CHAPTER 4

Geochemical Assessment

4.1 Introduction

A detailed review of the geochemistry of each mine site studied for the HMS-IRC project is contained in each site report. This section summarises the findings of the detailed geochemical assessment contained in Appendix 3. It summarises the main findings in respect of measured parameters and considers those findings in the context of human, animal or environmental impacts that may arise as a consequence of exposure to these parameters.

Table 4.1 provides a full listing of all parameters measured for the project, according to sample type. Not all parameters measured are discussed in this assessment, which focuses on those that are included in the HMS-IRC scoring system.

4.2 Standards

In assessing the environmental impact of mine waste, reference is made to national and European standards or guidelines where appropriate. In addition reference was also made to standards from the following countries, Canada, Holland, the UK and the USA. Standards define maximum permitted levels of various parameters in specified media. Guidelines on the other hand provide maximum levels above which adverse affects may be expected. Where there are no national or European standards then guidelines or standards from the most relevant international sources were used.

4.2.1 Soils

As yet there are no uniform European standards for soil. Various guidelines have been developed over the years including the Dutch Intervention values for 'standard' soil (Table 4.2) and the UK's Inter-Departmental Committee on the Redevelopment of Contaminated Land (ICRCL) threshold values. The latter were superseded in the 1990s by the soil guideline values (SGVs) produced by the UK's Department of Environment, Food and Rural Affairs (DEFRA). These in turn have been withdrawn pending new values that reflect an updated methodology. The SGVs are based on modelled exposure of humans in occupational and non-occupational settings to the relevant element. They can be viewed as trigger values above which there may be cause for concern for human health that warrants further assessment. Because they

are exposure or dose related, the SGVs differ for different soil categories or land uses. SGVs are similar in concept to the comparison values (CVs) defined by the US Agency for Toxic Substances and Disease Registry (ATSDR). These are also reproduced in Table 4.2.

Parameter	Solid Waste/Stream Sediment Analyses	Water Analyses	Leachate Analyses
Temperature		✓	✓
pH		✓	✓
EC		✓	✓
DO		✓	
Alkalinity/Acidity		✓	✓
BOD/COD		✓	
TDS/TSS		✓	
Al		✓	✓
As	✓	✓	✓
Ba	✓	✓	✓
Bi*	✓		
Ca*	✓	✓	✓
Cd	✓	✓	✓
Co**	✓	✓	✓
Cr	✓	✓	✓
Cu	✓	✓	✓
Fe	✓	✓	✓
Hg	✓	✓	✓
K*	✓	✓	✓
Mg		✓	✓
Mn	✓	✓	✓
Mo		✓	✓
Na*		✓	✓
Ni	✓	✓	✓
P/PO_4*	✓	✓	
Pb	✓	✓	✓
Rb*	✓		
S/SO_4	✓	✓	
Sb	✓	✓	✓
Se	✓	✓	✓
Sn*	✓	✓	✓
Sr*	✓		
Th	✓		
Tl**	✓		
U	✓	✓	✓
V	✓	✓	✓
W*	✓		
Zn	✓	✓	✓

* No relative toxicity value, not included in HMS-IRC scoring system.

** XRF analysis unreliable, not included in HMS-IRC scoring system.

Table 4.1 Parameters analysed for the HMS-IRC project, various media.

4.2.2 Water

Water standards are available for drinking water (European Communities Drinking Water Standards, SI 278, 2007) and surface water (Draft European Communities

Environmental Objectives (Surface Waters) Regulations, 2008). Neither of these standards includes all parameters of interest but in combination they cover the main ones. Table 4.3 summarises the standard data used in the HMS-IRC scoring system.

In the HMS-IRC project, water standards are used to determine if any parameter in groundwater or surface water downstream of a mine waste source exceeds the standard. This information is incorporated into the HMS-IRC scoring system and it is also used in the context of individual site descriptions to identify watercourses at risk of mine-related contamination.

