in them. The decomposition of household wastes can result in flammable gases such as methane. Alloway, 1995 states that; "The landfilling of municipal wastes can lead to several metals including cadmium, copper, lead and zinc being dispersed into the soil and groundwater." The disposal sites adjacent to the wire works and the iron works are likely to contain industrial wastes. These could be in the form of metals such as copper, zinc, lead, iron, nickel and cadmium. As stated in chapter 2 it is not clear where the ash originated from, a possible source is the iron works. If this were the case it would be expected that the ash contain high levels of metals and possibly PAHs and phenols.

CHAPTER 3: RISK ASSESSMENT

3.1 INTRODUCTION

Having identified the major contaminants likely to be present (chapter 3) it is now important to use a risk assessment in order to evaluate the site in terms of the risks of exposure to the contaminants. A risk assessment approach enables the hazards associated with the contaminants to be identified and their risks taken into consideration with a view to recognising potential targets. Hines and Failey, 1997 stated; "If we can determine how pollutants behave in the environment and the mechanisms by which they cause potential exposure to the site end user, then we can be more specific on the likely consequences from such exposure and the probability of those consequences occurring." The risk assessment undertaken here is designed to determine whether the levels of contamination found on the site are likely to cause an increased risk to the targets at present or in the future. One objective of risk assessment is identified by Harris in 1994 as "To identify the critical contaminants and associated factors (e.g. pathways) relevant to the site so that steps necessary to reduce risks to acceptable levels both currently and in the future can be determined." The ultimate aim therefore is to identify what areas of the site need remediation and the types of remediation needed in order to reduce the risks to the potential targets.

The following sections assess the hazards likely to have an effect on the targets for the three end uses being evaluated; residential, recreational and retail developments. Having identified the contaminants present on site, the risk assessment for the uses will be looked at in terms of a hazard - pathway - target relationship (chapter 1). In order to effectively assess the risks associated with the hazards for each end use the targets will be identified, this will be followed by an assessment of the likelihood of these targets coming into contact with the contaminants which are likely to pose a hazard. The first step however is to recognise the types of hazards with which each of the contaminants are associated in order to understand the effects they may have on the targets as defined by the USEPA, 2000.

3.2 RISK ASSESSMENT

3.2.1 HAZARD IDENTIFICATION

Table 3.1 shows the types of contaminants present on the site with the hazards that they are likely to pose. The contaminants have been determined from the site investigation carried out, the contaminants may be present in the soil, groundwater, surface water or as a gas.

HAZZARD	EXAMPLES	USES	EFFECTS
Carcinogenic	**Arsenic**	Wood preserve, insecticides, weed killer,	Can cause damage to body tissues such as nerves, stomach and skin. Sore throats, irritable lungs, vomiting, diarrhoea, decreased production of red and white blood cells, abnormal heart beat. Direct contact may cause redness and swelling of the skin.
	PAHs	Formed from the incomplete burning of fossil fuels	Lung cancer, scrotal cancer,
Phytotoxic (inhibit plant growth)	**Copper**	Metal alloys, wire making, sheet metal,	The body can block high levels of copper. Long term exposure can cause headaches, dizziness, nausea, diarrhoea.
	Zinc	Metal coating, dry cell batteries,	Stomach cramps, nausea, vomiting, anaemia, pancreas damage, metal fume fever.
	Nickel	alloys, coins. Nickel plating,	Allergic reactions (e.g. from nickel jewellery), asthma attacks, bronchitis
	Boron	batteries, catalysts.	
Zootoxic (harmful to humans)	**Cadmium**	Batteries, metal coatings, plastics	Lung damage, death, vomiting, diarrhoea, kidney disease.
	Lead	Batteries, metal products (solder, pipes), roofing, x-	Can affect the central nervous system in children. In adults can reduce reaction times, cause weakness of fingers, wrists, ankles, loss of memory.

	Mercury	ray shields Chlorine gas, caustic soda, thermometers, dental fillings, batteries.	Affects the central nervous system, brain damage, kidney damage, lung damage, nausea, vomiting, diarrhoea, increased blood pressure, skin rashes, eye irritation.
Substances that may cause skin damage	**Phenols**	Herbicides, pesticides, results from incomplete burning of fossil fuels	Skin irritation,
Corrosive	**Sulphate**		Corrosive to concrete
Asphyxiate	**Carbon Dioxide**		Asphyxiation

Table 3.1 Hazards associated with the site

3.2.2 HAZARD ASSESSMENT

The first stage of a hazard assessment is to assess the site in terms of the concentrations of contaminants present. Harris and Herbert, 1995 state that; "An important first step in risk assessment is deciding whether the site is actually contaminated. "This is done by comparing the levels of contaminants at the highest concentration or "worst state" with background concentrations. Alloway, (1995) expresses the normal range of metals found in soils and figure 3.1 shows the percentage of samples exceeding these background levels. Unfortunately background levels in soils for the other contaminants found on the site are not available. Reference should be made to the comparisons of these with the ICRCL threshold levels and Dutch levels.

The unavailability of the guidelines is in some cases, such as for the polyaromatic hydrocarbons, due to the fact that they are generally man made
Comparing contaminants with data on background levels provides information on which contaminants will need to be compare to the guidelines for a particular end use (ICRCL, 1987) (Layla Resources, 2000).

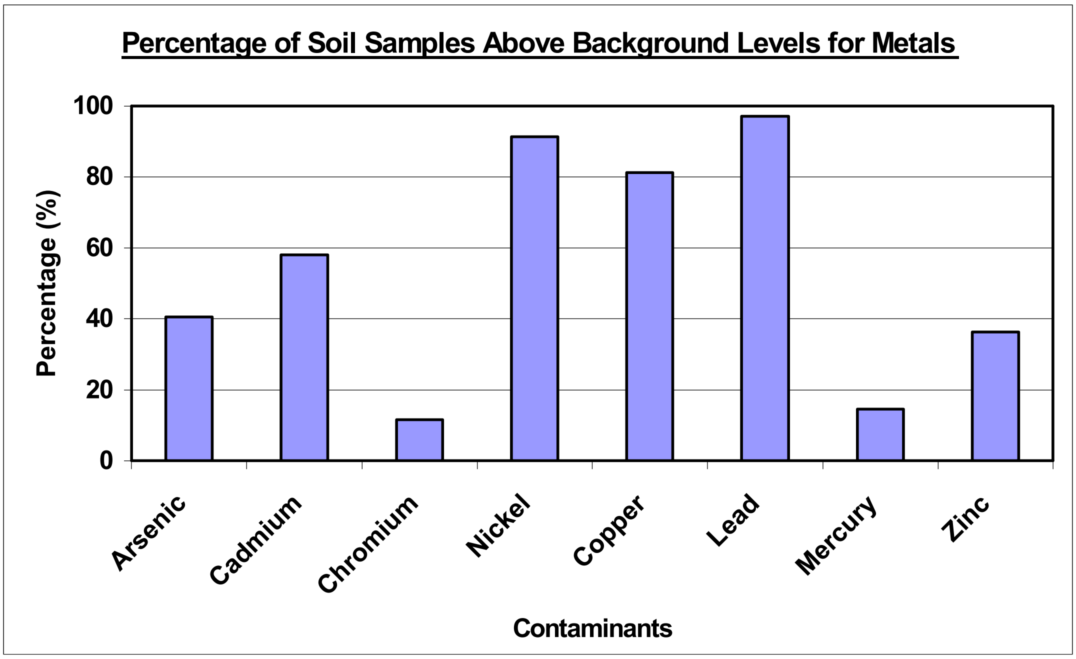

FIGURE 3.1 The percentage of samples taken from the soil with concentrations above the background soil concentrations.

As can be seen from figure 3.1 the majority of samples soil samples contain concentrations of metals above the natural background levels for soils. From this data it can be concluded that further investigation of the site is needed in the case of the metals, other contaminants as discussed will be analysed using the published guidelines available to assess whether they pose a threat to humans or the environment.

Once the hazards present on the site have been determined it is important to identify the pathways and targets. Without a verifiable pathway the target is not considered at risk from a hazard. Each of the end uses being studied can be assessed in terms of whether the target is likely to be at significant risk from the hazard present in soil, groundwater or surface water. Table 3.2 shows a matrix designed to summarise the risk of each end use.

Contaminated Medium	Pathway	End use of site A	B	C
Soil	Ingestion	4	4	6
	Dermal contact	4	4	6
	Inhalation (of volatiles)	4	4	4
Groundwater	Ingestion	6	6	6
	Dermal contact	6	6	6
Surface Water	Ingestion	6	6	6
	Dermal contact	6	6	6

TABLE 3.2 Matrix of hazard/pathway/target related to end use.

A Residential
B Recreational
C Retail

4 Likely to be significant
6 Unlikely to be significant

3.2.2.1 Target Identification

Each end use will expose a number of different targets in the scenarios being consulted. Here the targets will be humans, fauna and flora, and the buildings in each scenario are looked at in terms of the potential targets and associated risks. Harris and Herbert, 1995, class these risks as either acute (short term) or chronic (long term).

(a) Humans

Humans may come into contact with contaminants on the site in a number of ways. The site must be cleared before any development can take place Due to the spread of contaminants on the site, there is potential for the contaminants to be disturbed at this stage. The site workers are possibly at the greatest risk from contamination. Acute risks are related to coming into contact with hazardous substances on the site, and chronic risks are those associated with hazardous substances known to be carcinogenic and where the full effects may not materialise until some time after exposure. There is a risk from inhalation of volatile or asphyxiate gases, and enclosed spaces such as basements should be avoided. Since all end uses will require the site to be cleared and developed, the site workers will potentially be exposed to contaminants in the development of all the end uses.

(i) Risks

Each site will have future occupiers or users who have the potential to be exposed to the contaminants on the site. There are acute risks associated with a residential development. The homes will have gardens in which plants are grown. If these plants are to be grown for human consumption there is the potential that they may take up contaminants from the soil with their roots and these will be passed onto humans through ingestion. Direct ingestion, for example of soil, is a problem in residential areas where a child may innocently ingest a large quantity of soil in the garden of a house this is particularly relevant in the case of a pica child (a child that ingests soil). Inhalation of soil dust and gases from gardens is also a risk in residential areas. Direct contact with soils will produce a risk from contaminants which cause harm to the skin, and any open wounds will provide a direct pathway for a contaminant. Chronic risks to humans on residential areas is gained from the release of contaminants over a long period of time. In summary, humans using recreational areas will be at risk from direct ingestion of contaminants in soil or from absorption of contaminants through the skin via cuts. There will also be a risk from inhalation of soil dust and gases.

The planned retail unit will be covered with concrete prior to construction. This will greatly reduce human contact with contaminants present in the soil. Any gases present on the site may put humans at risk from asphyxiation, however they are present only in small quantities and there are very small amounts of flow. These gases may need to be vented to reduce any of these acute risks. Any chronic risks to humans will be from slow release of contaminants onto the site.

(b) Fauna and Flora

Fauna will be at risk from ingesting contaminants in the soil and from indirect ingestion of contaminants through eating contaminated plants. Those contaminants that are phytotoxic (boron, copper, nickel and zinc) will put flora at risk and will wipe out possibly large areas of plants. Residential and recreational areas will be at risk from phytotoxic contaminants, while the retail area will have little or no plant growth, and therefore no risk will exist.

(c) Buildings

Some building materials will be susceptible to corrosion from contaminants, and as such both the residential and retail sites may be affected. Certain corrosive contaminants such as sulphate may degrade the concrete used in the building foundations. This would cause the buildings to become fundamentally unstable unless corrosion resistant concrete is used.

3.2.2.2 Comparison of Contaminant Levels with Guidelines

Following the chemical analysis (appendices 1,2 and 3) of the site in which the levels of contaminants in the soils, water, leachates, building fabric and gases were analysed a general assessment can be made. The laboratory test results were compared to published guidelines. The ICRCL threshold levels (ICRCL, 1987) were used to assess the soils for particular uses, in this case for a residential development with gardens, a recreational area and for retail units and areas of car parking the results of which are shown in appendix 1.

The Dutch guidelines (Contaminated land Web Site, 2000) were used to assess the levels in soils, water and in the leachate tests carried out as shown in appendix 2. Gas concentrations (appendix 3) on the site have been compared with Waste Management Paper 27 (DOE, 1989) guidance on landfill gas in buildings (appendix 3).

The results gained from the laboratory analysis of samples of soil and water from the site, showed that the largest hazards on the site were in the forms of metals (Copper, Lead, Nickel, Zinc,), Arsenic, Polyaromatic Hydrocarbons and Sulphate were also found to have elevated levels. Out of these contaminants arsenic was present at the greatest levels in soil. With the highest concentration recorded being 6500 mg/kg. 69% of the results were above the ICRCL threshold trigger levels of 10mg/kg for an end use of domestic gardens and allotments, and 34% were above the Dutch action level for arsenic.

Figure 3.2 and 3.3 show the percentages of samples that contained contaminants above the guideline levels.

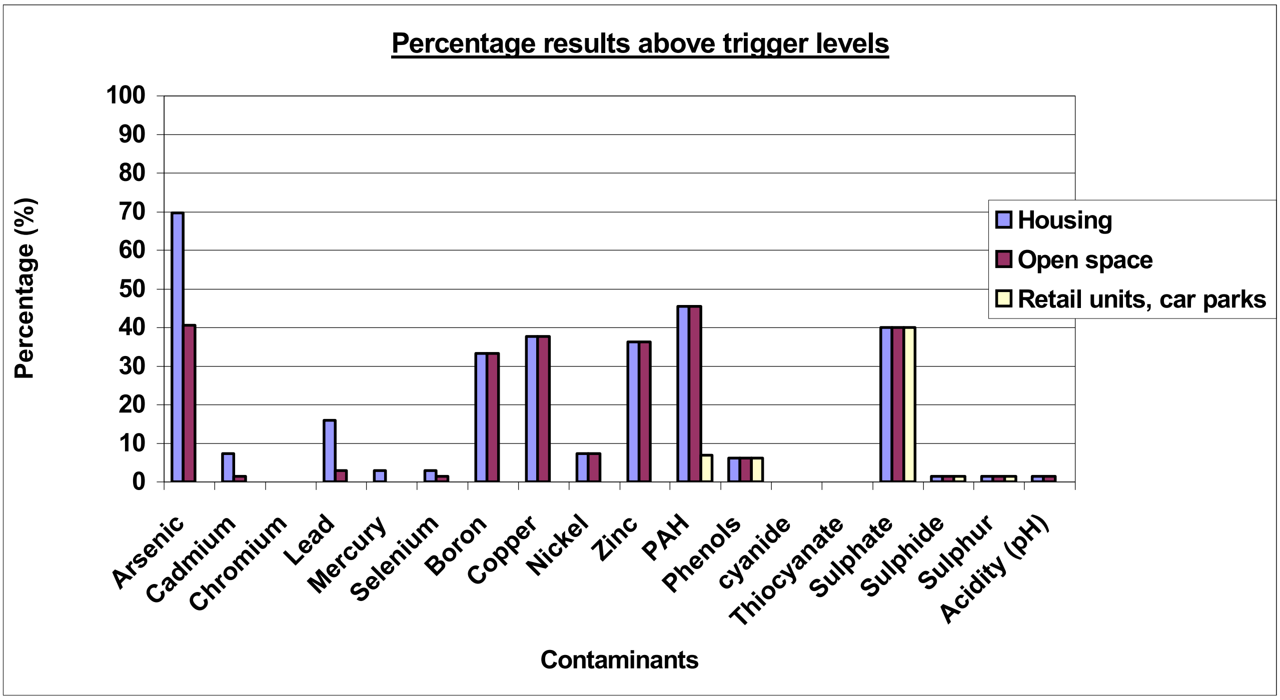

FIGURE 3.2 Percentage of samples containing contaminants above the ICRCL threshold levels in soils (ICRCL, 1987)

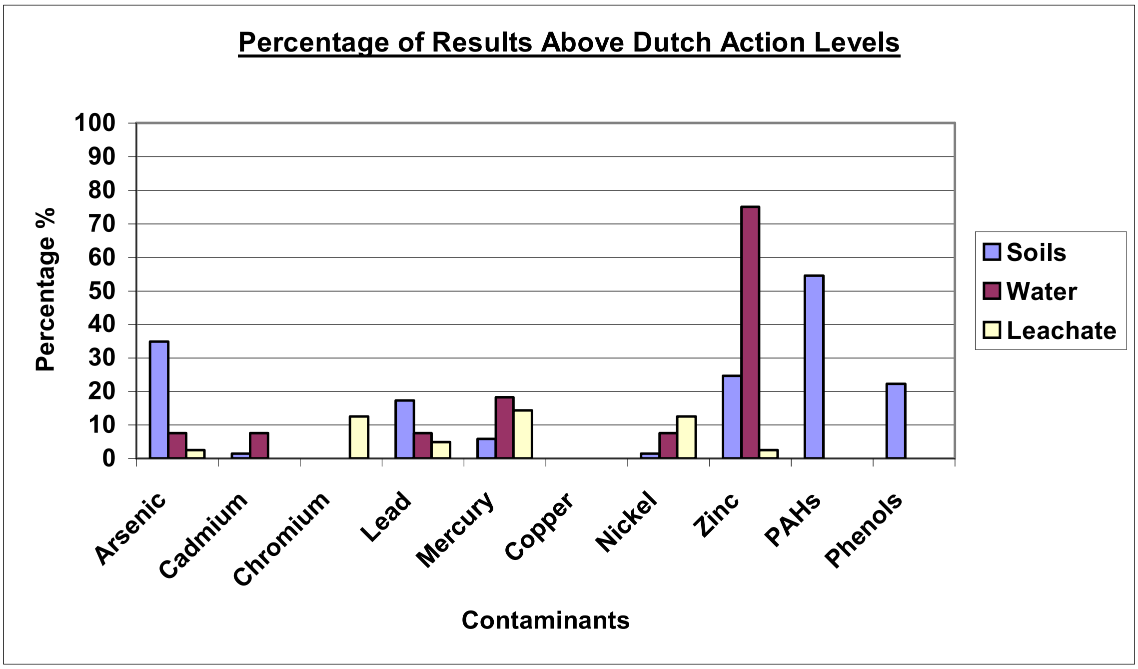

FIGURE 3.3 Percentage of samples containing contaminants exceeding the Dutch Action level (Layla Resources Ltd, 2000).

