Water Quality Protection Guidelines No. 3

Mining and Mineral Processing

Liners for waste containment

2000

1. Introduction

Liner systems are used in mining and mineral processing operations to restrict seepage of leachate from containment and storage areas. Their purpose is to prevent stored material from contaminating the environment. Premature failure of liner systems may result in severe effects on the environment and, in the case of heap leach operations, the loss of valuable mineral-enriched solution. It is important the integrity of liner systems is maintained throughout the life of a project and beyond to ensure long-term isolation of material harmful to the environment.

2. Purpose

These guidelines are designed to be used for the construction of liners required to contain chemicals, ores or waste.

3. Scope

These guidelines apply to any operation where liners are required to protect the quality of water resources in the vicinity of mining and mineral processing operations.

4. Regulatory requirements

The Department of Minerals and Energy (DME) will assess proposals for lining systems. There are also provisions under the *Environmental Protection Act 1986* (the EP Act) to issue a Works Approval (to construct) and Licence (to commission) the use of liners to contain leachates and other solutions at mine sites. The DME will assess proposals for lining systems. The DEP and DME may seek advice from the Commission on issues relating to the protection of water resources.

5. Guidelines

5.1 General

a. Selection of a liner system depends on the hazard posed by the contained material, susceptibility of the liner material to attack by the contained material, time span of containment, local soil conditions and vulnerability of the environment. The higher the risk or more sensitive the environment, the more comprehensive the containment should be.

b. Liner systems may consist of:

- natural or engineered in-situ low permeability soils, grubbed, ripped, watered to optimum moisture content, compacted and rolled to achieve > 95% Maximum Dry Density (MDD) as provided by Australian Standard (AS) 1289;
- single-layer clay or synthetic liners;
- multi-layer liners with interstitial water recovery/monitoring layers.

c. A competent and experienced professional should supervise construction of all containment facilities. A compliance document (required by DEP) should advise that the construction was completed as per the proposed and approved design specifications.

d. The type of materials that can be used for waste containment in non-rigid liner systems are listed on the following page.

Liner material	Attributes
Granular protective layer	* protects liner /drain system during initial dumping * minimises drying out of compacted clay liners * permits recovery of residue without liner damage * prevents UV light damage to PVC liners
Subsoil drain	* permits depressurisation of primary liner * enhances residue consolidation * enhances liquid recovery
Primary liner	
- compacted clay soil (permeability < 10^{-9} m/s)	* normally won't deteriorate
- high density polyethylene (HDPE)	* abrasion and ultraviolet radiation (UV) resistant * joints: heat weld or mechanical
- polyvinyl chloride (PVC)	* will deform without shearing in made-up ground * may lose plasticity with time * susceptible to UV deterioration (unless treated) * unsuitable for retention of some hydrocarbons
- composite synthetic	* polyethylene/bentonite * plastic/fibre reinforced
Underdrainage/ monitor layer	
- granular layer with drain pipes to collector sump	* permits seepage monitoring * permits seepage recovery * depressurises secondary liner
- free draining mesh or net separator to collector sump	* speedy installation * takes up little volume
Secondary liner	
- compacted soil with HDPE, PVC or composite synthetic	* natural or imported low-permeability (< 10^{-9} m/s) soils with HDPE, PVC and composite liner attributes as given above
Natural soil base layer	* surface cleared of vegetation, free of stones > 75 mm and any other material that may cause damage to a liner * fill well-graded and compacted to provide a firm, unyielding foundation sufficient to permit the movement of vehicles and welding equipment without causing rutting or other deleterious effects * suitable for sites > 2 m above maximum water table

NOTE: The greater the hazard, the greater the need for multi-layer liner systems

5.2 Non-synthetic (clay) liners

a. Compacted soil liner thickness should be 300 mm or greater.

b. The compliance document should indicate that:

- Soils used for the containment lining conform to the approved design specification for a water-retaining structure. Unless otherwise agreed, all selected liner material should conform to the following minimum criteria:

Percentage fines passing a 75-micron sieve: greater than 25% Liquid limit: less than 70 Plasticity index: greater than 15 Emerson class number: 5 to 6

- The soil liner has been placed in a maximum of 150-mm layers and compacted to achieve at least 95% of maximum dry density at optimum moisture content, in accordance with AS 1289.
- Each compacted layer has been tested to confirm that design densities have been achieved.

  <u>For gross area of less than 1 hectare:</u>

  A minimum of one test for every 1250 square metres of waste containment area and one test per 35 lineal metres of perimeter embankment are recommended.