	Dutch		SGV		ATSDR	
Parameter mg/kg	**Target Value**	**Intervention Value**	**Residential /Allotments**	**Industrial**	**Child**	**Adult**
As	29	55	20	500	20	200
Ba	200	625			4,000	50,000
Cd	0.8	12	1–8	1,400	10	100
Cr VI			130	5,000	200	2,000
Cr	100	380				
Cu	36	190			2,000	20,000
Hg	0.3	10	8	480		
Mn					3,000	40,000
Mo	10	200			300	4,000
Ni	35	210	50	5,000	1,000	10,000
Pb	85	530	450	750		
Sb					20	300
Se			35	8,000	300	4,000
U (soluble)					100	1,000
V					200	2,000
Zn	140	720			20,000	200,000

Table 4.2 Soil reference values (Dutch Intervention, DEFRA SGV and pre-2004 ATSDR CV). All values in mg/kg.

Parameter	Unit	Standard	Source
pH		≥ 6.5–≤ 9.5	SI 278 (2007)
EC	mS/cm	≤ 2.5	SI 278 (2007)
Al	µg/l	200	SI 278 (2007)
As*	µg/l	25	Draft EC (2008)
Ba	µg/l	2,000	US EPA
Cd	µg/l	0.25	Draft EC (2008)
Cr	µg/l	50	SI 278 (2007)
Cr III*	µg/l	4.7	Draft EC (2008)
Cr IV	µg/l	3.4	Draft EC (2008)
Cu* [hardness < 100 mg/l $CaCO_3$]	µg/l	5	Draft EC (2008)
Cu* [hardness > 100 mg/l $CaCO_3$]	µg/l	30	Draft EC (2008)
Hg	µg/l	0.05	Draft EC (2008)
Fe	µg/l	200	SI 278 (2007)
Mn	µg/l	50	SI 278 (2007)
Na	µg/l	200,000	SI 278 (2007)
Ni	µg/l	20	Draft EC (2008)
Pb	µg/l	7.2	Draft EC (2008)
Sb	µg/l	5	SI 278 (2007)
Se	µg/l	10	SI 278 (2007)
SO_4	µg/l	250,000	SI 278 (2007)
Zn* [hardness < 10 mg/l $CaCO_3$]	µg/l	8	Draft EC (2008)
Zn* [hardness 10–100 mg/l $CaCO_3$]	µg/l	50	Draft EC (2008)
Zn* [hardness > 100 mg/l $CaCO_3$]	µg/l	100	Draft EC (2008)

***Note: values for As, CrIII, Cu and Zn are to be added to background values.**

Table 4.3 Water standards used for the HMS-IRC project.

4.2.3 Stream sediments

Stream sediment data are included in the scoring system since contaminated stream sediments are a potential hazard to livestock that use streams as a source of drinking water. Reference values (Table 4.4) have been provided by the Central Veterinary Research Laboratory (CVRL) (Ireland), compiled from published sources, in the form of an estimated dry matter ingestion limit. These limits relate to the total stream sediment size fraction. Stream sediments analysed for the HMS-IRC project are typically from the <150-µm fraction. Metals tend to be concentrated in the finer fractions in stream sediments so that the 150-µm fraction generally has higher metal concentrations than the total fraction. An example of this is provided by stream sediments from Caim, Co. Wexford, where both the <150-µm and the much coarser <2-mm fractions were analysed. Lead concentrations in the <150-µm fraction in three samples were 557, 894 and 2,583 mg/kg, respectively, while in the <2-mm fraction in the same samples the concentrations were less than half as much, i.e. 234, 350 and 926 mg/kg, respectively. Although most stream sediment data for the HMS-IRC project are for the <150-µm fraction, nevertheless the standards in

Table 4.4 provide a useful indication of potential hazards to livestock arising from stream sediment contamination around mine sites.

