

***Scottish Environment Protection Agency scoping study
on metal contamination in the Glengonnar Water***

NHS Scotland Public Health Response

**Human Health Risk Assessment
of the implications of metal contamination of water sources
around Leadhills and Wanlockhead**

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SUMMARY

This NHS Scotland report has been produced in response to the findings of a recent investigation conducted by the Coal Authority, at the request of and funded by the Scottish Environment Protection Agency (SEPA), to determine levels of metal contamination in river waters draining from the Leadhills and Wanlockhead localities.

This locality is known to have a historical legacy of metal contamination resulting from mining activities over past centuries. The aim of this report is therefore to provide an interpretation of the results of the recent investigation in relation to the potential implications for human health.

The recent investigation is the latest in a series of environmental investigations carried out in the area in years past. The latest study again confirms what has long been known, that there is environmental residue of lead and other metals left over from the old lead mining activity.

The opportunity has therefore been taken to consider the new results along with older information on the extent of environmental contamination associated with the former lead mining industry in the local area. The combined historical and recent data has then been used to assess, as far as is possible, the risk to health associated with living in the Leadhills and Wanlockhead areas.

In order for there to be a potential health risk to local residents, there has to be an *environmental hazard* (the mine wastes); one or more *pathways* that allow humans to be *exposed* to the hazard and the possibility of such exposure causing an *adverse health effect* at the concentrations to which people are being exposed.

On balance and on the basis of existing evidence, hazards in the form of environmental contamination do exist (and are likely to continue to do so for some time), and potential pathways for human exposure also exist. However, the concentrations of contaminants to which local people are likely to be exposed do not appear to be high enough to pose a significant overall risk to health for local residents provided practical measures are followed. The risk to local residents associated with environmental contamination, derived from the former lead mining industry, is therefore considered to be low.

However, the historical legacy of the lead mining industry means that people living in the Leadhills and Wanlockhead area are likely to continue to be exposed to low levels of

environmental metal contamination above the norm for most of the population. On that basis some practical suggestions are provided on how residents in the area can minimise ongoing exposure to remaining environmental metal residues.

SITUATION

A report of an investigation by the UK Coal Authority, commissioned and funded by the Scottish Environment Protection Agency (SEPA), has confirmed the presence of lead, zinc and cadmium in watercourses in the former lead mining area of Leadhills in South Lanarkshire and Wanlockhead in Dumfries & Galloway.

Between November 2010 and March 2011, the Coal Authority carried out an initial surface water scoping study as a precursor to a more detailed assessment of the feasibility of various treatment options for the contamination in Glengonnar Water. The study report was completed in November 2011.¹ As well as Glengonnar, it incorporated an assessment of the nearby Wanlock Water, over the border in Dumfries & Galloway. Part of the River Nith's catchment, Wanlock Water's upper sections also receive a number of point source mine water inputs.

The SEPA-commissioned study considered whether remobilisation of deposited sediment and run-off from spoil tips and smelt mills could also have a role in the watercourse contamination. Its report highlighted the impact on local land of contamination due to air-borne particles arising from smelting processes – with elevated soil levels of lead, in particular, found around a former local smelter – and by pollutants from other processes, such as, ore washing. It noted a reference, in a 2006 report on Scotland's soil,² to a research study (then in-preparation) that revealed a high metal content of the soils in the Leadhills area, with “extremely high” levels of lead, zinc and copper found in the alluvial soils of the Glengonnar Water floodplain. [It may be relevant to note that, given its location proximal to a series of mineral veins consisting of lead, iron and other ores, the soils around Leadhills might be naturally high in levels of heavy metals].

The results of the SEPA investigation confirmed previous findings and identified levels of lead, cadmium and zinc that were in excess of acceptable environmental water quality standards.

In light of these findings, and prior to the planned release of the investigation report, SEPA requested that NHS Scotland provide an assessment of the risks to human health associated with the findings of elevated metal concentrations in the local watercourses. This NHS report provides that assessment.

In responding to this request, the NHS bodies (NHS Lanarkshire, NHS Dumfries & Galloway in collaboration with Health Protection Scotland (HPS)) considered that, in view of the recent study findings, and past information on environmental residues in the locality left over from old mining operations, it would be helpful to review all previously available environmental data, in order to make a more general assessment of the potential risks to health associated with living in the locality. On the basis of this broader assessment, conclusions have been drawn on the general level of risk to health associated with living in the area, and suggestions are made on how local residents may minimise future environmental exposure to remaining metal mining residues.

BACKGROUND

Reasons for the SEPA-commissioned investigation

The village of Leadhills in South Lanarkshire has long been the centre for lead mining in Scotland. Mining features, spoil heaps and other remnants of the industry, have, since its decline in the 1930s, continued to dominate the local landscape. One legacy is the impact of mining on the local water environment. For a number of years, SEPA has monitored Glengonnar Water, which flows near Leadhills and local former mining sites. Elevated levels of lead, cadmium and zinc have been identified in a 10 kilometre stretch of this watercourse between Leadhills and the River Clyde at Abington.

As a result of the contamination, Glengonnar Water fails to meet UK Specific Pollutant (zinc) and Priority Substances (lead and cadmium) minimum standards - leading to a chemical status of 'Fail' in the Scotland River Basin Management Plan (RBMP). The EU Water Framework Directive obliges member states to plan via RBMPs to achieve at least 'Good' status in all water bodies (the current overall classification of Glengonnar Water is at 'Moderate'); the target for achieving this in Scotland is 2027.³

Due to a limited number of monitoring points, SEPA had not been able to pinpoint the precise source and pathways of the pollution. A series of drainage levels that continue to carry water away from the now flooded mines into nearby watercourses were assumed to be one of the main contributors. Blockages caused by roof collapses within some of the drainage levels are thought to have resulted in mine waters being forced to the surface and discharged through abandoned shafts adjacent to Glengonnar Water.