The high levels of arsenic were found in samples taken from the foot of the ash slope and in the reservoir sediment, elevated levels were also found in samples taken from the soil below the buildings. The contaminants are to be analysed in terms of the medium in which they were found, as detailed in the following sections.

3.2.2.3 Soil and Water Analysis

(a) Metals

As mentioned previously the metals form the majority of the hazards on the site, and have been found in all areas examined. The metals found are copper, lead, nickel and zinc large concentrations of these metals have been found at points around the site, the maximum concentrations as shown in tables 3.1 and 3.2 were found in the soil samples. The metals appear in soil samples taken from boreholes sunk in the floor of the buildings housing the former wire works which cover an area from the west boundary of the site to the east boundary. Metals are also found in sediments taken from the reservoir behind the buildings to the north of the site. The highest concentrations of metals from the floor of the buildings appear at shallow depths of up to two metres. Below this depth the concentrations are Significantly lower. Metals can also be found in areas of made ground, with elevated levels found in a cluster of sample points in the former car park in front of the buildings at the south east end of the site, and also from areas immediately adjacent to the outside walls of the buildings. The ash slope also has elevated levels of metals. Levels of copper, lead and nickel are present above the ICRCL threshold levels for domestic gardens and allotments and above the Dutch action level for soils. Water analysis has shown that zinc is present in high concentrations, with a large percentage of tests above the Dutch action level as shown in figure 3.3. Leachate tests have revealed high levels of heavy metals above Dutch action levels in samples taken from the buildings. In these samples chromium is also found above Dutch action levels, having been found only in low concentrations in the soil and water samples.

(b) Polyaromatic Hydrocarbons

High levels of Polyaromatic Hydrocarbons (PAHs) have been found in the samples taken from the site. PAHs are described by Baird, 1995 as being; "Benzenelike hydrocarbons that contain several six membered rings connected together by the sharing of a pair of adjacent carbon atoms between adjoining fused rings."

The highest concentration for PAHs found on the site is 3600mg/kg, with 46% of tests above the ICRCL threshold level for domestic gardens, allotments, parks, play areas, and 7% above the threshold for landscaped areas, buildings and hard cover. 55% of the tests are above the Dutch action level for soils. No detected levels of PAHs found in the water and leachate tests above the Dutch action levels. PAHs at elevated levels are found in the ash slope, in the soil under the buildings and in made ground. The highest concentration occurs at the top of the ash slope to the rear of the iron works where a refuse tip was situated in 1963, before being later abandoned (chapter 2).

(c) Sulphate

Sulphate is present on the site at high levels The highest level in soil is 1800mg/kg. There were no tests undertaken for sulphate in the groundwater or leachate. This level is 40% above the ICRCL threshold levels for domestic gardens, allotments, landscaped areas, buildings and hard cover. The elevated levels are found in soil samples taken from the area of dense trees at the east of the site, and concentrations exceeding the 10000mg/kg action level for domestic gardens, allotments and landscaped areas are present. Other areas of the site contain relatively low levels of sulphate in the soil samples examined.

(d) Boron

Boron is found to be on the site with a maximum level of 72mg/kg, and 33% of the tests exceed the ICRCL threshold levels for any use where plants are to be grown. The highest levels of boron are found in samples of soil from the floor of the buildings and from made ground in front of the buildings. Levels of boron are not found at extremely high levels but where it is found above threshold levels it needs to be considered in terms of remediaton.

3.2.2.4 Gas Analysis

Gases found on the site were compared with guideline set out in Waste Management Paper Number 7 (DoE, 1989). The site was tested for gases on four occasions and over a period of up to fifteen minutes, each test revealing different levels of gas. From the analysis it is seen that Oxygen and Carbon Dioxide both exceed the recommended guidelines (appendix 3). Figure 3.4 shows that 11% of oxygen and 15% of carbon dioxide tests exceeding the guidelines. The highest levels of these gases are found in the ash slope, the lowest level of oxygen present is 11% by volume of air, the highest carbon dioxide level is 4.8% by volume of air. The gases were also tested for level of flow and from the results it can be seen that there is no flow of gases on the site.

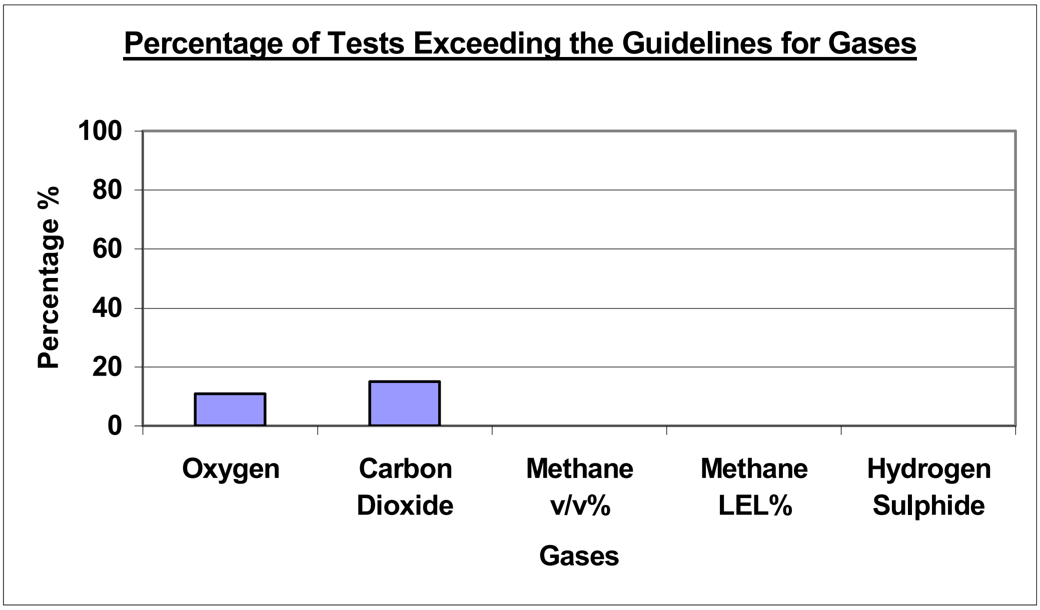

FIGURE 3.4. Percentage of gas tests above the guidance levels.

3.2.2.5 River Analysis

The results of the laboratory tests on the river water have shown that the levels of contaminants are inside the guidelines for surface waters not primarily for supply as set out in the EC Drinking Water Directive (98/83/EC), (Gray, 1999). The results show that as the river passes the site there is no increase in the levels of contaminants, indeed the levels fall at the midstream point.

3.2.2.6 Building Analysis

An analysis was undertaken on the buildings that housed the former wire works. Scrapings were taken from the interior walls of the buildings, and analytical procedures used to detect whether lead, boron, zinc, cyanide and sulphate were present, the acidity was also tested. As in the soil analysis large concentrations of metals (boron, lead and zinc) were found. Figure 3.5 shows the percentage of tests which produced concentrations of contaminants above the ICRCL threshold levels

(ICRCL, 1987) and figure 3.6 shows the percentage results above the Dutch Action Levels.

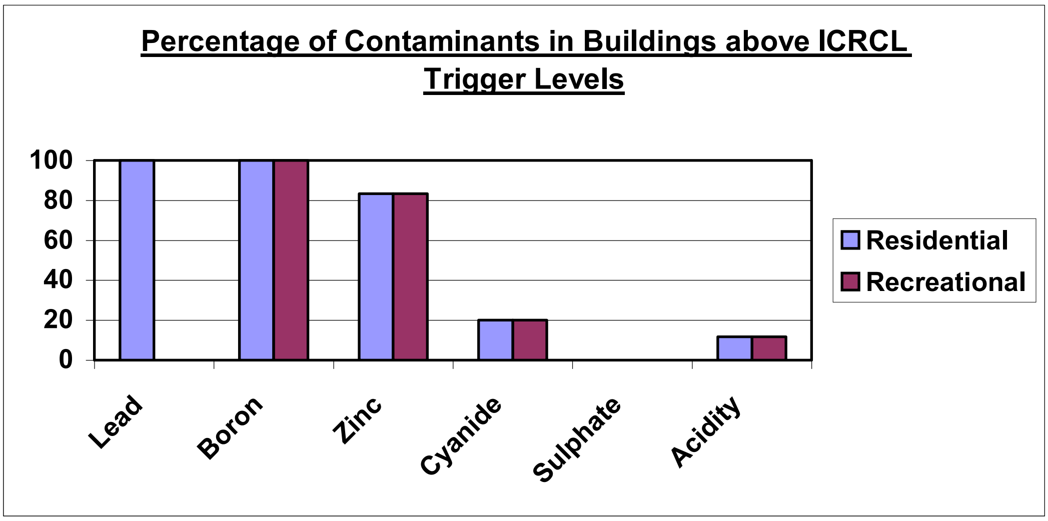

FIGURE 3.5. The percentage of building fabric tests containing concentrations of contaminants exceeding the ICRCL guidelines.

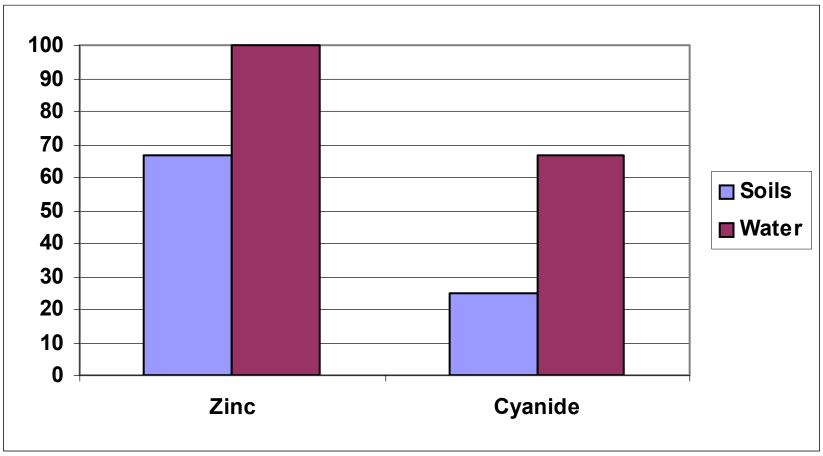

FIGURE 3.6. The percentage of building samples exceeding the Dutch Guidelines.

The greatest concentrations of contaminants are found in rooms 21 (wire cleaning department) and in rooms 25 and 26 (galvanising departments).

The operations in room 21 consisted of cleaning and coating the raw material wire rod. Here the contaminant discovered in the room in the highest concentrations is Boron, with a maximum value of 1200mg/kg. It is likely that this arises from the use of borax in this area. The galvanising rooms provided high concentrations of lead and zinc in excess of the ICRCL guidelines for domestic gardens, allotments, parks, playing fields, open spaces and any uses where plants are to be grown.

During wire production it is confirmed that spillages occurred on the site, and also that hydrochloric acid and zinc sulphate were piped to the area. Water samples were taken from rooms 14, 25 and 26, high concentrations of zinc were found in room 14 (19000mg/kg). This is in excess of the Dutch guidelines for water. Rooms 25 and 26 as mentioned earlier contained the galvanising department where the use of zinc sulphate accounts for the presence of high levels of zinc, the presence of lead in high concentrations is not easily accounted for.

3.2.3 RISK ESTIMATION

As outlined by CIRIA in 1995, risk estimation involves; "A process of estimating the probability that an unwanted event will occur." This is to be done by undertaking an exposure assessment and a toxicity assessment. The purpose of this is described by Harris, (1994); "The purpose of exposure assessment is to define the environmental transport and fate of contaminants, the purpose of toxicity assessment is to determine the effect (e.g. toxicological, carcinogenic, mutagenic, corrosive etc.) of the hazard on the target under the conditions of exposure defined in the exposure assessment."

3.2.3.1 Exposure Assessment

As identified in section 3.2.2.1, the likely targets for the three proposed end uses are humans (especially children and site workers), plants and buildings. Humans are unlikely to directly ingest soil from the gardens of the homes unless there is a Pica Child present, in which case the risk would be short term, and there is the added risk of ingesting an elevated amount of a contaminant. Table 3.6 shows the possible daily intake of contaminants by a pica child, the workings of the results are shown in appendix 4.

Soil Contaminant	Intake mg/kg per day
Arsenic	0.2600
Cadmium	0.0012
Chromium	0.0072
Lead	0.0007
Mercury	0.0004
Selenium	0.0088
Boron	0.0029
Copper	0.8000
Nickel	0.0156
Zinc	2.1200
PAHs	0.1440
Phenols	0.0016
Cyanide	0.0001
Thiocyanite	0.0001
Sulphate	0.0720
Sulphide	0.0132
Sulphur	0.3800

TABLE 3.3. Possible intake of contaminants

Humans growing crops in the gardens of the homes are likely to be exposed to the contaminants through uptake by the plants. The effects of ingestion of contaminants in this way are long term, and the target is unlikely to be able to identify a change in their health. For example, a contaminant such as arsenic taken up in plants may be carcinogenic, but the effects may take years to appear or may not appear at all.

Humans on a frequent basis inhale soil dust. The extent of this will depend on factors such as the proximity to the source and the amount of dust being produced, and during dry periods this will be greater. The exposure to soil dust is likely to occur over a long period of time on residential developments and recreational areas and therefore the effects will be long term. During demolition, clearing and construction, site workers will unavoidably disturb areas of soil. The dust produced will put them at risk from the short term effects of contaminants that are toxic through inhalation and long term effects of other contaminants, in particular those that are suspected to be carcinogenic. Site workers may come into contact with contaminated soil and water on the site. The effects of this will depend on the time-scale of exposure, the effects could be short term such as swelling or skin irritation, or long term if the contaminant is allowed to enter the body through an opening such as a cut to the skin.

The foundations of houses built in contaminated soil are at risk from corrosion from some contaminants, such as sulphate. The effects on the concrete in particular, will be long term, and will depend upon the composition of the material. Sulphate resistant concretes are now available.

The buildings used for the retail development will also be at risk from sulphate attack. A recreational area could put humans at risk, particularly from arsenic and nickel. Plants will be affected by contaminants in the soil on the residential development and recreational area, and phytotoxic contaminants (table 2.1) will cause areas of plants to die. The effects will depend on the magnitude of the contaminant in the soil. The uneven distribution of elevated levels of contaminants on the site will have a greater effect on plants in some areas than others. Another consequence of a low level of plant growth will be the exposure of the soil. A greater level of erosion may occur, with consequences such as contaminated runoff or increase in soil dust.

3.2.3.2. Toxicity Assessment

Humans are likely to have the greatest exposure to the hazards present on the site. This exposure will occur during development (demolition, clearing construction) and on completion of development. Table 3.1 outlines the hazards of certain contaminants on the site. Perhaps the most harmful effect of contaminants on the site is their ability to cause cancer. This is a long-term effect, and is not easily detected since it may take a number of years to materialise. The main carcinogenic materials on the site are arsenic and polyaromatic hydrocarbons (PAHs). Arsenic is found at levels exceeding the background levels in soils, and therefore care needs to be taken when the areas concerned are being developed (figure 2.9 - 2.1). PAHs can enter the human body by inhalation and by direct and indirect ingestion. Direct contact with PAHs has been demonstrated to produce cancer in humans, an extreme case is an account of scrotal cancer in chimney sweeps associated with soot lodged in the crevices of the skin of their genitalia (Baird, 1995). As PAHs are found as particulates that have settled onto the soil any disturbance of the soil will expose site workers to high levels of contaminated soil dust. The direct inhalation of this soil dust may lead to lung cancer (Baird, 1995).

As discussed earlier there are high levels of metal contaminants on the site (and these are found in high concentrations). The metals that are phytotoxic (copper, zinc, nickel and boron) found on the site are only toxic to humans in high doses. The ICRCL guidelines (ICRCL, 1987) provide threshold levels, above which these metals inhibit plant growth. High concentrations have been found on the site for zinc which greatly exceed the threshold level for any uses where plants are to be grown (ICRCL, 1987). At these elevated levels (up to 53000mg/kg) zinc will be toxic to humans if ingested, causing stomach cramps, nausea and vomiting among other effects (table 3.1). Copper is found on the site at concentrations up to 20000mg/kg. This also exceeds the threshold level for any uses where plants are to be grown (ICRCL, 1987). If copper is ingested in high concentrations and for a long period of time, it has the potential to cause dizziness, diarrhoea and nausea (table 3.1). In the case of the residential development and the recreational area any vegetation will be at risk from the presence of metals, in extreme cases large areas of plants could die, causing problems in gardens and any other vegetation covered areas.