Parameter	Unit	Guideline Value	Source
Ag	mg/kg (dry matter)	1,000	CVRL
As	mg/kg (dry matter)	300	CVRL
Ba	mg/kg (dry matter)	1,000	CVRL
Cd	mg/kg (dry matter)	100	CVRL
Cr III	mg/kg (dry matter)	1,000	CVRL
Cu	mg/kg (dry matter)	100	CVRL
Fe	mg/kg (dry matter)	10,000	CVRL
Hg	mg/kg (dry matter)	5	CVRL
Mn	mg/kg (dry matter)	5,000	CVRL
Ni	mg/kg (dry matter)	1,000	CVRL
Pb	mg/kg (dry matter)	1,000	CVRL
Sb	mg/kg (dry matter)	1,000	CVRL
Se	mg/kg (dry matter)	12	CVRL
Sn	mg/kg (dry matter)	1,000	CVRL
V	mg/kg (dry matter)	500	CVRL
Zn	mg/kg (dry matter)	5,000	CVRL

Note: values assume sediment is 10% of diet with no consumable herbage growth and that metals are bioavailable.

Table 4.4 Stream sediment guidelines used for the HMS-IRC project.

4.3 Summary of findings for measured parameters

4.3.1 Acidity, alkalinity and pH

Low pH and high acidity are features of mine water in the three Irish coalfields as well as in the Avoca mine. Some low-volume seepages draining coal waste can have very high acidity but only at Avoca are there high-volume discharges of mine water that are also highly acidic. Low pH and high acidity are of particular concern for aquatic ecosystems.

4.3.2 Aluminium – Al

Some mine waters have very high concentrations of both total and dissolved Al. There is an inverse relationship between pH and Al concentration, with those mine districts with low-pH water, such as Avoca and the three coalfields, having the highest concentrations of Al in mine water and downstream surface waters. There is no clear evidence that Al is toxic to humans but excess Al can have a significant impact on aquatic ecosystems. Concentrations of total Al measured in most downstream surface water samples at Irish mine sites are typically in excess of both drinking water standards and Canadian guidelines for the protection of the aquatic environment.

4.3.3 Antimony – Sb

Antimony is a significant component of solid waste on some Irish mine sites, notably Gortdrum, Glendalough, Silvermines, Tynagh and the minor Pb deposits in east Clare. Sb is probably chemically associated in sulphides with As. Gortdrum is the only mine with a reported Sb enrichment and this is reflected in the composition of mine water sampled on the site. With the exception of Gortdrum, Sb did not exceed 11 µg/l in water analysed for the HMS-IRC project. However, samples of seepage from tailings and spoil at Gortdrum had Sb concentrations in excess of 240 µg/l. In stream sediments, Sb was not detected at most sites investigated. Where it was detected, it was well below animal health guidelines.

4.3.4 Arsenic – As

Arsenic is a significant component of solid mine waste on some mine sites in Ireland, notably Avoca, Tynagh, Gortdrum, Silvermines and some small sites in east Clare. Typically, concentrations are less than 1,000 mg/kg but higher concentrations do occur, especially on the sites of former processing plants. Concentrations of As in stream sediments are generally below 100 mg/kg although a few samples on some sites exceed this. Among water samples, only mine waters, including adit/shaft discharges and waste seepages, have arsenic concentrations exceeding the standard of 25 µg/l for surface water (Draft European Communities Environmental Objectives (Surface Waters) Regulations, 2008). The total As concentrations measured in stream water samples, including those taken downstream of mine sites, are all ≤25 µg/l. In the context of Irish mine sites, arsenic is thus likely to be a concern where humans come in contact with solid waste containing high As concentrations or are likely to inhale As-bearing dust.

4.3.5 Barium – Ba

High concentrations of Ba have been found in solid waste on mine sites where barite is known to have been a significant component of the mineralisation. Concentrations exceed the ATSDR CVs in some cases, notably at Tynagh, Silvermines and Ballycorus, but are generally lower. Ba can be toxic to humans when present in drinking water in concentrations above 2,000 µg/l, the US EPA maximum concentration limit (MCL) for drinking water. All of the water samples collected for HMS-IRC project had barium concentrations well below this limit. However, Ba exceeded the guidelines for animal health in stream sediments at Silvermines.