Currently, the responsibility for discharges from non-coal former mining sources is not established with any individual person or agency. SEPA invited the Coal Authority to make an application to its Restoration Fund to carry out a scientific study that would more accurately identify the sources of the watercourse contamination around Leadhills. The Coal Authority has been monitoring and treating water polluted from former (predominantly coal) mining sources since 1994, and has experience of working with the Welsh government, DEFRA and the Environment Agency to carry out three major projects investigating water from metal mines in England and Wales.

2011 SEPA report findings

Scope

The investigation identified 31 locations (including three around Wanlock Water) for water and soil/sediment chemical sampling, and water level and flow monitoring. These were supplemented by additional ad-hoc and routine monitoring following initial results and further site visits. The sampling locations were chosen based on the key mechanisms identified by which dissolved and/or particulate pollutants could be being conveyed into watercourses:¹

- “Mine water” coming from drainage levels and abandoned shafts
- Hill-side run-off washing down prior airborne pollutants from smelting
- Surface run-off and infiltration of spoil heaps
- Surface run-off and infiltration from former ore processing areas

Water samples were evaluated in reference to Environmental Quality Standard Annual Average (AA-EQS) levels. The AA-EQS standard is that average (mean) concentrations of a particular contaminant at a specific monitoring point do not exceed the reference level.

Lead

The majority of lead in samples of mine water was in dissolved form. Concentrations of dissolved lead were generally either a little above or below the AA-EQS reference level of 7.2 µg/l. However both dissolved and total lead levels were substantially higher in Glengonnar Water, increasing in concentration heading downstream to a peak of 83 µg/l dissolved lead (174 µg/l total) below the Glendorch smelter mill.

High levels of dissolved lead in samples from Leadhills sewage works (17 µg/l) and two local upwelling / springs (48 and 83 µg/l), as well as in the local soils (up to 94 g/kg), floodplain and alluvium (both over 100 g/kg), all suggest potential sources for the high watercourse concentrations. Similarly, one of the mine water sample sites was an outlier, with an average of 20 µg/l of dissolved and 38 µg/l total lead, and one possible explanation is surface water influx. However, data were insufficient for any conclusions to be drawn on whether the major contributors to the lead pollution are point sources (e.g. shallow or deep springs), or more diffuse problems of surface run-off, spoil erosion, or leaching from contaminated sediments.

Zinc

Total mine and surface water zinc levels were all almost entirely comprised of the dissolved element – as would be expected in the acid-base neutral (pH 7) environment found in the samples. Average total zinc concentrations ranged between 35 and 79 µg/l in five out of six of the mine water samples, three of them exceeding the AA-EQS reference value of 50 µg/l. The mean total zinc at the sixth mine water outlet was much higher at 426 µg/l; this may reflect workings within the mine that are separate from the rest of the system.

Average total zinc levels in the Glengonnar Water were generally higher than the mine water at between 68 and 122 µg/l. Hence, there are likely to be substantial non-mine inputs of the metal into the watercourse. Elevated concentrations of zinc were detected in samples from nearby upwellings and discharge from the local sewage works (possibly arising from spoil run-off), and there is potential for zinc to be washed out from within the floodplain and soils, which also contained significant total levels of the element (around 1.5g/kg in the floodplain and alluvium and up to 2.0 g/kg in soil samples).

Cadmium

Cadmium in the mine water was, like zinc, almost entirely in the dissolved state. Average levels of between 0.3 and 0.6 µg/l represent substantial elevations above the AA-EQS value of 0.08 µg/l, more closely matching EQS maximum acceptable concentrations (MAC) of 0.45-0.6 µg/l. As with zinc, levels at one specific sample site were markedly higher – up to 4.6 µg/l. And as with both lead and zinc, average cadmium concentrations in Glengonnar Water generally increased moving downstream, ranging from 0.5 to 1.1 µg/l. Again, soil and floodplain samplings suggest that inputs from sewage works, local upwellings and leaching from soil/sediment, floodplain and alluvial material are all likely to contribute to the pollution.

Metals pollution in Wanlock Water

The sampling carried out at Wanlock Water suggests that it too is subject to significant pollution from zinc as well as cadmium (to an even greater extent than Glengonnar Water) and lead (to a lesser extent). Samples taken from two mine discharge sites and from the watercourse downstream of a smelter mill respectively contained 10, 32 and 39 µg/l of dissolved lead; 130, 381 and 270 µg/l of total zinc; and 1.7, 3.5 and 2.6 µg/l of dissolved cadmium. The concentrations of all three metals at all three sites exceeded the AA-EQS standards. Potential sources of the contamination in the watercourse were not explored in detail, but are likely to include both mine water and land surface pathways.

Other issues

Beyond the chemical contamination, the investigation identified several other possible hazards around Leadhills and Wanlockhead. A number of collapsed shafts and open fissures in one of the mine drainage levels were reported to present safety concerns, with a risk of further collapses changing water flows, increasing pressures in the system and possibly even resulting in a sudden release (“blow-out”) that would pose a threat to human settlements. These issues were mapped in a 1991 report prepared for the Clyde River Purification Board, but it is unclear how accurate this remains. The outcomes of more recent investigations and discussions between SEPA, South Lanarkshire Council and the landowner Leadhills Estates were not available at the time of completing this public health risk assessment.

Report recommendations

In the investigation report, a need was identified for further study to assess the impact of contamination from soils / sediments within the floodplain, and to design appropriate remedial interventions. Remedial options are also needed for the mine water pollutants, but further work is first required to assess and resolve the risks from the collapsed sections. Geochemical investigation of all inputs affecting Glengonnar Water and their sources is needed. A wider ecological and chemical assessment is also required to evaluate the extent and potential sources of the Wanlock Water contamination.

The report recommends that potential water treatment schemes, including addressing non-mine water inputs, should be assessed for feasibility and optimal location. A complete 12 months of chemistry, flow and water level data would assist these efforts.