  <u>For gross area of greater than 1 hectare:</u>

  A minimum of one test for every 5000 square metres of waste containment area and one test per 70 lineal metres of perimeter embankment are recommended.
- Special care has been exercised with embankments to achieve:
  a) equivalent low-permeability seal to the base liner;
  b) design soil densities;
  c) erosion resistance and resistance to the threat of slumping/piping failure (on slopes this may involve placement of extra fill and subsequent cut back to design dimensions).
- The completed holding facility has where practical been proof tested to confirm initial seepage from any containment module does not exceed 1000 litres/day or 0.04% of the design contained volume/day, whichever is the greater. This seepage rate has been based on a design maximum hydraulic conductivity for the liner of 1×10^{-9} metres per second (~ 8×10^{-5}metres/day), when subjected to one metre pressure head of water.

c. The base of containment area should be flooded on completion. The water cover should be maintained to avoid shrinkage cracking and consequent loss of seal. The supervisor should confirm that this requirement can be achieved. Alternatively, a continuous plastic membrane or a coarse granular cover may be used where there is insufficient available water. This cover should be maintained until waste is introduced in sufficient quantities to remove the risk of clay liner shrinkage.

d. Where there is a need to remove stored material by mechanical means, protective measures should be in place to avoid damage to the liner. One option is to provide a granular covering of at least 300 mm over the liner. The use of layers of tyres with sand infill has also been successful.

e. Where contained material with a high moisture content requires consolidation, a piped subsoil drainage system set in granular material protected with a filter fabric above the base liner is recommended. This system should drain to a lined holding basin outside the containment for evaporation or recycling. The subsoil drain system must be designed to resist silt intrusion and have access ports for maintenance rodding.

f. External monitoring facilities (e.g. bores) will normally be required to assess changes in groundwater quality and groundwater level occurring beneath the containment facility.

5.3 Synthetic lining

5.3.1 High density polyethylene (HDPE) geomembrane

a. The HDPE geomembrane liner should have the following properties:
   - minimum thickness of 0.75 mm, with a tolerance of 5%;
   - specific gravity of not less than 0.94 (ASTM D1505);
   - melt index of 0.05–0.30 g/10 minutes (ASTM D1238 condition E 190/2.16);
   - carbon black content of 2-3% (ASTM D1603);
   - minimum tensile strength at yield of 16 000 KN/m^2 and at break 550 KN/m^2 (ASTM D638 type IV 2);
   - minimum elongation at yield of 10% and at break 300% (ASTM D638).

b. The HDPE geomembrane liner should be fabricated to form the shape of excavation. All seams and joins made on site should be continuous. Panels of the geomembrane liner should be overlapped by a minimum distance as specified by the manufacturer.

c. All welding materials should be of a type supplied by the lining manufacturer and should be identical with the geomembrane liner.

d. All seams and joins should be quality assured and tested over their full length using a vacuum test unit, air pressure testing or other approved method.

e. The liner floor should fall to a sump that drains to an external monitoring well to facilitate seepage collection by gravity. The liner should fall no less than 1:100 to the sump and monitoring well.

f. Any geotextile used as a backing to a liner should be a minimum thickness of 2.5 mm and weigh a minimum of 280 grams/m^2.

g. HDPE should not be used on soils subject to differential movement.

5.3.2 Polyvinyl chloride (PVC)

a. The PVC liner should have a minimum thickness of 0.5 mm, with a tolerance of 5%.

b. PVC that is to be exposed to sunlight should be only used for short-term projects (i.e. less than three years) due to its susceptibility to UV attack. Longer periods may be achieved if the liner is buried. PVC should not be used to contain hazardous materials such as cyanide or hydrocarbons. It is particularly suited to made-up ground, as PVC stretches rather than shears.

c. Where PVC is used, appropriate protection should be in place to reduce the possibility of rodents or termites attacking the liner material. Mesh barriers or approved pesticides may be considered.

5.3.2 Composite membranes

Examples of these liner systems include polyethylene and bentonite, fibre-reinforced plastics, e.g. hypalon. The use of these materials will be considered on a case-by-case basis.

5.4 Monitoring

The effectiveness of liners should be determined by monitoring the groundwater adjacent to the site. For guidance on monitoring, see *Water Quality Protection Guidelines No. 4 – Installation of groundwater monitoring bores* and *Guidelines No. 5 – Minesite water quality monitoring* in this guideline series.

6. Useful references

Some components of these guidelines have been based on work already undertaken and reported in the following publications:

1. American Society for Testing Materials (1994). *ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics*, ASTM.
2. American Society for Testing Materials (1998). *ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer*, ASTM.
3. American Society for Testing Materials (1998). *ASTM D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique*, ASTM.