4.3.6 Cadmium – Cd

Cadmium concentrations in excess of standard limits have been detected in solid waste and stream sediments in the Glendalough District, Silvermines and Tynagh. Solid waste at Kilbricken in east Clare also has high Cd concentrations. Concentrations in some solid waste, in particular, are significantly above the ATSDR adult CV of 100 mg/kg. A few adit discharges, waste seeps and surface run-off samples at Avoca, Glendalough and Caim were found to have total Cd concentrations in excess of 10 or even 100 µg/l. These have potential implications for aquatic ecosystems where they discharge to streams.

4.3.7 Chromium – Cr

The analytical data available for Cr in both solid waste and stream sediments at Irish mine sites are somewhat limited in terms of quality. Moreover, they refer to total Cr and do not distinguish between different species. However, there is little evidence to suggest that Cr is a significant component of solid waste or stream sediments on Irish mine sites. The same is true for Cr concentrations in water discharging from and downstream of mine sites. The exception appears to be the Leinster Coalfield where elevated Cr concentrations were detected in seepages and run-off from coal-rich solid waste. The volumes of these discharges are very low, however, and are unlikely to represent a significant environmental risk.

4.3.8 Copper – Cu

Copper is a common component of ore deposits in Ireland and is present in significant concentrations in solid mine waste even on mine sites where it was not produced as a commodity. Sites with particularly high Cu in solid waste (median >1,000 mg/kg) include Allihies, Bunmahon, Gortdrum, the West Cork Cu–Ba District, Caim and Tynagh. However, standards or guideline limits for Cu are relatively high for solid matter and only those sites with concentrated processing waste, in which copper may be present at levels exceeding 20%, i.e. Gortdrum and Tynagh, can be considered a significant concern. Concentrations of Cu in stream sediment are very high downstream of some sites, notably Allihies, Avoca and, in West Cork, Glandore and Ballycummisk, and the potential impact of this on the aquatic ecosystem at these sites may warrant further investigation. The total Cu concentration in surface waters downstream of mines indicates some impact on water chemistry from mine discharges. However, numerous upstream surface water samples and even some groundwater samples also had Cu in excess of standard limits, suggesting that mine

waste is just one of a number of sources of elevated Cu in surface water and groundwater around the mine sites.

4.3.9 Iron – Fe

Mine sites in Ireland are associated with high concentrations of Fe in solid waste, water and stream sediments. The main risk associated with high Fe is the potential impact on the aquatic environment. Discharge of Fe-rich mine water to streams and rivers causes Fe to come out of solution as hydroxide minerals. These form colloids or flocs that then blanket the stream bed, having a severe impact on biota. Such discharges have been noted in particular at Avoca and in the Leinster, Slieve Ardagh and Connacht Coalfields.

4.3.10 Lead – Pb

Out of 27 mine districts examined for the HMS-IRC project, 13 have high concentrations of Pb in solid waste (median >1,000 mg/kg or 0.1%), namely Avoca, Ballycorus, Caim, the Clare Pb mines (3), Clements in Connemara, Glendalough–Glendasan, Glenmalure, Keeldrum in Donegal, Tassan in Monaghan, Silvermines and Tynagh. The UK guideline limit for soils (SGV) on industrial sites is 750 mg/kg Pb (Table 4.2). Concentrations of Pb in stream sediment exceed the 1,000 mg/kg guideline limit for livestock downstream of most of these sites, though only at Glendalough–Glendasan and Silvermines are such high concentrations known to be sustained over a significant length of stream bed. The Pb concentration in surface waters downstream of mines indicates a significant impact on water chemistry from mine discharges at three sites, Avoca, Glendalough and Silvermines, where significant volumes of mine water with high Pb concentrations discharge into local rivers and streams.