Previous Environmental and other Investigations in the area

South Lanarkshire Council reported that it has placed the area around Leadhills on its list of potentially contaminated land sites, and had carried out an initial inspection, consisting of a number of 'walkover surveys'. These concluded that there was no indication that the former mining areas were causing, or possibly could cause, significant harm to the local population.

In 1995, the results of a study into contamination in the Glengonnar Water catchment area were published.⁴ This identified elevated levels of metals including lead, zinc and cadmium in the flood plain and surrounding area. Levels for lead exceeded the "*action trigger concentrations*" recommended by the UK Inter-departmental Committee on the Redevelopment of Contaminated Land (ICRCL). This study concluded that the source of the metal contamination in the Glengonnar Water catchment was the waste material from the historical mining activity.

In 1989, a study was published that reported the results of environmental sampling carried out in Leadhills and Wanlockhead.⁵ This study, by Moffat, also investigated the association between environmental contamination and evidence of human exposure in the form of blood lead levels in adults and children in the two villages. The main findings of the Moffat study were that there was evidence of a potential environmental hazard associated with lead.

Compared to a control area (Moniaive), there was evidence for significantly increased levels of lead in environmental samples: garden soil; house dust; airborne dust; kitchen surface wipes; and drinking water (although lead levels in the drinking water were described as low and within accepted limits for the time).

The Moffat study found evidence of potential pathways of human exposure to the lead; the lead concentrations detected on hand wipes of resident in the villages were significantly higher than subjects from Moniaive. This was concluded to mean that residents of Wanlockhead and Leadhills (compared to Moniaive) had an increased potential risk of exposure to lead contamination from these sources via inhalation of airborne dust and /or ingestion of dust or soil directly or via garden produce, or via hand to mouth contamination.

The Moffat study also reported that the residents of the mining area villages had elevated blood lead levels (men, women and children) compared to residents in Moniaive. Average (mean) blood lead levels were 15.9, 12.4 and 17.6 µg/dL respectively in men, women and children resident in Leadhills and Wanlockhead – 45-70% higher than among controls. Although higher than in controls, the blood lead levels measured in local residents in 1989 were within then-current European guidelines. Those reported in adults are also below the present-day “action limits” of WHO guidance and UK and EU occupational regulations.^{6,7} The levels detected were reported as being within acceptable levels and were very similar to, and in some cases lower than, blood lead levels elsewhere in the UK at the time. There was therefore no suggestion that, although local residents were exposed to increased amounts of lead in the relevant villages, that anyone was suffering ill effects as a result.

The levels detected in children in 1989 were above 10 µg/dL recommended much later in an OECD Declaration on Lead Risk Reduction calling for lead in all children’s blood to be reduced.⁸ Epidemiological studies have consistently found adverse effects above this concentration; and lead-induced IQ decrements have recently been reported in children even with levels below 10 µg/dL.⁹ However, since 1989, lead levels in the UK generally including in children have reduced as a result of the removal of lead from paints, food cans, toys and from petrol. The overall burden of environmental lead contamination has therefore fallen as a consequence. This reduction will very probably have also resulted in a reduction in the blood levels of residents, including children, in the former lead mining areas since the 1989 study.

The Moffat study also reported that of all the potential sources of environmental lead contamination, lead in drinking water appeared to be the factor that was most important in determining the level of lead in blood samples of local residents, despite the actual water lead levels being within acceptable limits. This may indicate that sources of lead within the properties themselves, such as lead pipe work, may have been contributing to the residents' blood lead levels at that time. It is possible that some older properties in the area still have internal plumbing using lead pipes.

Despite the findings in relation to blood lead levels and environmental sources of lead, the Moffat study concluded by saying that *“health effects from exposure to high environmental lead levels (in the affected areas) are improbable”*.

PUBLIC HEALTH RISK ASSESSMENT

In theory, excessive exposure to metals such as those detected in environmental samples taken in the Leadhills / Wanlockhead area might result in a variety of adverse health effects, but only if residents are exposed to high enough doses. The potential adverse health effects of exposure to the metals detected in the recent investigations are described in Annex A.

In making an actual health risk assessment, the possibility of harm occurring has to be determined on the basis of the evidence of known hazards, their concentrations in the local environment, and the pathways creating opportunities for actual exposure of the local residents. A number of potential sources of hazard to the public were identified in the SEPA report, which largely confirmed information from previous investigations. A description of the possible pathways of exposure, followed by an assessment of the health risk associated with each one, is provided below.

Potential exposure pathways

Potential pathways of exposure are conventionally considered as:

- *Dermal* – via physical skin exposure
- *Inhalation* – via airborne vapour or dust

- *Ingestion* – directly as consumption of contaminated drinking water, dust or soil, or indirectly via contamination on food produce or via contaminants taken up by plants, livestock or fish.

In this situation, direct physical *dermal (skin) exposure* could in theory occur via bathing if using contaminated water, and there could be a potential hazard associated with *inhalation* of contaminated water vapour (e.g. if the water was used for showers, etc). However, given the local circumstances, in practical terms, both of these pathways are unlikely to be significant.

The primary exposure pathways of concern for this health risk assessment are therefore associated with the potential *ingestion* of:

- contaminated water;
- contaminated soil and dust
- and contaminated (locally grown) food crops and other produce.

Direct risk from the contaminated watercourses

The direct risks presented by the contaminated watercourses relate to the potential for physical contact with and/or ingestion of the affected water, river sediments or catchment soil. The concentrations of lead, zinc and cadmium measured in Glengonnar and Wanlock Waters are very unlikely to pose a significant risk to health via external physical (skin) contact alone.

Also, none of the watercourses involved at Leadhills and Wanlockhead are used for public drinking water supplies. Although there are a small number of properties in the area with private water supplies, which are monitored by two local councils, none of these are believed to abstract water directly from the contaminated watercourses investigated in the recent study.

Hence, any risk associated with consumption of water from these contaminate sources is considered to be limited to people using the area for occupational (farmers/shepherds) or recreational purposes (walkers/ hikers), and anyone drinking water directly from polluted sources. Such individuals can be expected to be relatively few in number, especially as local residents are likely to be aware of the mining heritage of the area and so conscious of the potential for watercourse contamination. Recreational users are, though, less likely to be aware of the hazards and consequent risks to health of consuming the open source water.

