ANNEX B2

SUPPORTING MATERIAL FOR THE SIMPLIFIED CONTAMINATION RISK ASSESSMENT

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B.2.1 Acidity and alkalinity

Acid Rock Drainage (ARD) is produced by chemical and biological oxidation of sulphide, creating a sulphate acid solution that has a significant impact on the environment. In acidic conditions (pH <5.5) metal ions and toxic salts are brought into solution, the activity of micro-organisms, the agents of breakdown and decay, is restricted, and shortages of available calcium and phosphate are induced in soils. In acidic water and soil, toxic concentrations of aluminium, iron and manganese are commonplace and other metals, such as Cu, Pb, Cd, may be present in toxic concentrations (Williamson, Johnson and Bradshaw, 1982).

The main source of acidity in mine wastes and water is iron pyrite. This may be present in three common forms: pyrite (Fe_2), marcasite (FeS_2) and pyrrhotite (Fe_nS_{n+1}). Each of these weathers at a different rate, with marcasite oxidizing nine times faster than pyrite and pyrrhotite eighteen times faster. Pyrite bearing wastes disposed of at neutral or slightly alkaline pH can weather within months or years to produce extreme acidity, assisted by the ferrous-ion oxidizing bacteria, *Thiobacillus ferrox-idans*, which thrives at pH 1.5 – 3.0 (Williamson, Johnson and Bradshaw, 1982).

Runoff and seepage from the pyritic tailings at Otjihase are causing pollution in the nearby river. Note the formation of salts. The reddish colour is from iron precipitation.

The rate of oxidation in mine wastes and in underground workings is influenced by the surface area of the material available for weathering; small particulates such as mill tailings weather faster than larger pieces of rock. Humidity, oxygen concentration, pH and the presence of sulphur oxidizing bacteria all influence the oxidation rate (Williamson, Johnson and Bradshaw, 1982).

In the case of rock fractures that contain acid-generating minerals, acid drainage occurs on their faces and other areas that are exposed to oxidation. Generally, infiltrating rainwater is the medium that carries the dissolved metals. Additionally, if the mine progressed below the level of the water table, it is normal for the water table to recover once the mine is closed and thus groundwater will come into contact with acid-generating materials. Water carrying dissolved metals can move towards the regional groundwater aquifer or daylight on surface causing contamination in groundwater or in surface water bodies respectively. The severity of the pollution will depend on a number of factors such as mean annual precipitation, dilution factors in the receiving water body and the buffering or neutralizing capacity of the host rock and/or receiving aquifers.

Considering that the sites covered in this Handbook have been abandoned or shut down and have been out of operation for several years, acid mine drainage may become a major long-term problem since there is no longer any active dewatering of the underground workings. This means that groundwater will slowly build up underground and its residence time in contact with acid-generating materials will exacerbate the problem.

The main evidence that acid drainage is occurring is the pH of the water that drains out of the mine site. Because of this, measuring this parameter is essential for assessing contamination risk.

It is important to point out that almost neutral or alkaline drainage can exist under certain conditions, with pH values more than eight. The secondary effects of alkalinity are of great significance for rehabilitation, particularly in soils and mine waste materials; deficiencies of the macro-nutrients Fe, Mn, B and Mg may occur and phosphates are removed from solution by the formation of insoluble calcium phosphates. Nitrogen, an important plant nutrient, may also be lost as ammonia by the action of strong bases on ammonium salts (Williamson *et al* 1982).

Increased solubility of the atmospheric metals aluminium and zinc causes toxicity at very high pH. Zinc begins to come into solution at pH of 9.0 and aluminium at about pH 7.8. Alkaline tailings frequently have excessive quantities of soluble salts that restrict plant growth. Therefore runoff from these types of wastes usually has a high salinity.

For these reasons, this Handbook includes assessment criteria for contamination when pH readings are Basic, i.e. when their value is greater than 8.

For more information about ARD, the following references may be useful:

> The Methodological Guide to Acid Drainage in the Mining Industry, created by the National Clean Production Council - Mining Council, in November 2002.
>
> Acid Rock drainage Technical Guide, prepared for the British Columbia Acid Mine Drainage Task Force by Steffen Robertson and Kirsten Inc. August 1989.