4.3.11 Manganese – Mn

High concentrations of Mn occur in solid waste on some sites but only a small proportion of samples (5%) exceeds the relatively modest child CV (Table 4.2) of 3,000 mg/kg. Mine water with low pH tends to have relatively high Mn concentrations and sites such as Avoca and the coalfields can exhibit high concentrations of manganese (>1,000 µg/l). However, most water analysed around mine sites has a Mn concentration below the Irish Drinking Water standard of 50 µg/l. There are examples of localised extreme Mn concentrations in stream sediments downstream of some mines but, in general, Mn concentrations in stream

sediments in Irish mine districts are consistent with those measured in regional surveys at sites unaffected by mining.

4.3.12 Mercury – Hg

High Hg concentrations measured by XRF in solid waste from the processing areas at Gortdrum and Tynagh have been confirmed by analysis in an external laboratory. Both of these sites are work places where there is potential for human exposure to the waste. Some samples of solid waste in the Glendalough District may also contain significant Hg concentrations, although this has not been confirmed by external analysis. Other sites investigated for the HMS-IRC project do not appear to contain concentrations of Hg in solid waste that are detectable by XRF. Hg was detected in mine water and downstream surface water at a number of sites, principally Avoca, where the concentration of dissolved mercury ranged up to 0.38 µg/l, well above the Draft EC value (0.05 µg/l).

4.3.13 Nickel – Ni

Nickel was below the detection limit in most solid mine waste samples analysed for HMS-IRC. Exceptions were samples at Tynagh mine, where Ni–Cd-rich zones were known to occur in the ore, slag waste at Ballycorus and Allihies and phosphatic shales in Clare. Both water and stream sediment samples reveal an association between Ni and coalfields – samples from all three Irish coalfields have elevated Ni in one or both of these media. Other than in mine water, Ni does not generally exceed reference values in surface waters with the exception of some waters downstream of coalfield sites and the sulphide mines, such as Avoca and Tynagh.

4.3.14 Selenium – Se

Selenium has been detected at very low concentrations in solid waste and stream sediments in several mine districts, notably Allihies and Doolin (Clare Phosphate). Water samples generally have Se concentrations below the detection limit or at least below the Drinking Water standard. Although there appears to be no indication of Se toxicity on farms in the north Clare area, nevertheless care is needed when interpreting the solid waste data, particularly with reference to the Clare Phosphate District. Phosphate mines, in particular, are associated with downstream Se contamination as a result of leaching of relatively small concentrations of Se from solid waste. The concentration selenium measured in solid waste in the Clare Phosphate District (18–30 mg/kg) are similar to the median concentration of Se in phosphate rock and waste rock in phosphate mines in the US that have been

associated with excess Se in downstream environments. Se concentrations in soils in north-west Clare, where the phosphate deposits are located, are in the upper 25th percentile of the range for soils in Ireland (Fay *et al.*, 2007).

4.3.15 Silver – Ag

Silver was detected in solid waste at most mines investigated for the HMS-IRC project, usually in concentrations well below 100 mg/kg. Several Pb mines had relatively high concentrations of Ag, especially in solid waste on former processing areas or in processing waste itself. Most stream sediments samples analysed had silver concentrations below the detection limit, estimated to be 10–20 mg/kg. Ag has a very low toxicity to humans and is generally not included under regulations that set statutory limits for water or other media.

4.3.16 Thorium – Th

Thorium was detected in a small number of samples of solid waste and stream sediments at a limited number of mine districts investigated for the HMS-IRC project, usually in concentrations below 50 mg/kg. It is not known if Th is directly associated with ore minerals in sulphide mines in Ireland – at Avoca, at least, it is known to occur in relatively high concentrations in host volcanic rocks. In the Clare Phosphate deposits, it is probably associated with U in apatite, the main ore of phosphate. The lack of any reference values make it difficult to assess any potential risks associated with the occurrence of Th on Irish mine sites. However, comparison of concentrations measured for this study with the range of concentrations in Irish rock types suggest that, for the most part, Th is not enriched in mine sites relative to normal background levels.