With respect to the risk from ingestion of water, the maximum permissible level (Prescribed Concentration Value, PCV) of lead in drinking water in Scotland is currently 25 µg/l (reducing to 10 µg/l in December 2013). The peak lead concentration measured in Glengonnar Water (174 µg/l) is nearly seven times the current PCV limit and, if consumed repeatedly over a significant period, would constitute a significant hazard to health. The PCV for cadmium, 5 µg/l, was not exceeded by the highest study sample concentration, and there is no PCV for zinc. PCVs are set based on avoidance of health risks from continued long-term exposure and are inherently very precautionary. The risk to health associated with one-off, or infrequent limited consumption, such as are likely to be associated with occasional exposure by occupational or recreational users of the area to water from the contaminated watercourses, is unlikely to be of significant public health concern.

Risk associated with domestic household or commercial premises water supplies

Scottish Water has confirmed that the Leadhills and Wanlockhead settlements have been supplied with mains tap drinking-water from outside the contaminated area, via the Daer treatment works in South Lanarkshire, since approximately 2000. Prior to that, each village was supplied by local systems. There is no known connection between Glengonnar and Wanlock Waters and any public water supply systems. Data accumulated by Scottish Water in the last ten years from 22 separate regulatory and customer-driven samples of tap water in the two locations, confirm there have been no detections of excess lead or non-PCV compliant waters with regard to other heavy metals in the public supply. The last sample taken from Leadhills in 2009 had a lead level below the limit of detection (< 0.2µg/L). Any detections of lead at customers' taps in the past have been attributed to the presence of lead plumbing within older properties, and these have been dealt with on an individual basis. Scottish Water advise that they have also taken steps to remove any lead "communication" pipes (the pipes leading up the boundary of a consumer's property) in the area. Responsibility for the water pipes within a property lies with the relevant property owner.

A number of properties have private water supplies not regulated by Scottish Water. South Lanarkshire and Dumfries & Galloway Councils' environmental health services identified up to five properties on the Glengonnar site each with a private water supply, and five users of private supplies across three separate (spring-fed) sources in the vicinity of Wanlock Water.

South Lanarkshire Council report that there have been no concerns regarding lead and zinc levels in samples taken every 3-5 years as part of routine monitoring for the Glengonnar sites; cadmium concentrations had not been measured previously. The most recent results held by Dumfries & Galloway Council for the Wanlockhead private supplies are from ad hoc samplings dating to between 2003 and 2006, and were all well within the current PCV of 25 µg/l for lead, although neither zinc nor cadmium had been measured.

As complete current data regarding the three metals of interest was lacking for each of the private supply sites, both councils indicated that they would themselves be willing to fund and carry out a new comprehensive set of measurements. South Lanarkshire Council proceeded to collect seven samples from properties with private water supplies in the Leadhills area. All were satisfactory for lead, cadmium and zinc, although four exceeded acceptable acidity levels. Three of those had elevated copper concentrations, likely to be the result of pipework corrosion; the occupiers were given advice about remediation.

For consistency it would be preferable if sampling of the private water supplies around Wanlockhead for the same contaminants could be carried out, ideally after discussions between Dumfries & Galloway Council and the source owners regarding the possible need for a remediation strategy should contamination be detected in such supplies.

Pending the results of outstanding tests required for the private supplies described above, the evidence to date suggest that consumption of publicly and privately supplied drinking-water in the Leadhills and Wanlockhead areas does not pose a health risk associated with mine working derived metals.

Risk associated with soil and dust.

Physical (skin) contact with soil in gardens or farmland, even with the heavily contaminated soil/sediment of the Glengonnar Water, may pose only a very limited direct risk to health. Of more potential concern is the possible hazard associated with inhaling or consuming soil or dust containing high levels of metals; children in particular can have a natural propensity to ingest soil accidentally or deliberately.

The SEPA report makes several references to 'run-off' of water from the land as a potential source of watercourse contamination around Leadhills, including from spoil heaps, former ore processing sites, and previously airborne pollutants (dust) derived from smelting. However, contamination of the local land was investigated to a very limited extent in the 2011 investigation, in relation to sources of waterborne contamination only, by sampling the floodplain of Glengonnar Water (i.e. soil samples were taken adjacent to the floodplain and of alluvial sediment from within the water course). All samples showed significant levels of lead, zinc and cadmium, as well as copper and nickel. This was consistent with the previous research in the area described earlier.⁴ Lead concentrations were over 100 times greater than mean values for Southern Uplands soils, and zinc levels over 20 times greater.

The new study did not provide a clear indication of the form (e.g. elemental or dissolved) or bio-availability of these soil/sediment heavy metals, which environmental pH and various other factors determine, and which significantly influence uptake/absorption in exposed plants, animals (and humans). The study also did not explore to what extent high levels of the metals may be natural, rather than the result of pollution.

The SEPA report recommended further study to establish the scale and nature of land and soil contamination in the Leadhills and Wanlockhead area. Adequate data regarding soil acidity and the bio-availability of the contaminant metals, and on the distributions of 'high-risk' bare earth versus grass and covered soil were also unavailable in the present report.