The metals that are classed as zootoxic (harmful to humans) by the ICRCL (ICRCL, 1987) are Cadmium, Lead and Mercury. These can enter the body directly through ingestion of soils (by children for example) or by the ingestion of crops that have been grown in soils contaminated with the metals. Ingestion of these metals has very serious toxic effects on humans, in the worst cases causing death (cadmium). Whilst nausea, vomiting and diarrhoea are the most common effects of the contaminants, lead and mercury can affect the central nervous system of adults and children and lead in particular could lead to brain damage in children. High levels of lead can affect reaction times and cause weakness in the wrists and ankles of adults and in some cases loss of memory (Harris and Herbert, 1995). Direct contact with high concentrations of lead can lead to skin and eye irritations. Phenols may also cause skin damage through direct contact with high concentrations.

3.2.4 RISK EVALUATION

From the above discussion the magnitude of risks associated with each proposed end use is evaluated in this section. Even if the risk of a certain event occurring that will release harmful contaminants is low, the effects of the contamination in terms of human health or the environment may be much higher (Harris and Herbert, 1995). The areas of the site posing the greatest risks can also be identified and therefore risk reduction efforts can be discussed. The evaluation of the proposed risks to the targets causes a number of uncertainties. These uncertainties are addressed using assumptions on the likely effects of the contaminants. These have been made by CIRIA, 1995 to estimate human health risks, therefore uncertainties and the assumptions for this investigation are as follows:

Uncertainties

- **Extent, concentration and chemical form of contaminants.**
- **Behaviour of contaminants in the environment e.g. effects of chemical reaction, degradation, attenuation, dilution, adsorption, dispersion etc.**
- **Pathways and length of exposure time.**
- **Short and long term effects of the contaminants.**
- **Difference in human reaction to the contaminants in terms of age, gender and general health characteristics.**
- **Effect of exposure to more than one substance simultaneously.**

Assumptions

- **Typical exposures are to highest observed concentrations of contaminants (worst case scenario).**
- **All or most of the material is biologically available.**
- **Low levels of attenuation, degradation etc. occur along the exposure pathway.**
- **Exposure assessment is based on maximally exposed and most vulnerable individual.**

Taking into account these uncertainties and assumptions, each scenario has been considered in terms of the magnitude of risks and nature of effects. Risk reduction efforts and the costs and benefits of taking action for each end use will be evaluated individually. Common to all the proposed end uses are the clearing and landscaping of the site therefore this will be discussed first.

(a) Clearing and Landscaping of the Site

There are a number of problems related to the clearing of the site these are associated with the contamination of the building fabric, soil and water. The likely targets of the contaminants will be the site workers coming into contact with the contaminants via ingestion, inhalation and direct skin contact. As has been discussed, extremely high levels of lead, boron and zinc, high enough to be toxic to humans, contaminate the buildings. There are also several storage tanks, and empty or full drums located in the buildings, the content of which is unknown or in cases where labels are present cannot be assumed. There is potential for these contaminants to be released during demolition of the site and therefore care is needed in proximity of the so-called hot spots of contaminants. The soils and in some cases groundwater, directly below the buildings have also been found to be contaminated. This is another area where site workers may be at risk during demolition and during landscaping. Metals are predominant here, and the main hazards will be inhalation of any soil dust created, and indirect ingestion of contaminants through the skin via cuts. The presence of high levels of arsenic in this area provides a carcinogenic hazard, and contact with the arsenic could cause skin irritation. Generally the site workers will have a short-term exposure to the contaminants, and therefore serious side effects should be avoided. However care must be taken to avoid coming into contact with high concentrations of contaminants. Other areas of the site such as the made ground, ash slope and dense trees to the east of the site, also contain high levels of contaminants. Again these areas have the potential to cause harm to the site workers through ingestion (direct and indirect), inhalation of soil dust and direct contact.

During building construction there is the potential for contaminants in the ground to be disturbed. Any foundations being dug or pile driven could provide new pathways for the contaminants or otherwise release pockets of previously undisturbed contaminants, again putting the site workers at risk. As well as releasing contaminants, foundations could be at risk themselves from corrosion by sulphate compounds. Sulphates are found at elevated levels at the east of the site, in an area of dense trees on a steep slope. This area is unlikely to be used for the construction of buildings.

(b) Residential Development

The magnitude of the risks depends upon the degree of exposure to contaminated soils in the gardens of the houses, and the amount of crops grown on the land for human consumption. A worst case scenario is assumed. This is that humans will consume contaminated crops on a daily basis. Changes in the assumptions made would result in a subsequent change in the level of the identified risks. For example if one assumption was that adults would come into more contact with the soil, then the magnitude of the effects would be less. Adults are less likely to directly ingest the soil, and therefore will not be at risk from a high dose of the contaminants present. Long term effects would be more likely to pose a risk to adults through consuming crops grown in the gardens of the houses or by inhalation of soil dust. The importance of the risks to humans on a recreational area is high; the future occupiers of the houses should not be put at unnecessary risk from the contaminants over a short or a long period of time. Due to the presence of metals which are known to be phytotoxic, there may be problems in growing plants in the gardens and open space of a residential development. Consideration needs to be given to reduce the contaminants in the soils to levels below those where plant growth may be inhibited. Layers of topsoil would be needed to significantly reduce the effects and levels of arsenic and PAHs would need to be reduced significantly in order to reduce the long-term effects of exposure.

(c) Recreational Development

Exposure to the contaminants on the recreational area could be through direct ingestion of soil, or by indirect ingestion through the skin via cuts. The magnitude of risks would be specific to each individual, and would depend upon the amount of times that a subject used the recreational area. The assumptions are that a person uses the area at least once a day, and that contaminants are likely to be ingested. In the case of children, it is assumed that a child will ingest the contaminated soil. Using these assumptions it can be stated that there is a high magnitude of risk associated with the recreational area. The concentration of contaminants in the soils on the site are above the ICRCL guideline levels for open spaces (ICRCL, 1986). Therefore without any remediation it can be assumed that harm will be caused to persons using the recreational area.

The phytotoxic metals present would affect the growth of plants and may cause harm to humans in high doses. Other contaminants on the site such as PAHs would also increase the magnitude of risks. Risk reduction should be concentrated on reducing the levels of the contaminants to acceptable levels.

(d) Retail Development

Construction of the retail development will incorporate areas of hard cover for uses such as car parking. This hard cover will reduce the risks posed by the contaminants on the site. Levels of risk to end users of the site will therefore be low. Risk of gases collecting in the basements of the buildings will also be low due to there being no flow involved with the gases that are present on the site. It is assumed that the buildings in areas where sulphate is present will use sulphate resistant concrete to reduce the long-term effects of exposure. It is assumed that due to the contaminants being isolated by the construction there will be a low magnitude of risks associated with the retail development.

CHAPTER 4: RISK REDUCTION AND REMEDIATION

4.1 RISK REDUCTION

Risk reduction on the site is to be achieved through choosing a suitable remedial action. In chapter 3 the risks associated with the contaminants on the site, and the areas of the site with the most potential to pose a hazard were identified. The remediation option chosen for the site needs to be acceptable in terms of reducing or controlling the risks to an acceptable level. The end uses being studied (residential, recreational and retail) will each be dealt with separately in terms of remediation, due to the presence of the different targets in each case. Remediation and risk reduction will be concentrated on the following areas:

- **Buildings.**
- **Ash slope.**
- **Areas of made ground to the south of the buildings.**

The buildings contain the highest levels of contaminants; within their fabric and in the soils below them. Site workers need to subjected to minimal risks during the decontamination and demolition of the buildings, and the clearing and landscaping of the site. The wire works underwent decommissioning after closure. However as described in section 2, there are a number of hazards still present on the site. Therefore prior to demolition of the buildings further decommissioning and decontamination of the building fabric needs to be undertaken. Decommissioning as outlined by Harris and Herbert in 1995, and involves; "Removal of drums and other packages, removal of surface deposits and emptying pipe work. Decontamination will involve; "Removal, destruction, and detoxification of contaminants and action to prevent contaminants from harming specified targets." (Harris and Herbert, 1995). Harris and Herbert in 1994, identify the purpose of remedy selection in terms of risk reduction as being; "To identify and evaluate remedial methods with the aim of identifying the best remedial strategy."

The following sections will identify the remedial options available, these will be short-listed and then the most appropriate remedial option(s) will be chose for each end use.

4.2 REMEDIAL OPTIONS

Remedial options are split into 2 broad technical groups, civil engineering based methods and process-based methods. There is however a third group that is not related to technical means. This is known as the administrative method (Harris and Herbert, 1994) and incorporates the following procedures;

(a) adopting a less sensitive approach for the land,
(b) restricting access to the land and
(c) altering the form or layout of a development.
(Harris and Herbert, 1994).

Civil engineering based methods can be classified into three main groups (Harris and Herbert, 1994);

- **Removal** (excavation) of contaminated solid material.
- **Physical Containment** (of the contaminated ground) using covers and in-ground barriers.
- **Hydraulic Controls**, used in support of removal and physical containment; as the principal means of control; or specifically for the treatment of contaminated surface.

Generally civil engineering methods are carried out on a large scale and are not generally used for smaller areas of contamination. The advantages of using these methods are that they are well established and familiar to designers and contractors. There is also plant and equipment developed specifically for the purpose. Disadvantages are outlined by Harris and Herbert; "Excavation may pose health and environmental impacts; containment systems do not materially reduce the volume or the hazardous properties of contaminated material, they have a finite life and their effectiveness is thought to decrease over time."

Process based methods are split into five main types;

- **Thermal Treatment:** using heat to remove, stabilise or destroy contaminants.
- **Physical Treatment:** using physical processes, or exploiting physical attributes, to separate contaminants from host media, or different fractions of contaminated media.
- **Chemical Treatment:** using chemical reactions to remove, destroy or modify contaminants.

- **Biological Treatment:** using natural metabolic pathways of micro -organisms and other biological agents to remove, destroy or modify contaminants.
- **Stabilisation/Solidification:** in which contaminants are chemically stabilised and/or mobilised to reduce their availability to targets.

Process based methods of remediation can be used on a much smaller scale and can be more specific as to which contaminants they treat. However as a result, they can be restricted by the range of contaminants that they can be used to process. Advantages are that they can greatly reduce the amount of contaminants in an area and therefore provide a more permanent solution to the contamination.

It is important to look at remediation methods in terms of their effectiveness on a site specific basis. A number of remediation methods are looked at here in terms of their advantages and disadvantages. The information is based on that set out in Harris and Herbert, 1994 and Harris et al, 1995.

4.2.1 Civil Engineering Based Methods

(a) Excavation

Excavation involves the removal of contaminated media from the site and disposal either on or off site, or for treatment on or off site.

Advantages

- Provides a permanent solution for the site provided all contaminated material is removed.
- Can be integrated with other remedial methods such as process based methods.
- Once contaminated material is 'cleaned' it can be used for fill on the site.
- Is widely used and has been proven.
- Plant and equipment is readily available.
- Familiar to designers and contractors

Disadvantages

- Does not reduce the volume of untreated material as it is only transported elsewhere.
- Disposal off site comes under landfill tax.

- May be limitations on depth or extent of excavation (e.g. due to presence of services and stability of ground).
- Potential for dust, gases and odours to be released and vehicle movements, therefore having an impact on human health and the environment.
- The availability of off-site disposal facilities is reducing.

Examples

- Excavation and off site disposal
- Excavation and on site disposal

(b) Surface Covers

Surface covers incorporate barriers that are placed over a contaminated area, they are intended to isolate the targets from hazards in the ground. They may also reduce the influx of water to the contaminated area or restrict gases and liquids from reaching the surface and may also provide a platform for building purposes.

Advantages

- May provide an economic solution on a large site provided that all potential hazards are addresses.
- Has the potential to improve the engineering properties of the site.
- Material from the site could be used and conventional construction techniques and equipment are used.

Disadvantages

- Does not reduce the amount of contaminated material on site.
- A hole may be formed in the cover by human disturbance, tree roots, flooding etc.
- Potential deterioration over a long period of time
- Covers have not been tested over long time periods.
- May restrict the future use of the site.

Examples

- Landfill covers
- Hardstanding covers

(c)In-ground Barriers

These are structures that are designed to prevent the migration of contaminants in the ground, in or out of a contaminated zone. There are two types; **vertical barriers** are classified in terms of the method of placement and include displacement, excavated, and injected. **Horizontal barriers** can be used together with vertical barriers, this means that complete capsulation of the contaminant is achieved.

Advantages

- Can provide an economic remedial solution to sites where migration of contaminants may be a problem.
- Applicable to a wide range of contaminant types and media.
- Techniques, equipment and material are readily available.
- There is a low level of risk to public health and the environment.

Disadvantages

- Contaminated material is left on site.
- Future construction may cause disturbance, therefore constraints on future use of site.
- May deteriorate over time.
- Installation may be difficult in some ground conditions.
- Need long term monitoring.

Examples

- Slurry walls.
- Reactive barriers.
- Clay, plastic membrane.

(d) Hydraulic Measures

Used to control migration of groundwater whether in a plume of contaminant or a body of contaminated groundwater. Water may be pumped out and treated or disposed of.

Advantages

- Provide a means of dealing with a contaminated aqueous environment.
- Can easily be integrated with other remediation techniques.

- Flexible therefore can cope with dynamic changes in conditions.
- Techniques and procedures are well practised.

Disadvantages

- The duration of the treatment is uncertain.
- The contaminated liquids need to be collected, treated or disposed.
- The ground conditions may reduce the effectiveness of pumping (e.g. permeability).
- Ceasing to pump may result in a rise in concentration of contaminants in the water.

Examples

- No examples

4.2.2 Process Based Methods

(a) Thermal Processes

Involves the use of heat to remove, destroy or immobilise contaminants, this may be applied in- or ex-situ.

Advantages

- Able to reduce the hazards associated with a contaminant.
- Can provide permanent remediation, provided the contaminants are completely removed, destroyed or immobilised.

Disadvantages

- Energy intensive process.
- Effectiveness varies depending upon the chemical composition and physical characteristics of the contaminated media.
- Can produce other wastes (e.g. gases), these must be contained or treated.

Examples

- Incineration
- Vitrification

(b) Physical Processes

This method relies on physical methods to separate the contaminants from the medium that they are found in.

Advantages

- Can reduce the volume of contaminated material.
- Provides a permanent solution provided all contaminants are moved.

Disadvantages

- Produces other wastes that need to be disposed of, therefore a further risk to public health and the environment.
- Effectiveness depends upon ground conditions and contaminants present.
- Difficult to find a disposal site in-situ.

Examples

- Soil washing (ex and in-situ).
- Solvent extraction (ex-situ)
- Electrokinetics (in-situ).

(c) Chemical Processes

Methods rely on chemical reactions that destroy or change the properties of contaminants.

Advantages

- Reduces hazardous properties of the contaminants.
- Can provide a permanent solution.

Disadvantages

- Produces toxic wastes that need to be disposed.
- Outcome of chemical reaction is difficult to predict.
- The treatment agents can be toxic, therefore further treatment may be required to remove them.

Examples

- Dechlorination.
- Ion exchange.

- Carbon absorption.
- Precipitation.

(d) Biological Processes

Incorporate the use of natural metabolic pathways of living organisms to destroy, remove or transform contaminants into a less hazardous form.

Advantages

- Can reduce the hazardous properties of contaminated material.
- Can provide a permanent solution to the contamination problem.

Disadvantages

- Can produce toxic substances.
- Not effective for some contaminants.
- Substances may be present (e.g. metals) that inhibit plant growth.

Examples

- Bioreactors.
- Phytoremediation.
- Bioleaching.

(e) Stabilisation/Solidification Processes

These methods involve the chemical stabilisation/immobilisation of contaminants within a solid matrix.

Advantages

- Use of available equipment and materials are readily available.
- Reduce hazardous properties of materials.
- may improve engineering properties of a material
- Can easily be integrated with other forms of remediation.

Disadvantages

- Not applicable to a complex mix of contaminants.
- Long term performance uncertain.
- May increase the volume of material handled on site.
- Monitoring may be required.

- Potential health and environmental impacts.

Examples

- Cementation.

4.3 REMEDIAL STRATEGIES

Having identified the remedial options available, a number of site specific strategies are to be selected. The strategies are to be developed in terms of the requirements of each end use related to the likely targets.

Strategy A: Excavation and Ex-Situ Soil Washing

The soils are excavated and removed from the site for washing purposes. The method of soil washing that is recommended is chemical leaching as outlined by Mulligan et al, 1999 and involves; "Washing the soils with inorganic acids (sulphuric or hydrochloric) with a pH less than 2 or organic acids (acetic or citric) with a pH not less than 4, chelating agents such as ethylenediaminetetraacetic acid (EDTA) and nitrilotriacetate (NTA)." This will remove the contaminants from the soil and as the soil is returned to the site, and the area can then be landscaped effectively. The material from the ash slope would be of most use if returned to the level part of the site. This would leave a natural slope to the north of the site and a larger, flatter area for construction. A layer of topsoil is recommended in the areas where plants are likely to be grown (gardens and open spaces). Contaminated groundwater on the site is to be pumped out and treated. This strategy provides a permanent, long term solution to contamination.

Strategy B: Surface Covers and Excavation of the Ash Slope

Surface covers are placed over the areas of high concentrations of contaminants (below wire works and the area to south of wire works). This would isolate the potential targets from the hazards. The covers could be of the landfill type, such as compacted clay liners (CCL), with a low permeability. A solid foundation for construction would be formed from using covers. The ash slope material is to be excavated, and one of two things which could be done with the ash; (a) the ash could be taken to an off-site landfill and (b) the ash could be taken away, washed and returned to site and used for fill or mixed with the cover material.