Williamson, NA, Johnson, MS and Bradshaw, AD (1982): *Mine Wastes Reclamation: the Establishment of Vegetation on Metal Mine Wastes.* Mining Journal Books, London, 1982.

B.2.2. Identification of Hazardous Waste inside the site

Hazardous waste found at a SD/AMS not only represents an important safety risk but could also pose a risk of contamination due to its toxicity, which could affect any sort of receptor that it comes into contact with. The Assessor must carry out a detailed inspection of the site, looking for direct and indirect evidence to determine the presence of such waste. Special care must be taken to detect the existence of buried waste that may not have proper signage.

The types of hazardous substances that an Assessor may find in a SD/AMS include the following:

- ✓ Waste with a high metal content, such as arsenic waste that comes from the roasting of concentrates, mercury waste from amalgamation processes, smelter dust and sand, waste containing copper, molybdenum, zinc, etc.
- ✓ Waste solutions that may have remained in the old plant tanks or ponds.
- ✓ Remains of consumables or reagents used in the plant processes.
- ✓ Materials with asbestos used in construction and as insulation in equipment.
- ✓ PCBs in electrical capacitors and oil in transformers.
- ✓ Oil and lubricant sediments or materials contaminated with this type of waste.
- ✓ Scrap iron and other minerals impregnated with hazardous substances.
- ✓ Waste containing explosive, corrosive or inflammable substances.
- ✓ Radioactive waste e.g. mine tailings.
- ✓ Explosives.

The type of hazardous substances that can be found in a SD/AMS is related to the type of deposit and extraction processes used and, therefore, to the substances that were used when the plant was in operation; for this reason the Assessor must compile as much information as possible regarding the minerals and processes that were used.

The Assessor must determine the existence of hazardous waste and at the same time assess the possibility that this waste could come into direct contact with receptors, either through the soil or through surface or groundwater (this last point will be dealt with in the following section).

In order to determine if mining or industrial waste present at a SD/AMS is hazardous or not, the Assessor must refer to the definitions contained in the IMDG Code for hazardous wastes. The sequential analysis described below has been based on best practice, which enables identification of the hazardous characteristics of certain types of waste (Figure 1):

- **Step 1.** When dealing with large-scale mining waste (potentially hazardous because old sites are involved) such as tailings, semi-processed material, or waste from leaching, sample taking is recommended to determine hazardousness of the material through a **Synthetic Precipitation Leaching** test for measuring toxicity.

  Such tests are required because of the potentially hazardous nature of waste that has remained at sites which were abandoned or shut down years ago. This waste probably has higher concentrations of Chemicals of Potential Concern than those found in waste generated nowadays; it is therefore useful to determine if any of the large-scale mining wastes present at the site (especially process waste such as tailings, or semi-processed ore) displays toxicity and is therefore hazardous waste.

  Where the Assessor determines that the large-scale mining waste is not potentially hazardous (possibly slag and sterile waste), it is deemed to be non hazardous waste.

- **Step 2.** If the mining waste is not large scale the Assessor should check to see if it is included in the IMDG Code. If it is not on the list, the waste is not hazardous.

- **Step 3.** The following step is to check if the waste features in the IMDG Code. If it appears on the list, the waste is hazardous.