However, accepting the limitations of the data presented in the new report, for the majority of local residents the actual opportunities for human exposure to the soils (and any dust derived from these sediments) in the locations tested in the new study are likely to be very limited. As with exposure to the waterborne contamination, any exposure to soils and dusts in the watercourse catchments is also considered likely to be restricted to occupational users (farmers, shepherds) and recreational users. On that basis the health risk associated with exposures to soil or dust from the test locations is unlikely to be significant

As the new study did not sample soils or dust in the local villages the only source of relevant information here is the Moffat study discussed earlier.⁵ The average lead concentration in local garden soil from Leadhills and Wanlockhead was 6,902 µg/l, over 30 times higher than control samples from Moniaive but orders of magnitude smaller than the soil and sediment levels reported in the more recent SEPA study. The Moffat study however found very little

evidence of any correlation between lead levels detected in soil or dust in Leadhills or Wanlockhead and blood lead levels of residents. This is consistent with a number of other studies worldwide which also failed to identify an association between living in former lead mining areas with detectable environmental lead contamination and blood lead levels.^{10,11} The absence of evidence for such an association indicates that even when lead is present in soils and dust, it is not readily absorbed internally. This has been attributed to the predominant forms of lead found in mine wastes, frequently consisting of Galena (lead sulphide) which is of poor bio-availability to humans. If lead is not detectable in blood in excessive amounts, it is extremely unlikely that it is present in sufficient amounts to cause ill health.

Risk associated with contaminated local crops and produce

Although not part of the SEPA-commissioned investigation, normally for the purposes of a contaminated land health risk assessment, the hazards associated with the risk of exposure to contamination via local food sources, including plant produce, would be included. Potential exposure pathways of concern in this situation therefore also include direct *skin (dermal)* contact with soils on plants and vegetation, and *ingestion* of soil on unwashed produce and via contamination taken up by plants grown in contaminated soils or irrigated by contaminated water. There may also be risks associated with ingestion of livestock or their products (e.g. eggs) reared in the locality (via their consumption of metal-contaminated vegetation or water).

In relation to this aspect, South Lanarkshire Council's Waste and Environmental Services shared some historical sample results. In 2008, in response to enquiries from a Leadhills resident, samples of potatoes, cabbage, turnips and kale grown in the resident's garden, and an egg from one of their chickens, were sent to a laboratory to establish the levels of various metals they contained. The analyses of the vegetables were conducted on the whole plants, rather than washed and peeled as they would normally be consumed. The results therefore may have been affected by residual soil, thus over-estimating the actual levels of contaminants someone eating the vegetables would be exposed to. Following the release to local agencies of SEPA's investigation report, South Lanarkshire Council asked the Food Standards Agency (FSA) for a risk assessment in relation to the earlier (2008) food sample results. For the vegetables, the FSA advised that levels of nickel, cadmium, chromium,

copper, arsenic and zinc are not a concern. However, the concentrations of lead were much higher than normal UK background levels, “probably because of soil [containing high lead levels] adhering/trapped within the leaves.” The egg sample also contained concentrations of lead much higher than background levels.

FSA advised that consumption of eggs and vegetables from this location, if not peeled and washed, would significantly increase dietary exposure to lead – by up to several hundred times in the case of the cabbage, which had the highest levels among the samples tested, and up to eleven times for a toddler consuming the eggs in high quantities. FSA advised that these increases in exposure would not be advisable, and for infants, toddlers, young children, would well exceed the minimum level associated with a decrease in IQ (without taking into account any additional exposure through ingested water and soil, and household dust). FSA further advised that the cumulative risks would be lowered if the vegetables were consumed only rarely, and thoroughly washed and peeled beforehand; occasional consumption of the eggs, and of the turnips (which contained the least lead), may be less of a concern. The FSA concluded that consumers (of the produce from that one source) should be strongly advised to wash and peel any of the vegetables before eating them, and that consumption of vegetables and eggs from this source, by children and pregnant women, is not advisable.

It must be noted however that this analysis was on samples of produce from one single location in Leadhills, on one occasion only, in 2008. The samples were not analysed in accordance with normal practice in terms of washing and peeling before use and the results may well have overestimated the lead levels as a result. These results cannot therefore be considered as representative of produce for the whole area under investigation and should not be generalised for all produce from the area.

In the absence of more representative data on food produce for the Leadhills and Wanlockhead area, comparison can usefully be made with the former zinc and lead mining village of Shipham in Somerset, where a detailed investigation of the impacts of heavy metals contamination of local soil was launched in 1979.¹² This found high levels of cadmium, lead and zinc in particular in locally-grown potatoes, cabbage, spinach and other similar crops – although the concentrations tended not to exceed a maximum ‘plateau’ level. Despite some villagers consuming considerable quantities of these vegetables, no evidence of adverse

health effects was reported, including amongst children. A similar picture has been found with respect to areas of high soil concentrations of cadmium in Jamaica.¹³

The Shipham investigation found that offal from local animals tended to be particularly high in contaminant metals, but this was unlikely to present a major hazard given typically low levels of consumption. Animal pastures tend to have a natural threshold for uptake of metals, and there is some evidence for mutual displacement in plants between zinc and cadmium. The FSA provides general advice to farmers and landowners who graze livestock in areas where there is the potential for higher than normal background levels of geochemical lead, including advice on grazing practices on known contaminated areas.

In an assessment of the human health risks arising from the consumption of meat derived from flocks grazing in lead-contaminated areas such as Leadhills, the FSA made reference to seven cases of on-farm lead poisoning in animals that occurred in and around the Leadhills area between 2005 and 2011. Specific information about these incidents, including any direct association with elevated soil lead levels (rather than, say, batteries or lead paint), was not available. Other information that would have helped interpret the significance of these cases, including the “background” incidence of clinical lead poisoning in sheep in the UK, the frequency of subclinical and undetected clinical cases, and relative likelihood of ‘geochemical’ versus other sources of lead was not available at the time of completing this assessment. However, the FSA assessment concluded that “the risk for the public health arising from grazing of farmed animals for human consumption in a known lead contaminated area such as Leadhills is low.” This was based on the existence of measures for managing the risk from possible contamination: routine clinical surveillance of animal health, checks undertaken at slaughterhouse (post-mortem inspection of offal), and a national statutory programme of checking lead and other heavy metal levels in meat. The Scottish Government Animal Health and Welfare Division have reportedly advised that these measures are proportionate for the level of risk currently measured.

With respect to animals hunted as game, lead is known to accumulate in the liver, kidneys and bones. FSA therefore would advise avoiding consumption of offal from locally-sourced game, as well as removing any visible shot.