Strategy C: Surface Covers and Phytoremediation

The whole site is cleared and covered with a layer of concrete containing a geosynthetic liner. The concrete will contain any contaminants present, and provide a solid base for construction purposes. Sulphate resistant varieties of concrete would need to be used. As metals are relatively immobile in soil, the migration of these contaminants would be minimal once they have been covered. The ash would be left in-situ, and planted with phytoremediation plants. Examples of such plants are given by Mulligan et al, 1999, and include "*Thlaspi, Urtica, Chenopodium, polygonum*, and *Alyssin*." These plants are capable of extracting contaminants from the soil. The area would have to be isolated from wildlife and humans and the plants need disposing of in an appropriate fashion, such as a landfill site.

Strategy D: In-Situ Soil Washing and Concrete Covers

The soil is extracted and cleaned on site using extractants (Mulligan et al, 1999). Extractants will remove any metals in the soils and any organics present. The soil is then mixed with untreated ash and returned to the site. The ash contains relatively low concentrations of contaminants, and these will be reduced by mixing with clean fill. The fill is used to landscape the site in preparation for a cover of concrete. The concrete will form a base for construction purposes and provide a barrier for any contaminants.

Strategy E: Excavation of Soil and Ex-Situ Biological Treatment

The soil is excavated from the area under the wire works, the area in front of the wire works and from the ash slope. Biological washing is most effective using biosurfacants (Mulligan etal,1999). The biosurfacants remove metals from soils, and are also biodegradable, so do not produce any toxic side products. The clean soils would be returned to the site and landscaped for construction.

4.4 REMEDY SELECTION

In order to select the preferred remedy for each end use a ranking system is used to analyse the strategies using selected criteria (table 4.1).

Criterion	Rank	Weighting for each strategy					Overall score for each strategy				
		A	B	C	D	E	A	B	C	D	E
Long-term effectiveness	10	3	1	2	2	3	30	10	20	20	30
Reduction in hazard	8	3	1	2	2	3	24	8	16	16	24
Acceptability to local community	6	2	2	2	2	2	12	12	12	12	12
Operational requirements	4	3	3	2	2	2	12	12	8	8	8
Short-term health and safety impacts	2	1	2	2	2	2	2	4	4	4	4
Short-term environmental impacts	2	2	2	2	2	2	4	4	4	4	4
Overall score							**84**	**50**	**64**	**64**	**82**

TABLE 4.1 Ranking system used to select the preferred strategy for remediation of the site using selected criteria.

The criteria enable the strategies to be analysed in terms of their strengths and weaknesses, and are based on those formulated by Harris and Herbert, 1994. Long-term and short-term criteria have been addressed, and are classified as follows;

- **Long-term effectiveness,**
- **Reduction in hazard,**
- **Acceptability to the local community,**
- **Acceptable operational requirements,**
- **Minimal short-term health and safety implications,**
- **Minimal short-term environmental impacts.**

4.4.1 Costs of Remediation

The cost of remediation can vary greatly depending on the site characteristics and the proposed remedial method(s). Costs are calculated by considering the amount of material (in tonnes) to be excavated and the cost of barriers and covers to be implemented. Costs are reduced by remediating the site only to a level that is suitable for use, and by reducing the amount of waste that goes to landfill (landfill tax = £10/tonne, (1999 figure)). The costing of the remedial options is beyond the scope of this project, which looks at remediation in terms of the end use specified and reducing the risks posed by the contamination.

As can be seen, the preferred remediation technique is strategy A (excavation and soil washing). However, the UK 'suitable for use' approach (chapter 1) determines that this strategy would not necessarily be the one chosen for all the proposed end uses.

4.4.2 Remedy Selection for the Proposed Uses

As mentioned the 'suitable for use' approach used in the UK means that remediation options chosen for the three end uses should be chosen depending upon the sensitivity of each end use to the hazards identified. Cost is also an important factor as providing full remediation for some sites would not be cost effective. This section attempts to provide a 'suitable for use' remedy for each of the end-uses proposed.

4.4.2.1 Remediation for a Residential Development

For a residential development, a high level of remediation is required due to the increased likelihood of the contaminants posing a hazard to the targets. Domestic gardens will form a part of the development; these areas will put humans at risk from exposure to the contaminants. It is recommended that strategy A is used for this end use. This strategy will remove all of the contaminants from the soil and groundwater. The excavation of soil should be focused in three areas; the area to the west of the site beneath the wire works, the ash slope and the area of made ground in front of the wire works to the east of the site. Ground water removal and washing need only be done in the areas where high concentrations of contaminants are found. This area is beneath the wire works in BH104 and TP105. The soil is best treated off-site as this will enable the metals to be removed effectively. The site can then be landscaped for development to commence using the clean ash and soil as fill. The gardens of the houses will require a layer of topsoil up to 3 metres thick in order to reduce the risk of the roots absorbing any contaminants still present.

4.4.2.2 Remediation for a Recreational Development

The remediation method for the recreational development needs to isolate the contaminants from the targets, which are mainly being humans. Strategy B would be the most appropriate way to isolate these contaminants. The surface covers would ensure that none of the contaminants would be exposed at the surface. Returning the ash to the site after washing would be the most appropriate technique, and would provide fill for the site and reduce the cost of landfill. The ash would be placed on top of the cover, and there would be a probable need for extra topsoil to be placed on the site in order for plants to be grown on the area. It is likely that a recreational area would mostly be grassed. Grass has short roots so would not penetrate the cover. In any areas where larger plants or trees are to be grown a thicker layer of topsoil would reduce the likelihood of the roots reaching the contaminated soil.

4.4.2.3 Remediation for a Retail Development

The development of retail units has been considered for the site. The retail units proposed are to be non-food and there are to be areas of car parking. The exact layout of the proposed development is unknown. In preparation for the buildings it is proposed that a concrete base be laid. The concrete base will provide a cover system, and therefore isolate the contaminants. It is therefore proposed that strategy B is used for remediation for the retail development. However, instead of using a landfill type liner, such as a Compacted clay liner (CCL), the cover will be provided by the concrete base incorporating a geotextile layer as described by Harris and Herbert, 1996. The ash slope would be excavated, washed and used to landscape the area prior to the concrete base being laid. In order to minimise the corrosion of the concrete it is advised that a sulphate resistant variety of concrete be used. The car parking areas would also ensure isolation from the contaminants by using concrete or asphalt as covers.

The other strategies, while they provide a high level of remediation, would be unsuitable for using in preparation for the retail units. This is primarily because they would not prove to be cost effective as the level of remediation is higher than needed for this type of end use when using the suitable for use approach. Other countries such as the Netherlands would be inclined to either strategy A or strategy E in order to return the site to the required levels.

CHAPTER 5: CONCLUSIONS

5.1 FINDINGS

This project has presented a site investigation, risk assessment and remediation selection process for an industrial site containing a former wire works, brick and tile works and waste disposal sites. The site is to be redeveloped, and an analysis has been undertaken for different end uses, both residential and recreational. The potential contaminant types were investigated by looking at the history of the site dating back to 1842, when the site was being used as gardens and allotments. The processes undertaken on the site and, in particular, in the individual rooms of the wire works gave an insight as to the type of contaminants likely to be present. These were found to be metals (lead, copper, iron, zinc, cadmium, and nickel), cyanide, chlorides, polyaromatic Hydrocarbons and phenols. The site investigation looked at the general layout of the site, the history of use, the geology and hydrology.

The Consulting Engineers working for the developers contracted out a chemical analysis of the site to a site exploration group. The site developers have requested that the site is to remain confidential and also the groups working on it. Soil, water and building samples were taken as well as a detailed visual survey of the site. Samples were taken from boreholes, trial pits, window samples and scrapings from the building fabric. The consulting engineers decided on the position of the sampling points as a result of a preliminary investigation. Results of the chemical analysis showed that high levels of metals were present on the site, the metals being lead, boron, copper nickel and zinc. There were also high concentrations of arsenic, polyaromatic hydrocarbons (PAHs), phenols and sulphate. It was found that the areas of the site containing the highest levels of contaminants were the building fabric of the wire works, the soil and groundwater below the floor of the wire works, the ash slope to the rear of the wire works, an area of made ground in front of the wire work to the east of the site and a tree covered slope towards the eastern boundary.

The levels of contaminants present on the site were assessed using published trigger levels for contaminated land. The ICRCL Trigger Levels (ICRCL, 1987) for soils were used and the Dutch Action Levels for groundwater. The guidelines were used to identify whether the site required remediation. A risk assessment of the site focused on the contaminants present and looked at the likely hazard/pathway/target relationships. In terms of hazards the contaminants were found to be:

- **Carcinogenic substances,**
- **Zootoxic metals,**
- **Phytotoxic metals,**
- **Allergenic substances and sensitises, and**
- **Substances causing skin damage and corrosive substances**.

The pathways were found to be direct ingestion of contaminated soil and food, indirect ingestion through the skin via cuts, inhalation of soil particles and dust and by direct contact with contaminated material. The main targets were found to be children on the residential and recreational developments and on all developments, the site workers were found to be at risk.

Risk reduction on the site requires the removal of the contaminants likely to cause harm or to use methods to isolate the targets from the contaminants. A remediation study outlines five remediation strategies for the site, and the remediation strategies were selected in terms of the reduction of perceived risks generated by the contaminants. A ranking system based on risk reduction criteria highlighted the most appropriate remediation scheme for the site the result being the excavation of the contaminated soil and soil washing. For each end use being studied remediation options were recommended. For the residential development excavation of the contaminated soil and soil washing is described. For the recreational development surface covers are recommended to isolate the contaminants and excavation of the ash slope followed by washing is described. The retail development requires a cover system of concrete and a geosynthetic, the ash is washed and mixed with the existing soil prior to the cover being laid.

5.2 LIMITATIONS AND FURTHER STUDIES

Limitations in the study have meant that in some areas of the have may have been overlooked. The major limitation of the study is time. In an industrial situation the study of a piece of contaminated land for redevelopment would take many months and in some cases years. Indeed the consulting engineers undertaking the study have spent almost a year gathering information for the site investigation and risk assessment. The study would benefit from re-valuation prior to the risk assessment to perhaps reduce the risks, or to expose any risks previously overlooked. A remediation study would benefit from the costs of the various strategies, unfortunately time constraints have not allowed these to be included. Some information regarding the site has been unavailable due to the confidential requirements of the report. In particular, the planned layout of proposed development has not been consulted, therefore limiting the recommendations for exact positions of remediation. The current UK guidelines for investigation of contaminated land prepared by the ICRCL (ICRCL, 1987) are developed entirely for soil, lack some of the possible contaminants and for some of the contaminants action levels are excluded. The substitution of these limitations, for the Dutch equivalent, for water has its own inherent problems. These are developed primarily for use in the Netherlands, where land is required to be returned to nature reserve standards and where groundwater levels are significantly higher than those in the UK. Guidelines in the UK are due to be updated in the very near future by the Department of the Environment, Transport and Regions (DETR), who are developing a Contaminated Land Exposure Assessment (CLEA) (Layla Resources, 2000). "The main purpose of these guidelines will be to establish whether a site poses actual or potential risks to human health, in the context of the existing or intended usage of the site" (Layla Resources, 2000). However until these are introduced the situation will remain as it is at present. Further studies on the contamination and remediation of this site would benefit greatly from the use of the CLEA guidelines.

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APPENDIX 1: COMPARISONS OF THE SAMPLES WITH THE ICRCL GUIDELINES

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

	Concentration below threshold
	Concentrationbelow threshold/above action
	Concentration above action level
N/S	No test scheduled

Contaminant	Units	Planned uses	Threshold level	Action level	Ash pile B1-B2	Ash Pile B1+B2	Ash Pile B1+B2	BH104 at 0.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	66	57	68	<1.0
		Parks, playing fields, Open spaces	40	*	66	57	68	<1.0
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	<0.50	<0.50	1.5
		Parks, playing fields, Open spaces	15	*	<0.50	<0.50	<0.50	1.5
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	15	13	21	22
		Parks, playing fields, Open spaces	1000	*	15	13	21	22
Lead	mg/kg	Domestic gardens,allotments	500	*	110	110	110	250
		Parks, playing fields, Open spaces	2000	*	110	110	110	250
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.36	0.38	0.48	0.22
		Parks, playing fields, Open spaces	20	*	0.36	0.38	0.48	0.22
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.88	1.1	1	0.17
		Parks, playing fields, Open spaces	6	*	0.88	1.1	1	0.17
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.55	0.49	0.6	2.3
Copper	mg/kg	Any uses where plants are to be grown	130	*	81	100	87	670
Nickel	mg/kg	Any uses where plants are to be grown	70	*	30	33	30	46
Zinc	mg/kg	Any uses where plants are to be grown	300	*	73	77	80	4900
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	130	160	93	16
		Landscaped areas, buildings, hard cover	1000	10000	130	160	93	16
Phenols	mg/kg	Domestic gardens, allotments	5	200	1.8	3.5	2	1.6
		Landscaped areas, buildings, hard cover	5	1000	1.8	3.5	2	1.6
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	5.8	5.5	6.8	N/S
		Buildings, hard cover	100	500	5.8	5.5	6.8	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	0.54	1.8	1.3	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	8	20	24	16
Sulphur	mg/kg	All proposed uses	5000	20000	960	1400	1300	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	6.9	6.4	6.4	7.7
		Buildings, hard cover	NL	NL	6.9	6.4	6.4	7.7

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	BH104 at 1.50m	BH104 at 4.00m	BH106 at 3.00m	BH107 at 0.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	<1.0	51	4.7	40
		Parks, playing fields, Open spaces	40	*	<1.0	51	4.7	40
Cadmium	mg/kg	Domestic gardens,allotments	3	*	0.93	0.64	1.3	0.59
		Parks, playing fields, Open spaces	15	*	0.93	0.64	1.3	0.59
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	25	30	40	24
		Parks, playing fields, Open spaces	1000	*	25	30	40	24
Lead	mg/kg	Domestic gardens,allotments	500	*	150	94	78	1400
		Parks, playing fields, Open spaces	2000	*	150	94	78	1400
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.2	0.28	0.2	0.21
		Parks, playing fields, Open spaces	20	*	0.2	0.28	0.2	0.21
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.19	2.2	0.43	0.39
		Parks, playing fields, Open spaces	6	*	0.19	2.2	0.43	0.39
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	4.4	2.2	4.4	11
Copper	mg/kg	Any uses where plants are to be grown	130	*	320	67	38	93
Nickel	mg/kg	Any uses where plants are to be grown	70	*	48	39	51	36
Zinc	mg/kg	Any uses where plants are to be grown	300	*	5800	2000	140	1200
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	<10	N/S	<10	N/S
		Landscaped areas, buildings, hard cover	1000	10000	<10	N/S	<10	N/S
Phenols	mg/kg	Domestic gardens, allotments	5	200	0.78	N/S	1.2	N/S
		Landscaped areas, buildings, hard cover	5	1000	0.78	N/S	1.2	N/S
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	N/S	8	N/S
Sulphur	mg/kg	All proposed uses	5000	20000	<100	N/S	<100	N/S
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	8.5	6.6	6.7	7.6
		Buildings, hard cover	NL	NL	8.5	6.6	6.7	7.6

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	BH107 at 1.55m	BH108 at 1.50m	BH112 at 1.50M	BH112 at 3.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	14	1.2	<1.0	4.3
		Parks, playing fields, Open spaces	40	*	14	1.2	<1.0	4.3
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	0.69	0.72	<0.50
		Parks, playing fields, Open spaces	15	*	<0.50	0.69	0.72	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	37	23	12	12
		Parks, playing fields, Open spaces	1000	*	37	23	12	12
Lead	mg/kg	Domestic gardens,allotments	500	*	1200	170	130	40
		Parks, playing fields, Open spaces	2000	*	1200	170	130	40
Mercury	mg/kg	Domestic gardens,allotments	1	*	<0.10	0.23	0.17	0.16
		Parks, playing fields, Open spaces	20	*	<0.10	0.23	0.17	0.16
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.11	0.23	<0.10	0.47
		Parks, playing fields, Open spaces	6	*	0.11	0.23	<0.10	0.47
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	8.3	1.6	0.56	0.7
Copper	mg/kg	Any uses where plants are to be grown	130	*	42	130	85	61
Nickel	mg/kg	Any uses where plants are to be grown	70	*	41	43	31	22
Zinc	mg/kg	Any uses where plants are to be grown	300	*	510	120	91	120
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	3600	300	N/S
		Landscaped areas, buildings, hard cover	1000	10000	N/S	3600	300	N/S
Phenols	mg/kg	Domestic gardens, allotments	5	200	N/S	41	4.6	3.5
		Landscaped areas, buildings, hard cover	5	1000	N/S	41	4.6	3.5
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	N/S	28	12	32
Sulphur	mg/kg	All proposed uses	5000	20000	N/S	<100	360	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	7.4	6.8	6.6	8.5
		Buildings, hard cover	NL	NL	7.4	6.8	6.6	8.5