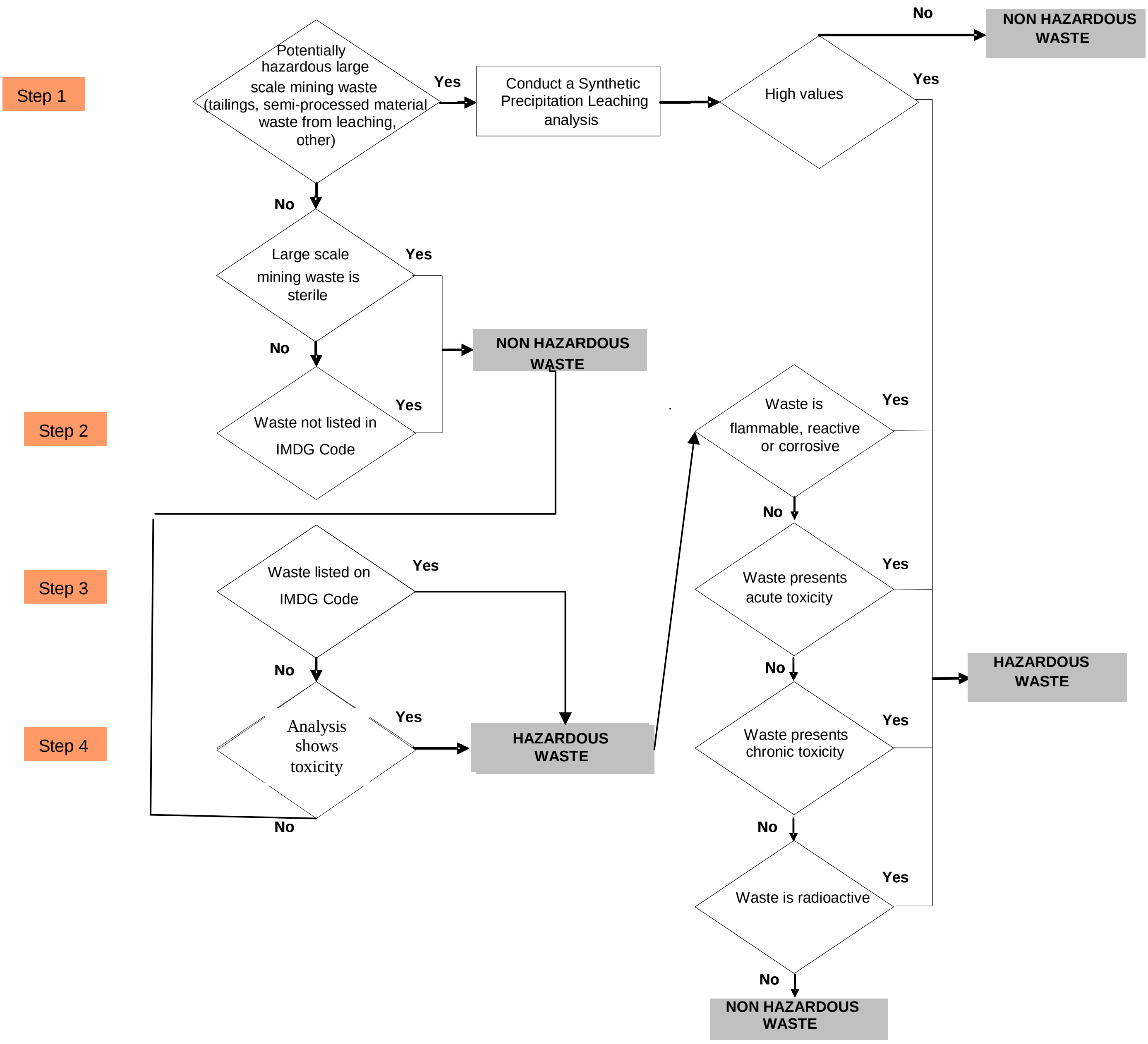
- **Step 4**. If the nature of the waste is unknown, it must be sampled to determine its chemical composition.

Finally, in order to determine if a waste is hazardous or not, it is worth bearing in mind the following:

- The toxicity of waste on the ground must be assessed. This is done using the **'Leaching Toxicity Test'.** The waste shall be considered hazardous when the test yields concentrations greater than the Maximum Permissible Concentrations, MPC.

- Alternatively, the MME can determine that waste IS NOT hazardous when, after analysis by an approved laboratory, it is found that the concentration of substances expressed in milligrams of substance per kilogram of waste, is lower than the prescribed concentrations contained in the Regulations of the Pollution and Waste Management Act.

Figure 1. Suggested flow chart for identifying Hazardous Waste



- '**Synthetic Precipitation Leaching'** is used instead of the **'Leaching Toxicity Test'** in order to determine the extrinsic toxicity of large-scale mining waste.

- The **relevant government ministries** reserve the right to sample, analyze and determine the hazardous nature of large-scale mining waste (sterile waste, low-grade ore, heap leach waste, slag and tailings), whenever they deems necessary.

B.2.3. Runoff or seepage of toxic or hazardous substances from processing plants or small-scale waste due to rainfall runoff.