From an NHS public health perspective, on the basis of the limited evidence available, there is insufficient data to provide general advice in relation to the risk associated with consumption of locally produced foods including fruit and vegetables, and livestock products including eggs or meat. However, evidence from other similar situations (e.g. Shipham) suggests that the risk of harm associated with consumption of local produce is likely to be low. Residents may however wish to have their own produce analysed on an individual basis, especially if there are young children or a pregnant woman in the household and likely to consume the products.

Risk associated with contaminated fish

There may be some risk attached to consuming trout or other fish caught from contaminated waterways. It is reported that angling is concentrated locally at Leadhills Dam, and is very limited in Glengonnar and Wanlock Waters. However, in the absence of data confirming that, or on the levels of metals in fish from Glengonnar and Wanlock Waters, the risk associated with this potential exposure pathway cannot be fully assessed. Given that these watercourses are considered sufficiently contaminated to need remediation, precautionary advice would be to avoid the consumption of any fish caught in them, unless and until there are data to confirm the absence of excessive accumulation of contaminants in the fish. The same advice could reasonably be applied to other local waters that have not been subject to testing, until there is evidence confirming a lack of contamination in the water or fish. However, testing of a sample of fish from Leadhills Dam has been carried out, and all were satisfactory for lead, zinc and cadmium, so there is no need to avoid consumption of fish from this source from point of view of metals contamination.

Risk associated with physical health and safety (accidents and injuries)

SEPA's report makes reference to the possibility of a sudden release of water, and health and safety issues around collapsed mine shafts and open pits in the area. The potential for more gradual accumulation of water leading to flooding / water ingress into local properties may also be a concern. Discussions and investigations into these issues involving SEPA, South Lanarkshire Council and the landowners have taken place. The Council reports that it has

undertaken improvements to reduce the risk of flooding and damage to the local road, that no damage has occurred since this work was completed, and the work is inspected regularly.

This is reassuring, but more information would be needed to fully assess the hazards from a public health perspective, to quantify the scale of the risk of a water 'blowout' and to map the size, distribution, accessibility and fragility of fissures and shaft collapses etc around the communities concerned. In the absence of further information on the results of the investigations and remedial work carried out, NHS Lanarkshire and NHS Dumfries & Galloway were unable to make an assessment of the levels of risk associated with these hazards at the present time.

Impacts on human health: other available evidence and guidelines

The Joint Expert Committee on Food Additives (JECFA) previously set a Provisional Weekly Tolerable Intake (PWTI) for lead. However, this has very recently been withdrawn on the basis that evidence continues to accumulate that lead exposure, even in low doses, resulting in absorption may have low level impacts on health (e.g. low level increases in blood pressure and small reductions in measured IQ). The JECFA view is now that there is effectively no acceptable minimal exposure, particularly via lead in drinking water or food sources.

Given that there is no longer an accepted threshold for lead's effects on human health, the long-standing nature of the contamination around Leadhills and Wanlockhead means that residents may be more likely than the general population to be exposed to lead. Consequently such long term exposure might have some low level impact. Such impacts directly attributable to chronic lead exposure are likely to be very difficult to detect, given all the other factors which determine any individual's health status. NHS Lanarkshire and NHS Dumfries & Galloway have explored the availability of local-level data through which to investigate any potential impacts of the contamination on local morbidity and mortality rates further. However, the potential unreliability of health data analyses based on small populations meant that a detailed statistical evaluation was beyond the scope of the present assessment. This paper therefore represents the best assessment of health risks based on the information that is currently available.

CONCLUSIONS ON THE PUBLIC HEALTH RISK ASSESSMENT

- The recent SEPA report findings confirm past understanding that there is a historical legacy of local contamination associated with the old mining industry.
- The overall scale and nature of soil contamination in the Leadhills/Wanlockhead area is uncertain, and the potential for exposure is dependent on factors that have not been explored in detail in the recent investigation (e.g. soil acidity, contaminant bio-availability, and the ratio of bare earth to covered soil). However, the samples of floodplain soil and sediment from the watercourses all showed significant levels of lead, zinc and cadmium, plus copper and nickel. Physical contact, ingestion or inhalation of soil or dust originating from gardens and farmland may pose a very limited direct risk of increased exposure to lead and other metals but the available data are insufficient to justify advice on specific action to limit such exposures beyond good normal hygiene practice, outdoors and in the home.
- The concentrations of lead, zinc and cadmium measured in Glengonnar and Wanlock Waters are very unlikely to pose a significant risk to anyone via external physical contact.
- The risk from one-off, or limited instances of ingestion of raw water from these sources, such as are likely to be associated with exposure among occupational or recreational users of the area, is unlikely to be of significant public health concern.
- The evidence in relation to waterborne exposures suggests that local residents on public (Scottish Water) mains supply are not at risk, and that those reliant on private sourced drinking water are unlikely to be at significant risk (pending final tests on some supplies).
- With respect to the risk of exposure associated with consumption of locally grown plants and animal produce, the evidence from Shiphams and elsewhere, of an absence of harm to health, is reassuring. Although seven cases of lead poisoning in animals in the area were reported for 2005-2011, the inspections and surveillance regimes in place and the assessment of the FSA provide reassurance with regard to the risk to human health from meat produced from around Leadhills and Wanlockhead.