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	BH115 at 4.50m	Reservoir Sediment	TP102 at 0.50m	TP103 at 1.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	8.5	34	<1.0	13
		Parks, playing fields, Open spaces	40	*	8.5	34	<1.0	13
Cadmium	mg/kg	Domestic gardens,allotments	3	*	0.54	29	4.6	0.53
		Parks, playing fields, Open spaces	15	*	0.54	29	4.6	0.53
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	12	72	13	15
		Parks, playing fields, Open spaces	1000	*	12	72	13	15
Lead	mg/kg	Domestic gardens,allotments	500	*	300	7200	130	230
		Parks, playing fields, Open spaces	2000	*	300	7200	130	230
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.22	0.75	0.18	0.27
		Parks, playing fields, Open spaces	20	*	0.22	0.75	0.18	0.27
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.92	2.7	0.16	0.76
		Parks, playing fields, Open spaces	6	*	0.92	2.7	0.16	0.76
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	2.6	8.1	0.77	2
Copper	mg/kg	Any uses where plants are to be grown	130	*	37	690	39	72
Nickel	mg/kg	Any uses where plants are to be grown	70	*	17	150	16	21
Zinc	mg/kg	Any uses where plants are to be grown	300	*	430	53000	1800	290
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	200	15	330	<10
		Landscaped areas, buildings, hard cover	1000	10000	200	15	330	<10
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.1	20	3.3	1.6
		Landscaped areas, buildings, hard cover	5	1000	2.1	20	3.3	1.6
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	1300	0.47	N/S	1300
		Buildings	2000	50000	1300	0.47	N/S	1300
		Hard cover	2000	NL	1300	0.47	N/S	1300
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	330	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	9500	100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	10.3	7	11.4	10.8
		Buildings, hard cover	NL	NL	10.3	7	11.4	10.8

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP104 at 0.00m	TP105 at 0.00m	TP105 at 0.75m	TP105 at 2.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	**48**	**<1.0**	**25**	**14**
		Parks, playing fields, Open spaces	40	*	**48**	**<1.0**	**25**	**14**
Cadmium	mg/kg	Domestic gardens,allotments	3	*	**<0.50**	**<0.50**	**0.99**	**0.6**
		Parks, playing fields, Open spaces	15	*	**<0.50**	**<0.50**	**0.99**	**0.6**
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	**13**	**9.7**	**24**	**21**
		Parks, playing fields, Open spaces	1000	*	**13**	**9.7**	**24**	**21**
Lead	mg/kg	Domestic gardens,allotments	500	*	**180**	**170**	**570**	**42**
		Parks, playing fields, Open spaces	2000	*	**180**	**170**	**570**	**42**
Mercury	mg/kg	Domestic gardens,allotments	1	*	**0.51**	**0.16**	**0.1**	**0.12**
		Parks, playing fields, Open spaces	20	*	**0.51**	**0.16**	**0.1**	**0.12**
Selenium	mg/kg	Domestic gardens,allotments	3	*	**0.55**	**0.13**	**0.13**	**0.53**
		Parks, playing fields, Open spaces	6	*	**0.55**	**0.13**	**0.13**	**0.53**
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	**0.63**	**3.4**	**6.4**	**2**
Copper	mg/kg	Any uses where plants are to be grown	130	*	**69**	**51**	**3700**	**62**
Nickel	mg/kg	Any uses where plants are to be grown	70	*	**22**	**11**	**40**	**40**
Zinc	mg/kg	Any uses where plants are to be grown	300	*	**65**	**2100**	**1700**	**1700**
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	**N/S**	**N/S**	**<10**	**<10**
		Landscaped areas, buildings, hard cover	1000	10000	**N/S**	**N/S**	**<10**	**<10**
Phenols	mg/kg	Domestic gardens, allotments	5	200	**1.8**	**0.53**	**0.84**	**0.87**
		Landscaped areas, buildings, hard cover	5	1000	**1.8**	**0.53**	**0.84**	**0.87**
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	**N/S**	**N/S**	**N/S**	**N/S**
		Buildings, hard cover	100	500	**N/S**	**N/S**	**N/S**	**N/S**
Thiocyanate	mg/kg	All proposed uses	50	NL	**N/S**	**N/S**	**N/S**	**N/S**
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	**N/S**	**N/S**	**N/S**	**N/S**
		Buildings	2000	50000	**N/S**	**N/S**	**N/S**	**N/S**
		Hard cover	2000	NL	**N/S**	**N/S**	**N/S**	**N/S**
Sulphide	mg/kg	All proposed uses	250	1000	**16**	**<5.0**	**<5.0**	**<5.0**
Sulphur	mg/kg	All proposed uses	5000	20000	**<100**	**<100**	**<100**	**<100**
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	**8.2**	**10.8**	**7.5**	**10**
		Buildings, hard cover	NL	NL	**8.2**	**10.8**	**7.5**	**10**

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP106 at 0.60m	TP106 at 2.50 m	TP107 at 0.50 m	TP107 at 1.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	130	22	120	89
		Parks, playing fields, Open spaces	40	*	130	22	120	89
Cadmium	mg/kg	Domestic gardens,allotments	3	*	0.89	0.97	2.8	1.1
		Parks, playing fields, Open spaces	15	*	0.89	0.97	2.8	1.1
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	27	23	54	20
		Parks, playing fields, Open spaces	1000	*	27	23	54	20
Lead	mg/kg	Domestic gardens,allotments	500	*	56	49	350	20
		Parks, playing fields, Open spaces	2000	*	56	49	350	20
Mercury	mg/kg	Domestic gardens,allotments	1	*	<0.10	0.14	0.22	0.3
		Parks, playing fields, Open spaces	20	*	<0.10	0.14	0.22	0.3
Selenium	mg/kg	Domestic gardens,allotments	3	*	<0.10	0.38	1.3	1.7
		Parks, playing fields, Open spaces	6	*	<0.10	0.38	1.3	1.7
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	1	1.1	1	3.3
Copper	mg/kg	Any uses where plants are to be grown	130	*	52	38	0.2	770
Nickel	mg/kg	Any uses where plants are to be grown	70	*	53	28	25	16
Zinc	mg/kg	Any uses where plants are to be grown	300	*	160	110	250	260
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	<10	N/S	N/S	N/S
		Landscaped areas, buildings, hard cover	1000	10000	<10	N/S	N/S	N/S
Phenols	mg/kg	Domestic gardens, allotments	5	200	1.3	0.87	1.3	0.78
		Landscaped areas, buildings, hard cover	5	1000	1.3	0.87	1.3	0.78
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	<5.0	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	<100	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	8.2	7.8	5.3	5.6
		Buildings, hard cover	NL	NL	8.2	7.8	5.3	5.6

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP108 at 0.70m	TP108 at 1.00m	TP109 at 0.80m	TP110 at 0.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	75	12	6500	6.3
		Parks, playing fields, Open spaces	40	*	75	12	6500	6.3
Cadmium	mg/kg	Domestic gardens,allotments	3	*	4.1	6.9	1.4	<0.50
		Parks, playing fields, Open spaces	15	*	4.1	6.9	1.4	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	45	180	21	15
		Parks, playing fields, Open spaces	1000	*	45	180	21	15
Lead	mg/kg	Domestic gardens,allotments	500	*	1500	100	32	200
		Parks, playing fields, Open spaces	2000	*	1500	100	32	200
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.2	0.21	0.83	<0.10
		Parks, playing fields, Open spaces	20	*	0.2	0.21	0.83	<0.10
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.48	<0.10	0.63	0.15
		Parks, playing fields, Open spaces	6	*	0.48	<0.1	0.63	0.15
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	9.4	2.1	0.97	10
Copper	mg/kg	Any uses where plants are to be grown	130	*	140	210	35	450
Nickel	mg/kg	Any uses where plants are to be grown	70	*	52	120	37	15
Zinc	mg/kg	Any uses where plants are to be grown	300	*	3100	2100	200	1000
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	<10	N/S	<10
		Landscaped areas, buildings, hard cover	1000	10000	N/S	<10	N/S	<10
Phenols	mg/kg	Domestic gardens, allotments	5	200	1.1	0.67	3	<0.50
		Landscaped areas, buildings, hard cover	5	1000	1.1	0.67	3	<0.50
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	25
		Buildings, hard cover	100	500	N/S	N/S	N/S	25
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	1.3
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	2900
		Buildings	2000	50000	N/S	N/S	N/S	2900
		Hard cover	2000	NL	N/S	N/S	N/S	2900
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	<5.0	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	<100	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	6.5	6.6	5.5	<12.0
		Buildings, hard cover	NL	NL	6.5	6.6	5.5	<12.0

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP110 at 0.50 m	TP113 at 117/B	TP113A at 0.70m	TP113A at 2.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	2.2	34	71	22
		Parks, playing fields, Open spaces	40	*	2.2	34	71	22
Cadmium	mg/kg	Domestic gardens,allotments	3	*	0.89	0.83	0.97	1.3
		Parks, playing fields, Open spaces	15	*	0.89	0.83	0.97	1.3
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	25	20	13	31
		Parks, playing fields, Open spaces	1000	*	25	20	13	31
Lead	mg/kg	Domestic gardens,allotments	500	*	55	1300	57	49
		Parks, playing fields, Open spaces	2000	*	55	1300	57	49
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.21	1.6	<0.10	<0.10
		Parks, playing fields, Open spaces	20	*	0.21	1.6	<0.10	<0.10
Selenium	mg/kg	Domestic gardens,allotments	3	*	3	1.2	0.6	0.33
		Parks, playing fields, Open spaces	6	*	3	1.2	0.6	0.33
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	2.5	16	2.7	9.6
Copper	mg/kg	Any uses where plants are to be grown	130	*	83	830	25	32
Nickel	mg/kg	Any uses where plants are to be grown	70	*	49	36	12	50
Zinc	mg/kg	Any uses where plants are to be grown	300	*	230	870	55	130
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	600	N/S	<10
		Landscaped areas, buildings, hard cover	1000	10000	N/S	600	N/S	<10
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.9	7.9	1.4	1.7
		Landscaped areas, buildings, hard cover	5	1000	2.9	7.9	1.4	1.7
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	12	N/S	N/S	N/S
		Buildings, hard cover	100	500	12	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	0.68	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	8	8	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	<100	<100	120
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	6.6	7.1	7	7.8
		Buildings, hard cover	NL	NL	6.6	7.1	7	7.8

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP114 at 0.60m	TP114 at 1.40m	TP115A at0.15m	TP115A at 1.10m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	39	4.8	15	76
		Parks, playing fields, Open spaces	40	*	39	4.8	15	76
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	1.5	<0.50	<0.50
		Parks, playing fields, Open spaces	15	*	<0.50	1.5	<0.50	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	20	16	29	17
		Parks, playing fields, Open spaces	1000	*	20	16	29	17
Lead	mg/kg	Domestic gardens,allotments	500	*	180	130	100	150
		Parks, playing fields, Open spaces	2000	*	180	130	100	150
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.34	0.4	0.2	0.29
		Parks, playing fields, Open spaces	20	*	0.34	0.4	0.2	0.29
Selenium	mg/kg	Domestic gardens,allotments	3	*	2.8	0.92	0.14	0.96
		Parks, playing fields, Open spaces	6	*	2.8	0.92	0.14	0.96
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	5.6	9.8	48	8.3
Copper	mg/kg	Any uses where plants are to be grown	130	*	120	64	39	130
Nickel	mg/kg	Any uses where plants are to be grown	70	*	25	30	30	45
Zinc	mg/kg	Any uses where plants are to be grown	300	*	160	120	210	210
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	1500	N/S	140	62
		Landscaped areas, buildings, hard cover	1000	10000	1500	N/S	140	62
Phenols	mg/kg	Domestic gardens, allotments	5	200	13	2.2	2.8	1.5
		Landscaped areas, buildings, hard cover	5	1000	13	2.2	2.8	1.5
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	1.3
		Buildings, hard cover	100	500	N/S	N/S	N/S	1.3
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	32	8	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	180	<100	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	7.5	7.2	8.2	7.1
		Buildings, hard cover	NL	NL	7.5	7.2	8.2	7.1

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP115A at 2.10m	TP116 at 0.60m	TP116 at 1.20m	TP117 at 0.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	15	39	1.2	15
		Parks, playing fields, Open spaces	40	*	15	39	1.2	15
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	0.51	1	<0.50
		Parks, playing fields, Open spaces	15	*	<0.50	0.51	1	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	27	18	27	15
		Parks, playing fields, Open spaces	1000	*	27	18	27	15
Lead	mg/kg	Domestic gardens,allotments	500	*	45	210	2000	1800
		Parks, playing fields, Open spaces	2000	*	45	210	2000	1800
Mercury	mg/kg	Domestic gardens,allotments	1	*	<0.10	0.17	0.75	0.21
		Parks, playing fields, Open spaces	20	*	<0.10	0.17	0.75	0.21
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.23	2.7	0.43	0.18
		Parks, playing fields, Open spaces	6	*	0.23	2.7	0.43	0.18
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	2.6	48	72	15
Copper	mg/kg	Any uses where plants are to be grown	130	*	86	74	240	73
Nickel	mg/kg	Any uses where plants are to be grown	70	*	49	24	30	16
Zinc	mg/kg	Any uses where plants are to be grown	300	*	100	130	440	1300
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	750	2500	27
		Landscaped areas, buildings, hard cover	1000	10000	N/S	750	2500	27
Phenols	mg/kg	Domestic gardens, allotments	5	200	1.7	4.5	11	3.6
		Landscaped areas, buildings, hard cover	5	1000	1.7	4.5	11	3.6
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	4.1	N/S
		Buildings, hard cover	100	500	N/S	N/S	4.1	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	0.81	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	16	20	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	160	<10	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	6.1	7	7.8	7.1
		Buildings, hard cover	NL	NL	6.1	7	7.8	7.1

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP117 at 0.80m	TP117 at 3.00m	TP118 at 0.50m	TP118 at 2.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	55	<1.0	48	36
		Parks, playing fields, Open spaces	40	*	55	<1.0	48	36
Cadmium	mg/kg	Domestic gardens,allotments	3	*	0.57	1.3	1.5	1.1
		Parks, playing fields, Open spaces	15	*	0.57	1.3	1.5	1.1
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	56	32	21	21
		Parks, playing fields, Open spaces	1000	*	56	32	21	21
Lead	mg/kg	Domestic gardens,allotments	500	*	76	410	430	75
		Parks, playing fields, Open spaces	2000	*	76	410	430	75
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.22	0.14	0.45	0.37
		Parks, playing fields, Open spaces	20	*	0.22	0.14	0.45	0.37
Selenium	mg/kg	Domestic gardens,allotments	3	*	1.1	0.31	1.1	0.97
		Parks, playing fields, Open spaces	6	*	1.1	0.31	1.1	0.97
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.75	11	4.9	5.6
Copper	mg/kg	Any uses where plants are to be grown	130	*	85	64	360	190
Nickel	mg/kg	Any uses where plants are to be grown	70	*	61	64	49	110
Zinc	mg/kg	Any uses where plants are to be grown	300	*	190	340	790	280
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	N/S	210	18
		Landscaped areas, buildings, hard cover	1000	10000	N/S	N/S	210	18
Phenols	mg/kg	Domestic gardens, allotments	5	200	0.74	0.97	5.3	1.9
		Landscaped areas, buildings, hard cover	5	1000	0.74	0.97	5.3	1.9
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	47
		Buildings, hard cover	100	500	N/S	N/S	N/S	47
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	0.49
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	2000
		Buildings	2000	50000	N/S	N/S	N/S	2000
		Hard cover	2000	NL	N/S	N/S	N/S	2000
Sulphide	mg/kg	All proposed uses	250	1000	<5.0	<5.0	12	16
Sulphur	mg/kg	All proposed uses	5000	20000	<100	<100	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	9.6	6.6	7.2	7.8
		Buildings, hard cover	NL	NL	9.6	6.6	7.2	7.8

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP118 at 2.60m	TP120 at 1.20m	TP122 at 0.70m	TP123 at 0.50m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	<1.0	<1.0	2.9	190
		Parks, playing fields, Open spaces	40	*	<1.0	<1.0	2.9	190
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	<0.50	0.57	3
		Parks, playing fields, Open spaces	15	*	<0.50	<0.50	0.57	3
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	14	15	41	45
		Parks, playing fields, Open spaces	1000	*	14	15	41	45
Lead	mg/kg	Domestic gardens,allotments	500	*	300	660	220	200
		Parks, playing fields, Open spaces	2000	*	300	660	220	200
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.16	0.44	0.47	0.31
		Parks, playing fields, Open spaces	20	*	0.16	0.44	0.47	0.31
Selenium	mg/kg	Domestic gardens,allotments	3	*	0.31	220	0.14	<0.10
		Parks, playing fields, Open spaces	6	*	0.31	220	0.14	<0.10
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	7.7	2.8	0.53	35
Copper	mg/kg	Any uses where plants are to be grown	130	*	280	150	140	960
Nickel	mg/kg	Any uses where plants are to be grown	70	*	15	16	29	38
Zinc	mg/kg	Any uses where plants are to be grown	300	*	580	220	450	1500
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	N/S	N/S	N/S	38
		Landscaped areas, buildings, hard cover	1000	10000	N/S	N/S	N/S	38
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.3	1.9	3.2	1.1
		Landscaped areas, buildings, hard cover	5	1000	2.3	1.9	3.2	1.1
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	13
		Buildings, hard cover	100	500	N/S	N/S	N/S	13
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	0.68
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	12	8	12	16
Sulphur	mg/kg	All proposed uses	5000	20000	<100	540	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	9.7	10.1	9.6	7.6
		Buildings, hard cover	NL	NL	9.7	10.1	9.6	7.6