4.3.17 Uranium – U

Uranium was detected in a small number of samples of solid waste, mainly at Avoca, Doolin, Gortdrum and the Leinster Coalfield. Very few samples had a U concentration exceeding any published standards. At least some of the U in solid waste is in soluble form and, as a consequence, has been remobilised into mine water which, on some sites, has relatively high concentrations of total U. However, only one of the samples analysed (from Avoca) had in excess of 30µg/l U, the US EPA MCL for drinking water. Levels of U in stream sediments are typically very low.

4.3.18 Vanadium – V

Vanadium was detected in only a limited number of solid mine waste samples in the mine districts investigated for HMS-IRC, to a large extent as a consequence of the unfavourable detection limit for V in the XRF analyser used for *in-situ* analyses. The Clare Phosphate deposit at Doolin had the highest concentrations of V. V was also detected in the Leinster and Slieve Ardagh coalfields. The presence of V in these mine districts may reflect the occurrence of shales with a high content of organic carbon. The concentration of V in water analysed for HMS-IRC did not exceed 5 µg/l. In the absence of standards for V in water, it is difficult to assess the potential relevance of these results. Stream sediments in Doolin and the Connacht Coalfield had high V contents both upstream and downstream of the mines, suggesting that V is enriched in the country rock in both districts.

4.3.19 Zinc – Zn

Solid mine waste at Caim, Glendalough, Tassan mine in Monaghan, Silvermines and Tynagh is significantly enriched in Zn. Published reference values for soil vary significantly but Zn concentrations measured in mine waste on Irish mine sites do not appear to pose a risk to human health. Concentrations of Zn exceed 5,000 mg/kg in stream sediments downstream of Glendalough, Silvermines and Tynagh and may represent a risk to livestock. High concentrations of Zn in stream sediments also pose a potential threat to aquatic organisms. The Zn concentration in surface waters downstream of mines indicates a significant impact on water chemistry from mine discharges at Avoca, Glendalough, Silvermines and Tynagh.

4.4 Geochemical assessment: overview

4.4.1 Lead

Lead is the most important single contaminant on Irish mine sites in terms of the quantity of Pb-enriched material, the concentration in which it is found, its toxicity and its geographical dispersion on and around mine sites. It is present in high concentrations in 11 out of 23 districts investigated, not only in solid waste but also in mine waters and in surface waters and stream sediments downstream of mines. Mine districts and sites most severely contaminated by lead include Caim, Clare Pb Mines, Glendalough, Silvermines and Tynagh.

4.4.2 Acid mine drainage

Acid mine drainage is characterised by low pH and high acidity, and when generated in metal or coal mines is typically rich in metals such as Fe, Mn, Al, Cu, Pb, Ni and Zn, and therefore potentially toxic to aquatic organisms. At Avoca mine, AMD has had a major impact on the Avoca River. Low pH and high acidity are also found in some mine waters at the Slieve Ardagh, Leinster and Connacht Coalfields. However, only in the Connacht Coalfield are there volumetrically significant discharges of AMD. Relatively high concentrations of Al, Ba, Cd, Fe, Mn and Ni are present in water in these mine districts.

4.4.3 Former processing plant sites

The sites of the former ore processing plants at Gortdrum, Silvermines and Tynagh are significantly contaminated by heavy metals. In all three cases, the sites are being utilised by new businesses. Contaminants include not only the metals produced from the site, such as Pb, Zn and Cu, but also minor constituents of the ore that have become concentrated during processing. These minor constituents include As and Hg, which have been found in concentrations exceeding 1,000 mg/kg. Arsenic is also present in high concentrations in solid waste outside of processing areas at both Avoca and the Clare Pb Mines. Despite its occurrence at high concentrations in solid waste, As has not been detected in surface waters downstream of mine sites at concentrations in excess of the Draft EC Surface Water Regulations.

4.4.4 Aquatic ecosystems

Draft EC Surface Water Regulations (Table 4.3) set low limits for some metals that occur in significant concentrations in surface water downstream of Irish mine sites. These metals include Cd, Cu, Pb and Zn. They pose risks to aquatic ecosystems even at low concentrations and may require inclusion in surface water monitoring programmes.