Stormwater runoff from a potentially contaminated site can transport chemicals of potential concern into surface water courses and this water can also infiltrate into the groundwater. The rate of transport, degree of contamination and impact on the receptors depends on a number of factors including the following:

✓ The level of protection of the wastes against stormwater runoff; in other words, it is much easier for contaminants to be transported away when the wastes are uncovered, or are not enclosed, or when there is no stormwater control.

✓ Annual rainfall in the area, considering the possibility of unusually high rainfall in some years (the 'El Niño' phenomenon). The potential for run-off is reduced in very dry climates with annual rainfall around 200 mm, and increases progressively as annual rainfall increases.

✓ The slope where the abandoned site is situated, as steeper slopes provide more favourable conditions for natural runoff.

✓ The distance between the site and surface water sources.

✓ The depth of the water table. This is difficult to estimate on land but it can be obtained from wells close to the site and by interviewing local inhabitants.

In general, it is less feasible for hazardous waste to reach a receptor body when the site is located in an area with an annual rainfall of less than 200 mm. It is also less feasible in flat areas and where the nearest watercourses are more than 1 km away. On the other hand, it is more likely for hazardous waste to be transported under conditions of higher rainfall, steep slopes and where watercourses are close to the site.

The Assessor therefore must take all of these aspects into account when determining the likelihood of contaminant transport.

B.2.4 Wind drift of contaminated particulate matter

Abandoned tailings dams located in low rainfall areas usually have large expanses of dry, unconsolidated material. One of the main risks from these dams is the release of particulate matter into the atmosphere when fine particles (PM10) containing potentially harmful contaminants are transported to where they can damage the health of people and the surrounding environment.

The old tailings dam at Oamites is highly susceptible to wind erosion causing health problems at the nearby military camp. The tailings contain elevated concentrations of uranium and heavy metals (see Box 3 in Chapter 6)

Other sources that could release contaminated particulate matter into the atmosphere include small-scale accumulations of hazardous waste and, eventually, heap leach waste with fine material on the surface.

Airborne particulate matter (PM10) can be inhaled by people visiting the mine site or living in the surrounding area, putting their health at risk. This scenario is particularly relevant in cases where human receptors live less than 1 km away, or in zones 1 to 3 km away in the direction the wind usually blows. It is advisable to interview local inhabitants and authorities to determine whether particulate matter from the site's waste dumps has reached receptors located in the area of influence.

The emission of particulate matter from a tailings dam or other type of dump will depend on factors such as:

- ✓ Wind speed and direction: the force required to keep the material in suspension and the direction it is carried in.
- ✓ The moisture content of the material, as it can only be suspended from a dry surface.
- ✓ The material's grain size.

In order for particulate matter to be transported, fine material capable of being suspended by wind action must be present in the deposit. In general, the most common particulate matter in risk assessments is matter with a diameter of less than 10 microns (PM10), as this particle size can be breathed in, causing adverse health effects on different receptors.

Because special equipment is required to measure PM10, it is recommended that soils be classified using a 200 mesh (75 microns). Classification of fine material can be done on site by using the mesh to determine if most of the material in the deposit being assessed has the smaller grain size.

Where the deposits assessed, especially tailings, show cementing, agglomeration or any other feature that produces cohesion of the fine particulate matter present, the Assessor may assume that this material will not be suspended, even when a high percentage of fine material is present. The Assessor should also take into account the time of year, as more fine material may be present during dry periods than in the rainy season, when rain can favour agglomeration.

In general, the Assessor should consider the existence of fine material when it is found in dust form or could easily turn into dust.

The possibility of these substances being released and transported through the air is considerably reduced when coverings or other wind protection measures are placed over contaminated material. In general, the most efficient protection is provided by large grained materials (rocks and coarse and fine gravel) when they are at least 30 cm thick or when they are placed across the prevailing wind direction in ‘windrows’. These two conditions combined should offer resistance to wind erosion and as a consequence should prevent contaminated particulate matter from entering into suspension.

Other effective coverings include dense vegetation, chemical binders and synthetic materials such as geotextiles, geomembranes and others.

The Assessor must determine whether such cover exists and how efficient it is, in order to adjust the likelihood of occurrence of a Hazard Scenario to real levels in line with the conditions found at the deposit site.