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	TP201 at 1.00m	TP201 at 2.90m	TP202 at 0.50m	TP202 at 1.90m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	250	24	5.2	5.3
		Parks, playing fields, Open spaces	40	*	250	24	5.2	5.3
Cadmium	mg/kg	Domestic gardens,allotments	3	*	1.2	<0.50	<0.50	<0.50
		Parks, playing fields, Open spaces	15	*	1.2	<0.50	<0.50	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	17	18	28	29
		Parks, playing fields, Open spaces	1000	*	17	18	28	29
Lead	mg/kg	Domestic gardens,allotments	500	*	1600	63	32	18
		Parks, playing fields, Open spaces	2000	*	1600	63	32	18
Mercury	mg/kg	Domestic gardens,allotments	1	*	<0.10	<0.10	<0.10	<0.10
		Parks, playing fields, Open spaces	20	*	<0.10	<0.10	<0.10	<0.10
Selenium	mg/kg	Domestic gardens,allotments	3	*	<0.10	0.41	<0.10	<0.10
		Parks, playing fields, Open spaces	6	*	<0.10	0.41	<0.10	<0.10
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	4.7	0.52	9.8	0.22
Copper	mg/kg	Any uses where plants are to be grown	130	*	20000	130	66	31
Nickel	mg/kg	Any uses where plants are to be grown	70	*	120	36	55	45
Zinc	mg/kg	Any uses where plants are to be grown	300	*	1800	84	160	74
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	85	N/S	N/S	N/S
		Landscaped areas, buildings, hard cover	1000	10000	85	N/S	N/S	N/S
Phenols	mg/kg	Domestic gardens, allotments	5	200	4.6	1.1	1.4	0.85
		Landscaped areas, buildings, hard cover	5	1000	4.6	1.1	1.4	0.85
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	3200	690	800	490
		Buildings	2000	50000	3200	690	800	490
		Hard cover	2000	NL	3200	690	800	490
Sulphide	mg/kg	All proposed uses	250	1000	80	<5.0	<5.0	<5.0
Sulphur	mg/kg	All proposed uses	5000	20000	<100	<100	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	9.9	7.7	8	8.5
		Buildings, hard cover	NL	NL	9.9	7.7	8	8.5

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	WS101 at 0.70m	WS102 at 0.00m	WS201 at1.00m	WS202 at 0.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	38	80	37	62
		Parks, playing fields, Open spaces	40	*	38	80	37	62
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	0.82	<0.50	0.53
		Parks, playing fields, Open spaces	15	*	<0.50	0.82	<0.50	0.53
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	12	17	15	N/S
		Parks, playing fields, Open spaces	1000	*	12	17	15	N/S
Lead	mg/kg	Domestic gardens,allotments	500	*	36	190	100	560
		Parks, playing fields, Open spaces	2000	*	36	190	100	560
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.18	9.3	<0.10	0.38
		Parks, playing fields, Open spaces	20	*	0.18	9.3	<0.10	0.38
Selenium	mg/kg	Domestic gardens,allotments	3	*	1.2	1	0.2	1.8
		Parks, playing fields, Open spaces	6	*	1.2	1	0.2	1.8
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.45	0.48	0.63	0.82
Copper	mg/kg	Any uses where plants are to be grown	130	*	12	120	45	470
Nickel	mg/kg	Any uses where plants are to be grown	70	*	0.18	32	27	64
Zinc	mg/kg	Any uses where plants are to be grown	300	*	38	130	70	210
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	37	14	N/S	<10
		Landscaped areas, buildings, hard cover	1000	10000	37	14	N/S	<10
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.6	4.4	1.4	2.7
		Landscaped areas, buildings, hard cover	5	1000	2.6	4.4	1.4	2.7
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	5400	N/S	730	0.14
		Buildings	2000	50000	5400	N/S	730	0.14
		Hard cover	2000	NL	5400	N/S	730	0.14
Sulphide	mg/kg	All proposed uses	250	1000	16	8	<5.0	8
Sulphur	mg/kg	All proposed uses	5000	20000	1100	220	<100	<100
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	7	7.3	8.1	6.7
		Buildings, hard cover	NL	NL	7	7.3	8.1	6.7

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	WS203 at 0.00m	WS204 at 0.00m	WS205 at 1.50m	WS205 at 5.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	95	<1.0	55	80
		Parks, playing fields, Open spaces	40	*	95	<1.0	55	80
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	0.63	<0.50	0.91
		Parks, playing fields, Open spaces	15	*	<0.50	0.63	<0.50	0.91
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	2.5	N/S	N/S	N/S
		Parks, playing fields, Open spaces	1000	*	2.5	N/S	N/S	N/S
Lead	mg/kg	Domestic gardens,allotments	500	*	960	38	190	230
		Parks, playing fields, Open spaces	2000	*	960	38	190	230
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.3	<0.10	0.14	0.87
		Parks, playing fields, Open spaces	20	*	0.3	<0.10	0.14	0.87
Selenium	mg/kg	Domestic gardens,allotments	3	*	1.5	1	1.7	1.6
		Parks, playing fields, Open spaces	6	*	1.5	1	1.7	1.6
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.83	0.52	0.79	1.1
Copper	mg/kg	Any uses where plants are to be grown	130	*	1400	53	93	180
Nickel	mg/kg	Any uses where plants are to be grown	70	*	390	<0.10	0.14	0.87
Zinc	mg/kg	Any uses where plants are to be grown	300	*	270	120	68	470
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	22	<10	170	N/S
		Landscaped areas, buildings, hard cover	1000	10000	22	<10	170	N/S
Phenols	mg/kg	Domestic gardens, allotments	5	200	1.5	1.5	3.1	3
		Landscaped areas, buildings, hard cover	5	1000	1.5	1.5	3.1	3
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	0.28	0.1	0.6	1.4
		Buildings	2000	50000	0.28	0.1	0.6	1.4
		Hard cover	2000	NL	0.28	0.1	0.6	1.4
Sulphide	mg/kg	All proposed uses	250	1000	48	8	12	8
Sulphur	mg/kg	All proposed uses	5000	20000	230	<100	660	280
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	5.8	5.9	4.3	8
		Buildings, hard cover	NL	NL	5.8	5.9	4.3	8

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	WS206 at 2.50m	WS207 at 2.00m	WS207 at 5.50m	WS208 at 2.00m
Group A								
Arsenic	mg/kg	Domestic gardens,allotments	10	*	67	100	120	54
		Parks, playing fields, Open spaces	40	*	67	100	120	54
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	<0.50	0.78	<0.50
		Parks, playing fields, Open spaces	15	*	<0.50	<0.50	0.78	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	11	32	19	9.1
		Parks, playing fields, Open spaces	1000	*	11	32	19	9.1
Lead	mg/kg	Domestic gardens,allotments	500	*	29	110	150	130
		Parks, playing fields, Open spaces	2000	*	29	110	150	130
Mercury	mg/kg	Domestic gardens,allotments	1	*	<0.10	0.22	0.1	0.74
		Parks, playing fields, Open spaces	20	*	<0.10	0.22	0.1	0.74
Selenium	mg/kg	Domestic gardens,allotments	3	*	1.1	1	1.3	0.74
		Parks, playing fields, Open spaces	6	*	1.1	1	1.3	0.74
Group B								
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.41	0.86	1.5	0.54
Copper	mg/kg	Any uses where plants are to be grown	130	*	83	190	190	110
Nickel	mg/kg	Any uses where plants are to be grown	70	*	27	45	44	26
Zinc	mg/kg	Any uses where plants are to be grown	300	*	25	82	300	42
Group C								
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	88	440	24	340
		Landscaped areas, buildings, hard cover	1000	10000	88	440	24	340
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.8	1.7	2	4
		Landscaped areas, buildings, hard cover	5	1000	2.8	1.7	2	4
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	4500	18000	15000	3400
		Buildings	2000	50000	4500	18000	15000	3400
		Hard cover	2000	NL	4500	18000	15000	3400
Sulphide	mg/kg	All proposed uses	250	1000	76	24	24	20
Sulphur	mg/kg	All proposed uses	5000	20000	1100	250	130	690
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	6	6.3	6.8	5.2
		Buildings, hard cover	NL	NL	6	6.3	6.8	5.2

Appendix 1: Comparison of soil samples with ICRCL Guidelines (ICRCL, 1987)

Contaminant	Units	Planned uses	Threshold level	Action level	WS208 at 5.30m	WS208 at 7.35m	WS209 At 0.00m	WS210 at 2.00m	WS210 at 4.00m
Group A									
Arsenic	mg/kg	Domestic gardens,allotments	10	*	87	83	38	36	55
		Parks, playing fields, Open spaces	40	*	87	83	38	36	55
Cadmium	mg/kg	Domestic gardens,allotments	3	*	<0.50	<0.50	<0.50	<0.50	<0.50
		Parks, playing fields, Open spaces	15	*	<0.50	<0.50	<0.50	<0.50	<0.50
Chromium (total)	mg/kg	Domestic gardens,allotments	600	*	N/S	N/S	N/S	N/S	N/S
		Parks, playing fields, Open spaces	1000	*	N/S	N/S	N/S	N/S	N/S
Lead	mg/kg	Domestic gardens,allotments	500	*	240	190	250	36	180
		Parks, playing fields, Open spaces	2000	*	240	190	250	36	180
Mercury	mg/kg	Domestic gardens,allotments	1	*	0.91	0.96	0.5	0.12	0.25
		Parks, playing fields, Open spaces	20	*	0.91	0.96	0.5	0.12	0.25
Selenium	mg/kg	Domestic gardens,allotments	3	*	1.8	1.5	1.2	1.7	1.1
		Parks, playing fields, Open spaces	6	*	1.8	1.5	1.2	1.7	1.1
Group B									
Boron (water soluble)	mg/kg	Any uses where plants are to be grown	3	*	0.83	0.83	0.65	0.95	1
Copper	mg/kg	Any uses where plants are to be grown	130	*	190	150	110	39	110
Nickel	mg/kg	Any uses where plants are to be grown	70	*	47	42	29	13	36
Zinc	mg/kg	Any uses where plants are to be grown	300	*	86	64	190	22	140
Group C									
Polyaromatic hydrocarbons	mg/kg	Domestic gardens, allotments, play areas	50	500	170	150	51	<10	91
		Landscaped areas, buildings, hard cover	1000	10000	170	150	51	<10	91
Phenols	mg/kg	Domestic gardens, allotments	5	200	2.9	2.7	2.4	1.5	3.8
		Landscaped areas, buildings, hard cover	5	1000	2.9	2.7	2.4	1.5	3.8
Cyanide	mg/kg	Domestic gardens, allotments, landscaped ar	25	500	N/S	8.3	N/S	N/S	N/S
		Buildings, hard cover	100	500	N/S	8.3	N/S	N/S	N/S
Thiocyanate	mg/kg	All proposed uses	50	NL	N/S	<0.20	N/S	N/S	N/S
sulphate	mg/kg	Domestic gardens, allotments, landscaped ar	2000	10000	N/S	N/S	N/S	N/S	N/S
		Buildings	2000	50000	N/S	N/S	N/S	N/S	N/S
		Hard cover	2000	NL	N/S	N/S	N/S	N/S	N/S
Sulphide	mg/kg	All proposed uses	250	1000	24	16	8	8	20
Sulphur	mg/kg	All proposed uses	5000	20000	700	1100	260	180	290
Acidity (pH less than)	pH units	Domestic gardens, allotments, landscaped ar	pH5	Ph3	5.5	7.2	7.9	5.5	6.6
		Buildings, hard cover	NL	NL	5.5	7.2	7.9	5.5	6.6

APPENDIX 2: COMPARISONS OF THE SAMPLES WITH THE DUTCH GUIDELINES

Appendix 2: Comparisons of the Water Analysis with the Dutch Guielines

(green)	Concentration below optimum level
(yellow)	Concentration above optimum/below action level
(red)	Concentration Above action level

Contaminant	Units	Optimum level	Action level	BH-1 at 21.4m	BH101 at 5.29m	BH104 at 2.0.m	BH107 at 2.02m	BH115 at 4.94m	BH116 at 6.33m
Arsenic	ug/l	10	60	<10	<10	<10	<10	<10	<10
Cadmium	ug/l	0.4	6	1.2	0.6	18.9	1.5	<0.50	0.7
Chromium (total)	ug/l	1	30	<10	<10	<10	<10	<10	<10
Lead	ug/l	15	75	<10	<10	<10	<10	<10	<10
Mercury	ug/l	0.05	0.3	<0.10	<0.10	<0.10	<0.10	0.1	0.3
Copper	ug/l	15	75	45	<10	<10	<10	<10	<10
Nickel	ug/l	15	75	36	24	270	69	14	<10
Zinc	ug/l	65	800	210	460	190000	2000	140	170
Phenols	ug/l	0.2	2000	<0.20	<0.10	<0.10	0.11	<0.10	<0.10
Cyanide	ug/l	5	1500	N/S	N/S	N/S	N/S	N/S	<0.01
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S	<0.03

Contaminant	Units	Optimum level	Action level	River D/S	River M/S	River U/S	Reservoir Water	TP105 at 2.60m	TP106 at 2.60m	WS201 at 4.15m
Arsenic	ug/l	10	60	<10	<10	<10	21	401	<10	<10
Cadmium	ug/l	0.4	6	0.6	<0.50	0.8	<5.0	5.1	5.4	<0.50
Chromium (total)	ug/l	1	30	<5.0	<5.0	<10	N/S	N/S	N/S	<10
Lead	ug/l	15	75	<10	18	<10	<10	790	32	<10
Mercury	ug/l	0.05	0.3	<0.10	<0.10	<0.10	4	N/S	N/S	<0.10
Copper	ug/l	15	75	<10	<10	<10	30	140	<10	<10
Nickel	ug/l	15	75	<10	<10	<10	29	52	45	<10
Zinc	ug/l	65	800	2	18	24	120	8800	160	11
Phenols	ug/l	0.2	2000	<0.10	<0.10	<0.10	<0.10	0.16	<0.10	N/S
Cyanide	ug/l	5	1500	N/S	N/S	N/S	0.02	N/S	<0.01	0.07
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	0.21	N/S	0.08	0.43

Appendix 2: Comparison of Soil Samples with Dutch Guidelines

	Concentration below optimum level
	Concentration above optimum/below action level
	Concentration above action level
N/S	No test scheduled

Contaminant	Units	Optimum	Action	Ash pile	Ash Pile	Ash Pile	BH104	BH104	BH104	BH106	BH107	BH107	BH108
		level	level	B1-B2	B1+B2	B1+B2	at 0.50m	at 1.50m	at 4.00m	at 3.00m	at 0.50m	at 1.55m	at 1.50m
Arsenic	mg/kg	29	55	66	57	68	<1.0	<1.0	51	4.7	40	14	1.2
Cadmium	mg/kg	0.8	12	<0.50	<0.50	<0.50	1.5	0.93	0.64	1.3	0.59	<0.50	0.69
Chromium (total)	mg/kg	100	380	15	13	21	22	25	30	40	24	37	23
Lead	mg/kg	85	530	110	110	110	250	150	94	78	1400	1200	170
Mercury	mg/kg	0.3	10	0.36	0.38	0.48	0.22	0.2	0.28	0.2	0.21	<0.10	0.23
Copper	mg/kg	36	190	81	100	87	670	320	67	38	93	42	130
Nickel	mg/kg	35	210	30	33	30	46	48	39	51	36	41	43
Zinc	mg/kg	140	720	73	77	80	4900	5800	2000	140	1200	510	120
Polyaromatic hydrocarbons	mg/kg	1	40	130	160	93	16	<10	N/S	<10	N/S	N/S	3600
Phenols	mg/kg	0.05	40	1.8	3.5	2	1.6	0.78	N/S	1.2	N/S	N/S	41
Cyanide	mg/kg	1	20	5.8	5.5	6.8	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum	Action	BH112	BH112	BH115	Reservoir	TP102	TP103	TP104	TP105
		Level	Level	at 1.50M	at 3.50m	at 4.50m	Sediment	at 0.50m	at 1.50m	at 0.00m	at 0.00m
Arsenic	mg/kg	29	55	<1.0	4.3	8.5	34	<1.0	13	48	<1.0
Cadmium	mg/kg	0.8	12	0.72	<0.50	0.54	29	4.6	0.53	<0.50	<0.50
Chromium (total)	mg/kg	100	380	12	12	12	72	13	15	13	9.7
Lead	mg/kg	85	530	130	40	300	7200	130	230	180	170
Mercury	mg/kg	0.3	10	0.17	0.16	0.22	0.75	0.18	0.27	0.51	0.16
Copper	mg/kg	36	190	85	61	37	690	39	72	69	51
Nickel	mg/kg	35	210	31	22	17	150	16	21	22	11
Zinc	mg/kg	140	720	91	120	430	53000	1800	290	65	2100
Polyaromatic hydrocarbons	mg/kg	1	40	300	N/S	200	15	330	<10	N/S	N/S
Phenols	mg/kg	0.05	40	4.6	3.5	2.1	20	3.3	1.6	1.8	0.53
Cyanide	mg/kg	1	20	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Appendix 2: Comparison of Soil Samples with Dutch Guidelines