4.4.5 Copper

Concentrations of Cu in stream sediment are very high downstream of some sites, notably Allihies, Avoca and, in West Cork Glandore and Ballycummisk. The potential impact on the aquatic ecosystem may warrant further investigation. The total Cu concentration in surface waters downstream of mines indicates some impact on water chemistry from mine discharges. However, numerous upstream surface water samples and even some groundwater samples also have Cu in excess of regulatory

levels, suggesting that mine waste is just one of a number of sources of elevated Cu in surface water and groundwater in Ireland.

4.4.6 Zinc

High concentrations of Zn in solid mine waste pose no threat to human health. However, high concentrations of Zn in stream sediments and/or downstream surface waters at Avoca, Glendalough, Silvermines and Tynagh pose a risk to livestock and the aquatic environment.

4.4.7 Selenium

Selenium is a common component of phosphate rock and the shales that typically host it. Leaching of Se from solid waste heaps at phosphate mines in the USA has led to significant downstream Se contamination of aquatic organisms, mammals, birdlife and grazing animals. The concentration of Se in solid waste from the Clare Phosphate deposits (18–30 mg/kg) falls within the range of concentrations reported for US phosphate mine waste. While there is no evidence for leaching of Se into the aquatic environment, a large part of the former mine site is now grazing land and may pose a risk of Se toxicity to grazing animals.

4.4.8 Aluminium

Some mine waters have very high concentrations of both total and dissolved Al. There is an inverse relationship between pH and Al concentration, with those mine districts with low-pH water, such as Avoca and the three coalfields, having the highest concentrations of Al in mine water and downstream surface waters. Concentrations of total Al measured in surface water downstream of these sites are typically in excess of both Irish drinking water standards and the Canadian guidelines for the protection of the aquatic environment.

4.4.9 Nickel

Nickel is enriched in mine water, downstream surface water and stream sediments at some sites in the Irish coalfields. It is also found in excess of the Draft EC Surface Water Regulations downstream of mines such as Avoca and Tynagh.

4.5 Geochemical assessment: site-specific issues identified in the HMS-IRC investigation

4.5.1 Abbeytown

Pb- and As-rich leachate from the tailings pond enters the estuary at Ballysadare Bay.

4.5.2 Avoca

Measured Pb concentrations exceed 1% in solid waste at Connary, a site where sheep graze.

4.5.3 Ballycorus

Measured Pb concentrations exceed 1% in solid waste at Ballycorus in an area popular with walkers and horse riders.

4.5.4 Caim

Measured Pb concentrations exceed 5% in a solid waste heap at Caim, used by quad bikers and others.

4.5.5 Clare Pb District – Ballyvergin

Pb concentrations in excess of 20% were measured in fine-grained mine waste in an area used by cattle for feeding at Ballyvergin.

4.5.6 Glendalough–Glendasan

Measured Pb concentrations exceed 10% in solid waste at the Hero Processing site, at the head of the Glendasan Valley. The site is very popular with tourists. High concentrations of Pb and Zn are present in stream sediments in Glendasan River downstream of the mines.

4.5.7 Glenmalure

Measured Pb concentrations exceed 10% in solid waste at Ballinafunshoge, Glenmalure, a site popular with quad bikers.

4.5.8 Gortdrum

Very high concentrations of Hg and As (both >1%) were measured in solid waste at the site of the former processing plant, now the site of an active business.

4.5.9 Silvermines

Very high concentrations of Pb (>2%) and As (>0.1%) were measured in solid waste at the site of the former processing plant in Garryard, now the site of an active business.

4.5.10 Tynagh

Very high concentrations of Pb (>2%) and As (>0.1%) were measured in solid waste at the site of the former processing plant, now the site of an active business. A Cd-rich discharge from a waste heap crosses grazing land and seeps underground, potentially affecting groundwater.