- The limitations of the sampling and analysis methods on the food produce from a single location in Leadhills on one occasion in 2008, means that the results cannot safely be applied generally to produce grown in the area. The advice FSA issued can only be reasonably applied to the produce from that source. The data available at present do not permit a comprehensive assessment of the source, types and extent of contamination of soil and dust, and of vegetables, eggs and other local produce in the affected areas. Specific sampling and analyses would need to be carried out on an individual basis to provide advice on individual sources of local produce.
- In relation to the local fish, the confirmation that metal levels exceed environmental quality standards in the contaminated watercourses, together with the absence of any data on metal levels in fish found in these watercourses, could justify a precautionary approach; meaning that it would be prudent not to eat fish caught in these rivers. Similarly, although there is no direct evidence of contamination in other waters, the most precautionary approach would be to avoid consumption of fish caught elsewhere locally (lochs and streams), unless and until data confirming the absence of contaminants in such fish is available. Results of tests on samples of fish from Leadhills Dam, the local centre for angling, were satisfactory for lead, zinc and cadmium. There is therefore no need to avoid consumption of fish from this source in relation to metals contamination.
- There is clearly a degree of physical hazard. Although some remedial works have been carried out the information available at the time of completing this assessment was insufficient to quantify the risk of physical accident and injury associated with former mine workings across the whole area.
- In light of the limitations of existing data, it is not possible to provide a completely definitive public health assessment of the potential risks associated with the residual environmental contamination resulting from the lead mining legacy in the area. However, based on the existing data and other evidence from similar situations, the overall conclusion of this public health risk assessment is that the risk to the health of local residents is likely to be low.

Risk management and risk communication options

Complete removal of all residual mining waste material resulting in metals contamination in the Leadhills and Wanlockhead has never been suggested as an option and is not currently under consideration. On that basis, the potential for exposure to environmental metal contamination will remain. It therefore makes sense to take this opportunity to advise local residents on practical measures to reduce the potential for avoidable exposure to any contaminants in the local area, especially lead.

The above conclusions should therefore form the basis for providing advice to the local residents in Leadhills and Wanlockhead, timed to coincide with the formal release of the investigation report by SEPA.

The opportunity should be taken to remind people of the measures that could help limit any exposure to metal contamination (and other hazards such as general microbiological contaminants) via soil or dust, based on standard good food and kitchen hygiene practice, and domestic dust control (e.g. using damp dusting and possibly a particulate-filter type of vacuum cleaner). In addition local residents should be reminded of other avoidable sources of lead contamination, particularly from lead pipework in older properties. It may also be appropriate to publicise the finding from the Shipham study that smoking approximately doubles cadmium levels in the body, compared to the effect of environmental concentrations.

RECOMMENDATIONS

1) **Coordinated Multi-Agency Communications Strategy**

A co-ordinated strategy is required involving agreement by all the relevant public agencies, to provide information and agreed advice to the local residents, which should be based on the following principles:

- Residents of the affected areas should be given clear, accurate information about the contamination of the Glengonnar and Wanlock Waters, the investigation findings to date, and the conclusions and recommendations of this health risk assessment.
- Advice to the public about the implications of the recent SEPA-commissioned investigation results, and the relevance of previous data in relation to human health effects, should be based on the conclusions of the assessment above.
- This information should be conveyed to local residents and other stakeholders using a restricted set of co-ordinated communication materials, produced collaboratively by SEPA with contributions from NHS, local authority and other agencies involved. The range of materials distributed should be limited to agreed materials using agreed wording. Individual agencies should avoid producing additional materials for their sole use which contain any contradictory advice.
- The release of materials should be planned and coordinated to minimise the time intervals between different parties being informed.
- The priority target audience for advice should be the local residents, who should be provided with a specific door-delivered set of information comprising a letter and brief, plain English Q&A leaflet explaining the findings of the SEPA report and its implications. The main agencies involved should work together to identify the set of specific home addresses to which these materials should be distributed.
- The same materials should be provided to other significant individuals living and working in the local community, especially the local General Practitioners, Community Health service staff and community leaders.

- Local political representatives should be briefed at an appropriate point to enable them to respond to constituent enquiries.
- Prior to the distribution of the door-delivered materials, local GPs and other key primary care professionals should be given advice and assistance with preparing for any patients who may present with concerns or requests relating to the information they've received.
- Opportunities to generate feedback on the quality and utility of the information provided to residents, and details of who to contact for further information and advice (e.g. GPs, SEPA, the local authority or health board), should be incorporated in the materials distributed.
- Depending on desire or demand expressed by residents, local primary care staff and political representatives, the door-delivered distribution of materials should be followed up by the provision of additional avenues for information to be offered and concerns heard by the agencies involved. Appropriate arrangements should be discussed and carried out jointly by the main agencies involved in providing advice to the public on health risks, in particular the NHS and the local authorities.

Content of risk communication advice

The following are the priority risk communication messages which should be incorporated in advice materials for distribution.

1. Residents should be reassured about the low level of risk associated with casual physical contact with the contaminated waters, and the relative lack of risk of very occasional consumption of water direct from affected water courses.
2. Local residents should be reassured of the safety of the (Scottish Water) public water supply.
3. Users of the private water supplies in the affected area can be broadly reassured, with the caveat that testing is required in the Wanlockhead supplies to confirm the absence of any excess levels of metals not previously tested for; owners/users of those supplies should be advised to contact Dumfries & Galloway Council Environmental Standards to arrange testing.

4. Residents should be advised that there is likely to remain an ongoing low level hazard associated with lead and, potentially, other heavy metals and exposure via soil or dust. They should be advised that the risks of exposure to contaminants can be minimised by practising good household and kitchen hygiene, including regular (damp) dusting; vacuuming (e.g. with a particulate filter standard of machine); and by restricting the entry of soil and other potentially contaminated material into the home via shoes/clothing and household pets.
5. Residents should be advised to practice high standards of food and household hygiene, and to ensure they and their children avoid any ingestion of soil or other potentially contaminated non-food material. They should be advised that all fruit and vegetables, especially if sourced from the area, must be washed thoroughly in tap water and where appropriate, peeled before consumption. This is in line with the Food Standards Agency's general advice on the safe preparation of fruit and vegetables.
6. Residents should be advised that the risk to health arising from grazing of farmed animals for consumption is likely to be low, and is addressed by general advice to farmers/landowners, and routine checks on animal health and on meat. They should also be advised in respect to locally-sourced game that consumption of offal should be avoided, as liver, kidneys and bones can accumulate lead, and in general for game, any visible shot should be removed.
7. Individuals who grow their own produce, have egg laying chickens or rear livestock should be advised to consider having samples of produce analysed to determine if any limitations are required on consumption, especially if there are young children or a pregnant woman in the household.
8. As there is no data on metals in fish from the affected watercourses (Glengonnar and Wanlock Water), as a precautionary measure consumption of such fish should be avoided by everyone, unless and until appropriate analyses demonstrating their safety have been carried out. Avoiding consumption of fish caught from other local waters would likely be more of a precaution, given the evidence of absence of accumulation of lead or other metals in fish caught from Leadhills Dam,