Contaminant	Units	Optimum Level	Action Level	TP105 at 0.75m	TP105 at 2.00m	TP106 at 0.60m	TP106 at 2.50 m	TP107 at 0.50 m	TP107 at 1.50m	TP108 at 0.70m	TP108 at 1.00m
Arsenic	mg/kg	29	55	25	14	130	22	120	89	75	12
Cadmium	mg/kg	0.8	12	0.99	0.6	0.89	0.97	2.8	1.1	4.1	6.9
Chromium (total)	mg/kg	100	380	24	21	27	23	54	20	45	180
Lead	mg/kg	85	530	570	42	56	49	350	20	1500	100
Mercury	mg/kg	0.3	10	0.1	0.12	<0.10	0.14	0.22	0.3	0.2	0.21
Copper	mg/kg	36	190	3700	62	52	38	0.2	770	140	210
Nickel	mg/kg	35	210	40	40	53	28	25	16	52	120
Zinc	mg/kg	140	720	1700	1700	160	110	250	260	3100	2100
Polyaromatic hydrocarbons	mg/kg	1	40	<10	<10	<10	N/S	N/S	N/S	N/S	<10
Phenols	mg/kg	0.05	40	0.84	0.87	1.3	0.87	1.3	0.78	1.1	0.67
Cyanide	mg/kg	1	20	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum Level	Action Level	TP109 at 0.80m	TP110 at 0.00m	TP110 at 0.50 m	TP113 at 117/B	TP113A at 0.70m	TP113A at 2.00m	TP114 at 0.60m	TP114 at 1.40m
Arsenic	mg/kg	29	55	6500	6.3	2.2	34	71	22	39	4.8
Cadmium	mg/kg	0.8	12	1.4	<0.50	0.89	0.83	0.97	1.3	<0.50	1.5
Chromium (total)	mg/kg	100	380	21	15	25	20	13	31	20	16
Lead	mg/kg	85	530	32	200	55	1300	57	49	180	130
Mercury	mg/kg	0.3	10	0.83	<0.10	0.21	1.6	<0.10	<0.10	0.34	0.4
Copper	mg/kg	36	190	35	450	83	830	25	32	120	64
Nickel	mg/kg	35	210	37	15	49	36	12	50	25	30
Zinc	mg/kg	140	720	200	1000	230	870	55	130	160	120
Polyaromatic hydrocarbons	mg/kg	1	40	N/S	<10	N/S	600	N/S	<10	1500	N/S
Phenols	mg/kg	0.05	40	3	<0.50	2.9	7.9	1.4	1.7	13	2.2
Cyanide	mg/kg	1	20	N/S	25	12	N/S	N/S	N/S	N/S	N/S

Appendix 2: Comparison of Soil Samples with Dutch Guidelines

Contaminant	Units	Optimum Level	Action Level	TP115A at0.15m	TP115A at 1.10m	TP115A at 2.10m	TP116 at 0.60m	TP116 at 1.20m	TP117 at 0.50m	TP117 at 0.80m	TP117 at 3.00m	TP118 at 0.50m
Arsenic	mg/kg	29	55	15	76	15	39	1.2	15	55	<1.0	48
Cadmium	mg/kg	0.8	12	<0.50	<0.50	<0.50	0.51	1	<0.50	0.57	1.3	1.5
Chromium (total)	mg/kg	100	380	29	17	27	18	27	15	56	32	21
Lead	mg/kg	85	530	100	150	45	210	2000	1800	76	410	430
Mercury	mg/kg	0.3	10	0.2	0.29	<0.10	0.17	0.75	0.21	0.22	0.14	0.45
Copper	mg/kg	36	190	39	130	86	74	240	73	85	64	360
Nickel	mg/kg	35	210	30	45	49	24	30	16	61	64	49
Zinc	mg/kg	140	720	210	210	100	130	440	1300	190	340	790
Polyaromatic hydrocarbons	mg/kg	1	40	140	62	N/S	750	2500	27	N/S	N/S	210
Phenols	mg/kg	0.05	40	2.8	1.5	1.7	4.5	11	3.6	0.74	0.97	5.3
Cyanide	mg/kg	1	20	N/S	1.3	N/S	N/S	4.1	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum Level	Action Level	TP118 at 2.00m	TP118 at 2.60m	TP120 at 1.20m	TP122 at 0.70m	TP123 at 0.50m	TP201 at 1.00m	TP201 at 2.90m	TP202 at 0.50m	TP202 at 1.90m
Arsenic	mg/kg	29	55	36	<1.0	<1.0	2.9	190	250	24	5.2	5.3
Cadmium	mg/kg	0.8	12	1.1	<0.50	<0.50	0.57	3	1.2	<0.50	<0.50	<0.50
Chromium (total)	mg/kg	100	380	21	14	15	41	45	17	18	28	29
Lead	mg/kg	85	530	75	300	660	220	200	1600	63	32	18
Mercury	mg/kg	0.3	10	0.37	0.16	0.44	0.47	0.31	<0.10	<0.10	<0.10	<0.10
Copper	mg/kg	36	190	190	280	150	140	960	20000	130	66	31
Nickel	mg/kg	35	210	110	15	16	29	38	120	36	55	45
Zinc	mg/kg	140	720	280	580	220	450	1500	1800	84	160	74
Polyaromatic hydrocarbons	mg/kg	1	40	18	N/S	N/S	N/S	38	85	N/S	N/S	N/S
Phenols	mg/kg	0.05	40	1.9	2.3	1.9	3.2	1.1	4.6	1.1	1.4	0.85
Cyanide	mg/kg	1	20	47	N/S	N/S	N/S	13	N/S	N/S	N/S	N/S

Appendix 2: Comparison of Soil Samples with Dutch Guidelines

Contaminant	Units	Optimum Level	Action Level	WS101 at 0.70m	WS102 at 0.00m	WS201 at1.00m	WS202 at 0.00m	WS203 at 0.00m	WS204 at 0.00m	WS205 at 1.50m	WS205 at 5.00m	WS206 at 2.50m	WS207 at 2.00m
Arsenic	mg/kg	29	55	38	80	37	62	95	<1.0	55	80	67	100
Cadmium	mg/kg	0.8	12	<0.50	0.82	<0.50	0.53	<0.50	0.63	<0.50	0.91	<0.50	<0.50
Chromium (total)	mg/kg	100	380	12	17	15	N/S	2.5	N/S	N/S	N/S	11	32
Lead	mg/kg	85	530	36	190	100	560	960	38	190	230	29	110
Mercury	mg/kg	0.3	10	0.18	9.3	<0.10	0.38	0.3	<0.10	0.14	0.87	<0.10	0.22
Copper	mg/kg	36	190	12	120	45	470	1400	53	93	180	83	190
Nickel	mg/kg	35	210	0.18	32	27	64	390	<0.10	0.14	0.87	27	45
Zinc	mg/kg	140	720	38	130	70	210	270	120	68	470	25	82
Polyaromatic hydrocarbons	mg/kg	1	40	37	14	N/S	<10	22	<10	170	N/S	88	440
Phenols	mg/kg	0.05	40	2.6	4.4	1.4	2.7	1.5	1.5	3.1	3	2.8	1.7
Cyanide	mg/kg	1	20	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum Level	Action Level	WS207 at 5.50m	WS208 at 2.00m	WS208 at 5.30m	WS208 at 7.35m	WS209 At 0.00m	WS210 at 2.00m	WS210 at 4.00m
Arsenic	mg/kg	29	55	120	54	87	83	38	36	55
Cadmium	mg/kg	0.8	12	0.78	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Chromium (total)	mg/kg	100	380	19	9.1	N/S	N/S	N/S	N/S	N/S
Lead	mg/kg	85	530	150	130	240	190	250	36	180
Mercury	mg/kg	0.3	10	0.1	0.74	0.91	0.96	0.5	0.12	0.25
Copper	mg/kg	36	190	190	110	190	150	110	39	110
Nickel	mg/kg	35	210	44	26	47	42	29	13	36
Zinc	mg/kg	140	720	300	42	86	64	190	22	140
Polyaromatic hydrocarbons	mg/kg	1	40	24	340	170	150	51	<10	91
Phenols	mg/kg	0.05	40	2	4	2.9	2.7	2.4	1.5	3.8
Cyanide	mg/kg	1	20	N/S	N/S	N/S	8.3	N/S	N/S	N/S

Appendix 2: Comparisons of Leachate Tests with the Dutch Guidelines

(green)	Concentrations above optimum level
(yellow)	Concentrations above optimum/below action level
(red)	Concentrations above action level
N/S	No tests scheduled

Contaminant	Units	Optimum level	Action level	BH104 at 4.00m	BH107 at 0.50m	BH107 at 1.55m	BH112 at 1.50m	BH112 at 3.50m
Arsenic	ug/l	10	60	<10	<10	<10	<10	<10
Cadmium	ug/l	0.4	6	<0.50	<0.50	<0.50	N/S	N/S
Chromium (total)	ug/l	1	30	<10	<10	<10	37	<10
Lead	ug/l	15	75	<10	<10	<10	26	<10
Mercury	ug/l	0.05	0.3	<0.10	<0.10	<0.10	N/S	<1.0
Copper	ug/l	15	75	<10	<10	<10	18	14
Nickel	ug/l	15	75	12	<10	<10	25	<10
Zinc	ug/l	65	800	4600	31	21	27	<10
Phenols	ug/l	0.2	2000	N/S	N/S	N/S	N/S	N/S
Cyanide (total)	ug/l	5	1500	N/S	N/S	N/S	<0.01	0.03
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum level	Action level	Reservoir Sediment	TP103 at 0.00m	TP105 at 0.00m	TP105 at 0.75m	TP106 at 0.00m
Arsenic	ug/l	10	60	<10	<10	I/S	<10	<10
Cadmium	ug/l	0.4	6	N/S	N/S	N/S	N/S	N/S
Chromium (total)	ug/l	1	30	<10	<5.0	I/S	<5.0	38
Lead	ug/l	15	75	<10	35	I/S	37	11
Mercury	ug/l	0.05	0.3	N/S	N/S	N/S	N/S	N/S
Copper	ug/l	15	75	<10	<10	I/S	<10	<10
Nickel	ug/l	15	75	<10	<10	I/S	<10	<10
Zinc	ug/l	65	800	<10	<10	I/S	330	<10
Phenols	ug/l	0.2	2000	N/S	N/S	N/S	N/S	N/S
Cyanide (total)	ug/l	5	1500	0.02	N/S	I/S	0.02	<0.01
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Appendix 2: Comparisons of Leachate Tests with the Dutch Guidelines

Contaminant	Units	Optimum level	Action level	TP106 at 0.60m	TP107 at 0.50m	TP110 at 0.00m	TP113A at 0.70m	TP114 at 0.60m
Arsenic	ug/l	10	60	27	<10	27	22	<10
Cadmium	ug/l	0.4	6	N/S	N/S	N/S	N/S	<5.0
Chromium (total)	ug/l	1	30	49	38	55	<10	<10
Lead	ug/l	15	75	83	56	56	<10	31
Mercury	ug/l	0.05	0.3	N/S	N/S	N/S	<1.0	N/S
Copper	ug/l	15	75	45	990	140	<10	31
Nickel	ug/l	15	75	12	27	28	<10	<10
Zinc	ug/l	65	800	35	1700	<10	<10	<10
Phenols	ug/l	0.2	2000	N/S	N/S	N/S	N/S	N/S
Cyanide (total)	ug/l	5	1500	0.02	<0.01	0.37	0.29	0.02
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum level	Action level	TP115 at 0.00m	TP115A at 0.15m	TP116 at 0.60m	TP117 at 0.50m	TP118 at 0.50m
Arsenic	ug/l	10	60	<10	<10	<10	<10	<10
Cadmium	ug/l	0.4	6	N/S	<5.0	<5.0	<5.0	<5.0
Chromium (total)	ug/l	1	30	40	<10	13	<10	<10
Lead	ug/l	15	75	33	<10	<10	<10	<10
Mercury	ug/l	0.05	0.3	N/S	N/S	N/S	<1.0	<1.0
Copper	ug/l	15	75	<10	<10	29	<10	<10
Nickel	ug/l	15	75	<10	<10	<10	<10	<10
Zinc	ug/l	65	800	<10	<10	23	59	11
Phenols	ug/l	0.2	2000	N/S	N/S	N/S	N/S	N/S
Cyanide (total)	ug/l	5	1500	<0.01	0.15	0.04	<0.01	0.07
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Appendix 2: Comparisons of Leachate Tests with the Dutch Guidelines

Contaminant	Units	Optimum level	Action level	TP201 at 1.00m	TP201 at 2.90m	TP202 at 0.50m	TP202 at1.90m	WS101 at1.00m
Arsenic	ug/l	10	60	140	<10	<10	<10	<10
Cadmium	ug/l	0.4	6	<0.50	<0.50	<0.50	<0.50	<0.50
Chromium (total)	ug/l	1	30	23	12	<10	<10	<10
Lead	ug/l	15	75	32	<10	<10	<10	<10
Mercury	ug/l	0.05	0.3	<0.10	2	<0.10	<0.10	<0.10
Copper	ug/l	15	75	17000	140	2000	<10	<10
Nickel	ug/l	15	75	28	<10	<10	<10	<10
Zinc	ug/l	65	800	68	<10	13	<10	10
Phenols	ug/l	0.2	2000	15	11	<0.50	<0.50	0.12
Cyanide (total)	ug/l	5	1500	0.06	<0.01	0.02	<0.01	0.03
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum level	Action level	WS102 at 0.00m	WS201 at 1.00m	WS202 at 0.00m	WS203 at 0.00m	WS204 at 0.00m
Arsenic	ug/l	10	60	<10	17	<10	<10	<10
Cadmium	ug/l	0.4	6	<5.0	<0.50	<0.50	<0.50	0.5
Chromium (total)	ug/l	1	30	<10	<10	22	22	<10
Lead	ug/l	15	75	<10	<10	14	14	29
Mercury	ug/l	0.05	0.3	<0.10	<0.10	<0.10	<0.10	<0.10
Copper	ug/l	15	75	<10	<10	30	30	<10
Nickel	ug/l	15	75	<10	<10	11	11	<10
Zinc	ug/l	65	800	10	<10	43	43	<10
Phenols	ug/l	0.2	2000	N/S	2.7	0.54	0.54	<0.50
Cyanide (total)	ug/l	5	1500	0.03	0.02	0.04	0.04	0.04
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Appendix 2: Comparisons of Leachate Tests with the Dutch Guidelines

Contaminant	Units	Optimum level	Action level	WS205 at 1.50m	WS205 at 5.00m	WS206 at 2.50m	WS207 at 2.00m	WS207 at 5.50m
Arsenic	ug/l	10	60	<10	<10	<10	<10	40
Cadmium	ug/l	0.4	6	1.1	1.9	<0.50	<0.50	<0.50
Chromium (total)	ug/l	1	30	15	10	<10	<10	<10
Lead	ug/l	15	75	<10	<10	<10	<10	<10
Mercury	ug/l	0.05	0.3	<0.10	0.5	<0.10	<0.10	<0.10
Copper	ug/l	15	75	<10	<10	46	<10	24
Nickel	ug/l	15	75	52	160	140	<10	<10
Zinc	ug/l	65	800	360	430	77	29	25
Phenols	ug/l	0.2	2000	<0.50	<0.50	<0.50	<0.50	<0.50
Cyanide (total)	ug/l	5	1500	0.04	<0.01	0.02	<0.01	0.02
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S

Contaminant	Units	Optimum level	Action level	WS208A at 2.00m	WS208A at 5.30m	WS208A at 7.35m	WS209 at 0.00m	WS210 at 2.00m	WS210 at 4.00m
Arsenic	ug/l	10	60	<10	<10	<10	<10	<10	<10
Cadmium	ug/l	0.4	6	1.2	0.5	1.4	<0.50	<0.50	<0.50
Chromium (total)	ug/l	1	30	<10	22	21	25	29	17
Lead	ug/l	15	75	27	35	<10	<10	<10	<10
Mercury	ug/l	0.05	0.3	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Copper	ug/l	15	75	95	130	140	<10	<10	<10
Nickel	ug/l	15	75	180	170	220	<10	<10	<10
Zinc	ug/l	65	800	380	210	330	<10	<10	<10
Phenols	ug/l	0.2	2000	0.91	<0.50	<0.50	<0.50	<0.50	<0.50
Cyanide (total)	ug/l	5	1500	<0.01	0.05	0.03	0.06	0.05	0.03
Thiocyanate	ug/l	20	1500	N/S	N/S	N/S	N/S	N/S	N/S

APPENDIX 3: COMPARISONS OF THE GAS SAMPLES WITH THE DOE GUIDELINES

GASES ANALYSIS

*	less than detection level

(green)	Below action level
(red)	Above action level

Action levels
Oxygen <18%
Carbon dioxide >1.5%
Methane 1%v/v
20% LEL
Hydrogen Sulphide 10ppm

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	Methane LEL%	Hydrogen sulphide	Flow
			Detection limit	0.1 %	0.1 %	0.1 %	2.0 %	1.0ppm	*
BH 104	27.01.00	TOP VALVE		19.6	0.4	0.2	4.0	*	0
		BOTTOM VALVE		18.5	1.1	0.2	4.0	*	0
		1 min		19.6	0.4	0.2	4.0	*	*
		2 min		19.4	0.5	0.2	4.0	*	*
		3 mins		19.2	0.5	0.2	4.0	*	*
		4 mins		19.1	0.5	0.2	4.0	*	*
		5 mins		19.1	0.6	0.2	4.0	*	*
		6 mins		18.9	0.7	0.2	4.0	*	*
		7 mins		18.8	0.7	0.2	4.0	*	*
		8 mins		18.9	0.7	0.2	4.0	*	*
		9 mins		18.8	0.7	0.3	6.0	*	*
		10 mins		18.8	0.7	0.2	4.0	*	*
		11 mins							
		12 mins							
		13 mins							
		14 mins							
		15 mins							