4. American Society for Testing Materials (1999). *ASTM D638 Standard Test Method for Tensile Properties of Plastics*, ASTM.
5. Price, R.E. and Williams, D.J. (1994). 'Geomembrane Lining Systems', in *Proceedings of the Third International Conference on Environmental Issues and Waste Management in Energy and Mineral Production*, pp. 573–577. Curtin University of Technology, Perth. 2.
6. Standards Association of Australia (1984). *AS1289, Methods of Testing Soils for Engineering Purposes*, Standards Association of Australia, Homebush, NSW.
3. Water and Rivers Commission (1996). *Guidelines for Acceptance of a Non-Synthetic (clay) Lining for Low Hazard Waste Containment*, WRC, Perth.
4. Water and Rivers Commission, (1997). *Guide to Waste Containment in Non-Rigid Lining Systems*, WRC, Perth, WA.

Glossary and Abbreviations

1.	Bentonite	A clay-type material, usually highly colloidal and plastic, which swells and shrinks with changes in water content. Used in reducing seepages in mines and channels and also a major component of drilling mud.
2.	Commission	Water and Rivers Commission
3.	DEP	Department of Environmental Protection
4.	Emerson class	The classification number related to the dispersive nature of a soil. See AS 1289.
5.	Hydraulic conductivity	A measure of the capacity of a porous medium to transmit water.
6.	Leachate	Groundwater that contains material removed from the soil through the percolating process.
7.	Licence	Licence granted and in force under Part V of the *Environmental Protection Act 1986.*
8.	Liner	A synthetic or non-synthetic material used to contain hazardous substances, which might otherwise degrade water resources.
9.	Permeability	The capacity of a porous rock, sediment or soil to transmit water when subjected to unequal pressure.
10.	Plasticity index	The plasticity index (PI) is the range of water content over which the soil is in the plastic condition.
10	Works Approval	Works approval granted and in force under Part V of the *Environmental Protection Act 1986* to perform certain works (e.g. construct a tailings storage facility).

Further enquiries

Any project where the proponent/operator is unable to comply with these guidelines, or where site conditions prevent the application of these guidelines, should be submitted to the Commission as early as possible in the development of the proposal so that the matter may be resolved.

Any queries relating to the **content of these guidelines** should be directed to:

Project Manager Assessment and Advice
Water Quality Protection Branch
Water and Rivers Commission
Level 2, Hyatt Centre
3 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
Phone (08) 9278 0300
Fax (08) 9278 0585

For further enquiries on any matter relating to the **management of water resources**, please contact the Water and Rivers Commission's regional offices.

Swan-Goldfields-Agricultural Regional Office
849 Albany Highway
VICTORIA PARK WA 6100 Phone (08) 9362 0555 Fax (08) 9362 0500

Or
254 Fitzgerald St
NORTHAM WA 6401 Phone (08) 9690 2821 Fax (08) 9622 7155

North West Regional Office
Chiratta Road
KARRATHA WA 6714 Phone (08) 9144 2000 Fax (08) 9144 2610

South West Regional Office
U2 Leschenault Quays,
Austral Parade
BUNBURY WA 6230 Phone (08) 9721 0666 Fax (08) 9721 0600

Or
'Sholl House'
21 Sholl St
MANDURAH WA 6210 Phone (08) 9535 3411 Fax (08) 9581 4560

Mid-West Gascoyne Regional Office
Pass Street
Geraldton WA 6530 Phone (08) 9964 5978 Fax (08) 9964 5983

South Coast Regional Office
5 Bevan Street
ALBANY WA 6330 Phone (08) 9842 5760 Fax (08) 9842 1204

These guidelines are also available from the Water and Rivers Commission's web page at:
http://www.wrc.wa.gov.au/protect/policy/

Other related guidelines in this series include:

WATER QUALITY PROTECTION GUIDELINES NO. 1
Water quality management in mining and mineral processing: An overview

WATER QUALITY PROTECTION GUIDELINES NO. 2
Tailings facilities

WATER QUALITY PROTECTION GUIDELINES NO. 4
Installation of minesite groundwater monitoring bores

WATER QUALITY PROTECTION GUIDELINES NO. 5
Minesite water quality monitoring

WATER QUALITY PROTECTION GUIDELINES NO. 6
Minesite stormwater

WATER QUALITY PROTECTION GUIDELINES NO. 7
Mechanical servicing and workshop facilities

WATER QUALITY PROTECTION GUIDELINES NO. 8
Laboratory waste discharge

WATER QUALITY PROTECTION GUIDELINES NO. 9
Acid mine drainage

WATER QUALITY PROTECTION GUIDELINES NO. 10
Above-ground fuel and chemical storage

WATER QUALITY PROTECTION GUIDELINES NO. 11
Mine dewatering