9. Residents of older properties should be advised to check for any remaining lead plumbing or pipework and that this should be removed and replaced with modern lead free substitutes
10. Cigarette smokers should be advised that smoking increases body cadmium levels and is another reason to limit or stop smoking.
11. Residents and others should be advised of the hazards in the physical environment around the mine shafts and other workings. Details of these hazards will come from the latest discussions and investigations involving the local authority, landowners and SEPA. Any need for remediation that is achievable, or for the hazards to be better secured and marked to reflect the significant risks they pose to people, should be addressed.
12. Residents of Leadhills and Wanlockhead should be informed that, based on all the existing data, the overall risk to their health associated with exposure to mining waste metal contamination in the area is considered to be low.
13. Based on the existing evidence, the risk of excessive lead exposure is not considered sufficient to recommend individual health investigations, such as blood lead testing. However, if anyone is particularly concerned about the health implications, further advice on the need for investigations will be available from their local General Practitioner.

2) **Recommendations for potential further investigations of the longstanding environmental contamination due to the historical mining operations and their legacy:**

The area around Leadhills and Wanlockhead has long been known to be contaminated with the residue from the lead mining industry. It is likely that there has been a general acceptance that this is a long-standing situation by the local residents over generations. There has been no specific initiative to investigate the entire area as a potential contaminated land area under existing legislative measures, and there are no existing plans to do so. There are some uncertainties regarding the precise position of this area in terms of legislative responsibility, due to the history of the contamination being due to mine working. South Lanarkshire Council and SEPA have agreed to seek to use SEPA's Regeneration Fund to undertake work to

remediate the impacts of mining in the area, and on Glengonnar Water's water quality, in order to achieve the aims of relevant regulatory regimes. Whether any further environmental investigation would be useful, desirable or practicable is open to debate.

Given the limitations of the recent SEPA-commissioned investigation, and the limited historical data on the environmental contamination legacy from the historical lead mining operations, local residents will have their own views on whether further environmental investigations might be appropriate. Efforts should be made by SEPA and other agencies to capture such views and assess these in order to determine if there is a consensus on the desire for any further investigations.

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ANNEX A

Health risks associated with metal contaminants found at Leadhills and Wanlockhead

The primary sources of information used to generate this summary were the World Health Organisation International Programme on Chemical Safety's Environmental Health Criteria for Lead,¹⁴ Zinc¹⁵ and Cadmium,¹⁶ and the relevant pages of the Toxbase website.¹⁵

Lead can have a wide range of effects on health, depending upon the level and duration of exposure. It is relatively more toxic to very young children (especially under two years) and to the foetus in *utero*, hence pregnant women are also a risk group. Lead affects many biochemical processes, from inhibiting enzymes and disrupting haemoglobin synthesis, to producing marked morphological changes and impairing psychological and neuro-behavioural functioning. One of the main effects in children, measurable even at relatively low levels of exposure, is a small reduction in the average IQ scores. Long-term high-level occupational exposure has been associated with peripheral neuropathy, renal damage and carcinogenic effects.¹⁷ Such serious health effects are however, exceptionally rare in the general population who are normally exposed to lower lead levels.

Lead toxicity most frequently results from ingestion or inhalation and rarely from skin exposure. Elemental lead is less well absorbed than soluble lead salts, which are highly toxic and can be fatal in doses of as little as 0.5 g. Children absorb considerably more ingested lead (quoted ranges 50-80%) than adults (3-10%) and are thus at greater risk of developing toxicity.

Blood lead concentration reflects only recent exposure and so does not correlate well with total body lead burden. In the general population, whole blood concentrations are normally less than 2 micrograms/decilitre (2 µg/dL). Concentrations in excess of 60 µg/dL in children or 80 µg/dL in adults are usually associated with severe toxicity. At lower concentrations, non-specific symptoms may be present. There is substantial evidence that blood lead concentrations of 30-40 µg/dL have adverse effects on the nervous, haematopoietic, renal and reproductive systems. This informs the acceptable thresholds for action set in regulations, but practice does vary internationally; toxicologists in the US, for example, are generally more interventionist than in the UK, and typically apply a threshold of 10 µg/dL.

Zinc is an essential trace element. Acute zinc poisoning is associated with symptoms of nausea and diarrhoea, but the principal toxic effect from chronic ingestion is that of a disproportionate intake relative to copper, which can result in copper deficiency. High pharmacological intake of zinc (0.85-1 g / day of zinc gluconate) has been associated with effects ranging from leucopenia and anaemia to decreases in serum high-density lipoproteins.

Cadmium accumulates primarily in the kidneys and has a long biological half-life (10 to 35 years). The kidney is therefore the organ most at risk from cadmium toxicity. Ingestion in large quantities in the form of soluble cadmium salts causes acute gastroenteritis. Larger amounts can also have effects on the metabolism of calcium and zinc, and cause facial and pulmonary oedema. Death has been reported following ingestion of up to 150 g of cadmium chloride. Skin contact can cause irritation.

Long-term occupational cadmium exposure has caused severe chronic lung (primarily chronic obstructive airway disease) and kidney (tubular dysfunction leading to proteinuria) effects. High exposure to cadmium can disturb calcium metabolism, leading to formation of renal stones, and – most probably in combination with other factors such as nutritional deficiencies – may lead to osteoporosis or osteomalacia. The International Agency for Research on Cancer classes cadmium as a “probable” human carcinogen by inhalation exposure, but there is no clear evidence of carcinogenesis or genotoxicity by oral exposure.