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 107	27.01.00	TOP		19.9	0.5	<0.1	<2.0	*	0
		VALVE							
		BOTTOM		18.8	1.2	<0.1	<2.0	*	0
		VALVE							
		1 min		19.7	0.8	<0.1	*	*	*
		2 min		19.1	1.1	<0.1	*	*	*
		3 mins		19.1	1.1	<0.1	*	*	*
		4 mins		19.3	1	<0.1	*	*	*
		5 mins		19.3	1	<0.1	*	*	*
		6 mins		19.1	1.1	<0.1	*	*	*
		7 mins		19.1	1.1	<0.1	*	*	*
		8 mins		19.1	1.1	<0.1	*	*	*
		9 mins		19.1	1.1	<0.1	*	*	*
		10 mins		19.1	1.1	<0.1	*	*	*
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 108	27.01.00	TOP		20.1	<0.1	<0.1	<2.0	*	0
		VALVE							
		BOTTOM		13.3	5	<0.1	<2.0	*	0
		VALVE							
		1 min		11.10	4.80	<0.1	<2.0	*	0
		2 min		11.50	4.50	<0.1	<2.0	*	0
		3 mins		12.00	4.30	<0.1	<2.0	*	0
		4 mins		12.40	4.10	<0.1	<2.0	*	0
		5 mins		12.70	4.00	<0.1	<2.0	*	0
		6 mins		13.00	3.80	<0.1	<2.0	*	0
		7 mins		13.30	3.70	<0.1	<2.0	*	0
		8 mins		13.70	3.50	<0.1	<2.0	*	0
		9 mins		14.00	3.40	<0.1	<2.0	*	0
		10 mins		14.30	3.30	<0.1	<2.0	*	0
		11 mins		14.90	3.10	<0.1	<2.0	*	0
		12 mins		14.90	3.00	<0.1	<2.0	*	0
		13 mins		15.10	2.90	<0.1	<2.0	*	0
		14 mins		15.40	2.80	<0.1	<2.0	*	0
		15 mins		15.6	2.80	<0.1	<2.0	*	0

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 115	27.01.00	TOP		17.3	0.4	<0.1	<2.0	*	0
		VALVE							
		BOTTOM		19.3	0.7	<0.1	<2.0	*	0
		VALVE							
		1 min		17.3	0.4	<0.1	<2.0	*	0
		2 min		17.5	0.4	<0.1	<2.0	*	0
		3 mins		18	0.5	<0.1	<2.0	*	0
		4 mins		18.3	0.5	<0.1	<2.0	*	0
		5 mins		18.5	0.5	<0.1	<2.0	*	0
		6 mins		18.9	0.5	<0.1	<2.0	*	0
		7 mins		18.9	0.6	<0.1	<2.0	*	0
		8 mins		18.8	0.6	<0.1	<2.0	*	0
		9 mins		19.1	0.6	<0.1	<2.0	*	0
		10 mins		19.3	0.7	<0.1	<2.0	*	0
		11 mins		19.4	0.7	<0.1	<2.0	*	0
		12 mins		19.4	0.7	<0.1	<2.0	*	0
		13 mins		19.4	0.7	<0.1	<2.0	*	0
		14 mins		19.3	0.7	<0.1	<2.0	*	0
		15 mins		19.3	0.7	<0.1	<2.0	*	0

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 116	27.01.00	TOP		20	0.2	<0.1	<2.0	*	0
		VALVE							
		BOTTOM		20	0.1	<0.1	<2.0	*	0
		VALVE							
		1 min		20.2	0.2	<0.1	<2.0	*	0
		2 min		20.2	0.2	<0.1	<2.0	*	0
		3 mins		20.1	0.2	<0.1	<2.0	*	0
		4 mins		20.1	0.2	<0.1	<2.0	*	0
		5 mins		20.3	0.2	<0.1	<2.0	*	0
		6 mins		20.2	0.2	<0.1	<2.0	*	0
		7 mins		20.2	0.1	<0.1	<2.0	*	0
		8 mins		N/S	N/S	N/S	N/S	N/S	N/S
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 104	16.02.00	TOP		19.6	0.3	<0.1	<2.0	<0.1	<0.1
		VALVE							<0.1
		BOTTOM		17.2	1.7	<0.1	<2.0	<0.1	
		VALVE							
		1 min		19.4	0.4	<0.1	<2.0	*	*
		2 min		19.3	0.4	<0.1	<2.0	*	*
		3 mins		19.1	0.5	<0.1	<2.0	*	*
		4 mins		19	0.5	<0.1	<2.0	*	*
		5 mins		18.8	0.5	<0.1	<2.0	*	*
		6 mins		18.8	0.6	<0.1	<2.0	*	*
		7 mins		18.7	0.7	<0.1	<2.0	*	*
		8 mins		18.7	0.7	<0.1	<2.0	*	*
		9 mins		18.7	0.7	<0.1	<2.0	*	*
		10 mins		18.6	0.7	<0.1	<2.0	*	*
		11 mins		18.5	0.8	<0.1	<2.0	*	*
		12 mins		18.5	0.8	<0.1	<2.0	*	*
		13 mins		18.4	0.9	<0.1	<2.0	*	*
		14 mins		18.2	0.9	<0.1	<2.0	*	*
		15 mins		18.2	0.9	<0.1	<2.0	*	*

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 108	16.02.00	TOP		20.3	<0.1	0.2	4.0	<0.1	<0.1
		VALVE							
		BOTTOM		7.2	5.7	0.2	4.0	<0.1	<0.1
		VALVE							
		1 min		20.3	<0.1	0.2	4.0	N/S	N/S
		2 min		20.3	<0.1	0.2	4.0	N/S	N/S
		3 mins		20.1	<0.1	0.1	2.0	N/S	N/S
		4 mins		20.1	<0.1	0.1	2.0	N/S	N/S
		5 mins		20.1	<0.1	0.1	2.0	N/S	N/S
		6 mins		20.0	<0.1	0.1	2.0	N/S	N/S
		7 mins		20.0	<0.1	0.2	4.0	N/S	N/S
		8 mins		20.0	<0.1	0.2	4.0	N/S	N/S
		9 mins		20.0	<0.1	0.2	4.0	N/S	N/S
		10 mins		19.9	<0.1	0.1	2.0	N/S	N/S
		11 mins		19.9	<0.1	0.2	4.0	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 116	16.02.00	TOP		20.3	0.1	<0.1	<2.0	<0.1	<0.1
		VALVE							
		BOTTOM		20.3	0.1	<0.1	<2.0	<0.1	<0.1
		VALVE							
		1 min		20.4	0.1	<0.1	<2.0	*	*
		2 min		20.3	0.1	<0.1	<2.0	*	*
		3 mins		20.4	0.1	<0.1	<2.0	*	*
		4 mins		20.4	0.1	<0.1	<2.0	*	*
		5 mins		20.4	0.1	<0.1	<2.0	*	*
		6 mins		20.4	0.1	<0.1	<2.0	*	*
		7 mins		N/S	N/S	N/S	N/S	N/S	N/S
		8 mins		N/S	N/S	N/S	N/S	N/S	N/S
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 104	09.03.00	TOP		20.7	<0.1	<1.0	<2.0	<2.0	<0.1
		VALVE							
		BOTTOM		19.8	0.7	<0.1	<2.0	<2.0	<1.0
		VALVE							
		1 min		20.7	<0.1	<0.1	<2.0	*	*
		2 min		20.7	<0.1	<0.1	<2.0	*	*
		3 mins		20.7	<0.1	<0.1	<2.0	*	*
		4 mins		20.7	<0.1	<0.1	<2.0	*	*
		5 mins		20.7	<0.1	<0.1	<2.0	*	*
		6 mins		20.7	<0.1	<0.1	<2.0	*	*
		7 mins		20.7	<0.1	<0.1	<2.0	*	*
		8 mins		20.7	<0.1	<0.1	<2.0	*	*
		9 mins		20.7	<0.1	<0.1	<2.0	*	*
		10 mins		20.7	<0.1	<0.1	<2.0	*	*
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection limit	0.1 %	0.1 %	0.1 %	2.0 %	1.0ppm	None
BH 104	09.03.00	TOP VALVE		20	1.1	<0.1	<2.0	<1.0	
		BOTTOM VALVE		18.7	3	<0.1	<2.0	<1.0	
		1 min		20	0.9	<0.1	<2.0	*	*
		2 min		20	1.2	<0.1	<2.0	*	*
		3 mins		19.6	1.6	<0.1	<2.0	*	*
		4 mins		19.6	1.5	<0.1	<2.0	*	*
		5 mins		19.6	1.2	<0.1	<2.0	*	*
		6 mins		19.7	1.2	<0.1	<2.0	*	*
		7 mins		19.9	1.2	<0.1	<2.0	*	*
		8 mins		19.9	1.1	<0.1	<2.0	*	*
		9 mins		19.9	1.1	<0.1	<2.0	*	*
		10 mins		19.9	1.1	<0.1	<2.0	*	*
		11 mins		19.9	1.1	<0.1	<2.0	*	*
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection limit	0.1 %	0.1 %	0.1 %	2.0 %	1.0ppm	None
BH 108	09.03.00	TOP VALVE		20.6	<0.1	<1.0	<2.0	<1.0	<0.1
		BOTTOM VALVE		15.8	2.7	<0.1	<2.0	<1.0	<0.1
		1 min		20.7	<0.1	<0.1	<2.0	*	*
		2 min		20.7	<0.1	<0.1	<2.0	*	*
		3 mins		20.7	<0.1	<0.1	<2.0	*	*
		4 mins		20.7	<0.1	<0.1	<2.0	*	*
		5 mins		20.7	<0.1	<0.1	<2.0	*	*
		6 mins		20.7	<0.1	<0.1	<2.0	*	*
		7 mins		20.7	<0.1	<0.1	<2.0	*	*
		8 mins		20.7	<0.1	<0.1	<2.0	*	*
		9 mins		20.7	<0.1	<0.1	<2.0	*	*
		10 mins		20.7	<0.1	<0.1	<2.0	*	*
		11 mins		20.7	<0.1	<0.1	<2.0	*	*
		12 mins		20.7	<0.1	<0.1	<2.0	*	*
		13 mins		20.7	<0.1	<0.1	<2.0	*	*
		14 mins		20.7	<0.1	<0.1	<2.0	*	*
		15 mins		20.7	<0.1	<0.1	<2.0	*	*

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 115	09.03.00	TOP		20.6	<0.1	<1.0	<2.0	<1.0	<0.1
		VALVE							
		BOTTOM		20.5	0.2	<0.1	<2.0	<1.0	<1.0
		VALVE							
		1 min		20.3	<0.1	<0.1	<2.0	*	*
		2 min		20.2	<0.1	<0.1	<2.0	*	*
		3 mins		20.1	<0.1	<0.1	<2.0	*	*
		4 mins		20.0	<0.1	<0.1	<2.0	*	*
		5 mins		20.0	<0.1	<0.1	<2.0	*	*
		6 mins		20.0	<0.1	<0.1	<2.0	*	*
		7 mins		20.0	<0.1	<0.1	<2.0	*	*
		8 mins		20.0	<0.1	<0.1	<2.0	*	*
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 116	09.03.00	TOP		20.5	0.1	<1.0	<2.0	<1.0	<0.1
		VALVE							
		BOTTOM		20.5	0.1	<0.1	<2.0	<1.0	<1.0
		VALVE							
		1 min		20.6	0.1	<0.1	<2.0	*	*
		2 min		20.6	0.1	<0.1	<2.0	*	*
		3 mins		20.6	0.1	<0.1	<2.0	*	*
		4 mins		20.6	0.1	<0.1	<2.0	*	*
		5 mins		20.5	0.1	<0.1	<2.0	*	*
		6 mins		20.5	0.1	<0.1	<2.0	*	*
		7 mins		20.5	0.1	<0.1	<2.0	*	*
		8 mins		20.5	0.1	<0.1	<2.0	*	*
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 104	21.03.00	TOP		20.2	<0.1	<0.1	<1.0	<0.1	<0.1
		VALVE							
		BOTTOM		17.4	1.8	<0.1	<1.0	<0.1	<0.1
		VALVE							
		1 min		19.9	0.1	<0.1	<1.0	*	*
		2 min		19.9	0.1	<0.1	<1.0	*	*
		3 mins		19.8	0.2	<0.1	<1.0	*	*
		4 mins		19.7	0.3	<0.1	<1.0	*	*
		5 mins		19.5	0.3	<0.1	<1.0	*	*
		6 mins		19.4	0.4	<0.1	<1.0	*	*
		7 mins		19.5	0.4	<0.1	<1.0	*	*
		8 mins		19.2	0.5	<0.1	<1.0	*	*
		9 mins		19	0.6	<0.1	<1.0	*	*
		10 mins		18.7	0.7	<0.1	<1.0	*	*
		11 mins		18.9	0.8	<0.1	<1.0	*	*
		12 mins		18.7	0.8	<0.1	<1.0	*	*
		13 mins		18.6	0.9	<0.1	<1.0	*	*
		14 mins		18.4	1	<0.1	<1.0	*	*
		15 mins		18.2	1.1	<0.1	<1.0	*	*

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 107	21.03.00	TOP		19.9	0.4	<0.1	<1.0	<0.1	<0.1
		VALVE							
		BOTTOM		18.6	2.9	<0.1	<1.0	<0.1	<0.1
		VALVE							
		1 min		19.5	1.1	<0.1	<1.0	*	*
		2 min		18.7	2.2	<0.1	<1.0	*	*
		3 mins		18.7	2.2	<0.1	<1.0	*	*
		4 mins		18.9	2	<0.1	<1.0	*	*
		5 mins		19	2	<0.1	<1.0	*	*
		6 mins		18.9	2.1	<0.1	<1.0	*	*
		7 mins		18.7	2.2	<0.1	<1.0	*	*
		8 mins		18.7	2.2	<0.1	<1.0	*	*
		9 mins		18.8	2.1	<0.1	<1.0	*	*
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 108	21.03.00	TOP		20.1	<0.1	<0.1	<1.0	<0.1	<0.1
		VALVE							
		BOTTOM		9.3	4.6	<0.1	<1.0	<0.1	<0.1
		VALVE							
		1 min		20.2	<0.1	<0.1	<1.0	*	*
		2 min		20.1	<0.1	<0.1	<1.0	*	*
		3 mins		20.1	<0.1	<0.1	<1.0	*	*
		4 mins		20.1	<0.1	<0.1	<1.0	*	*
		5 mins		20	<0.1	<0.1	<1.0	*	*
		6 mins		20	<0.1	<0.1	<1.0	*	*
		7 mins		19.8	<0.1	<0.1	<1.0	*	*
		8 mins		20	<0.1	<0.1	<1.0	*	*
		9 mins		20	<0.1	<0.1	<1.0	*	*
		10 mins		19.9	<0.1	<0.1	<1.0	*	*
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring	Date	Time of		Oxygen	Carbon	Methane		Hydrogen	Flow
point	tested	reading		%	Dioxide %	v/v%	LEL%	sulphide	
			Detection	0.1	0.1	0.1	2.0	1.0ppm	None
			limit	%	%	%	%		
BH 115	21.03.00	TOP		19.9	<0.1	<0.1	<1.0	<0.1	<0.1
		VALVE							
		BOTTOM		19.1	0.7	<0.1	<1.0	<01	<0.1
		VALVE							
		1 min		19.7	<0.1	0.1	2.0	*	*
		2 min		19.6	0.1	0.4	8.0	*	*
		3 mins		N/S	N/S	N/S	N/S	N/S	N/S
		4 mins		N/S	N/S	N/S	N/S	N/S	N/S
		5 mins		N/S	N/S	N/S	N/S	N/S	N/S
		6 mins		N/S	N/S	N/S	N/S	N/S	N/S
		7 mins		N/S	N/S	N/S	N/S	N/S	N/S
		8 mins		N/S	N/S	N/S	N/S	N/S	N/S
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

Monitoring point	Date tested	Time of reading		Oxygen %	Carbon Dioxide %	Methane v/v%	LEL%	Hydrogen sulphide	Flow
			Detection limit	0.1 %	0.1 %	0.1 %	2.0 %	1.0ppm	None
BH 115	21.03.00	TOP VALVE		19.9	<0.1	<0.1	<1.0	<0.1	<0.1
		BOTTOM VALVE		19.9	0.1	<0.1	<1.0	<0.1	<0.1
		1 min		20	<0.1	<0.1	<1.0	*	*
		2 min		19.9	<0.1	<0.1	<1.0	*	*
		3 mins		20	0.1	<0.1	<1.0	*	*
		4 mins		20	0.1	<0.1	<1.0	*	*
		5 mins		19.9	0.1	<0.1	<1.0	*	*
		6 mins		20	0.1	<0.1	<1.0	*	*
		7 mins		19.9	0.1	<0.1	<1.0	*	*
		8 mins		N/S	N/S	N/S	N/S	N/S	N/S
		9 mins		N/S	N/S	N/S	N/S	N/S	N/S
		10 mins		N/S	N/S	N/S	N/S	N/S	N/S
		11 mins		N/S	N/S	N/S	N/S	N/S	N/S
		12 mins		N/S	N/S	N/S	N/S	N/S	N/S
		13 mins		N/S	N/S	N/S	N/S	N/S	N/S
		14 mins		N/S	N/S	N/S	N/S	N/S	N/S
		15 mins		N/S	N/S	N/S	N/S	N/S	N/S

APPENDIX 4: INTAKE EQUATION

APPENDIX 4: INTAKE EQUATION

Equation: Intake (mg/kg/day) = (CS % IR % CF % FI % EF % ED) / (BW % AT)

CS = Concentration of chemical in soil (mg/kg)

IR = Ingestion rate (mg soil/day) = 100

CF = Conversion factor = 10^{-6}

FI = Fraction ingested from source (unitless) = 1

EF = Exposure frequency (days/year) = 365

ED = Exposure duration (years) = 30

BW = Body weight (kg) = 25

AT = Averaging time (period over which exposure is averaged)

Assumptions

CS: Maximum concentration (worst case scenario)

IR: Based on age groups >six years old (US data)

CF: 10^{-6} (mg/kg)

FI: Conservative assumption

EF: Maximum exposure (worst case scenario)

ED: National (US) upper bound time at one residence

BW: based on age groups between 6 and 9 years old (US data)

AT: Obtained by multiplying Exposure Duration (ED) % Exposure Frequency (EF)