

**ACTION LEAKAGE RATE GUIDELINE**  
**INDUSTRIAL WASTE AND WASTEWATER BRANCH**  
**MAY 1996**

**1. INTRODUCTION**

This guideline has been developed by Alberta Environmental Protection because of the reality that all liners will leak to some extent and because of the resultant history of groundwater contamination at some sites. This guideline focuses on double lined ponds with a primary liner consisting of a geomembrane liner, a secondary liner (normally consisting of a geomembrane liner or a clay liner), and a leak detection/collection system in between the two liners, by ensuring that the liner leakage is minimal and that it is controlled.

This process primarily involves monitoring the amount of leakage through the first or primary liner of a double lined system, comparing this leakage to the action leakage rate (ALR), and taking corrective action when needed. Leakage through the primary liner into the leak detection/collection system is monitored and compared to expected performance for a properly functioning geomembrane liner (i.e. the action leakage rate). The ALR is set by this guideline as the amount of leakage that would occur through a geomembrane liner that was constructed with good construction quality assurance. If the ALR is exceeded, the owner or operator is to take remedial actions. Taking appropriate remedial action when needed will ensure that any hydraulic head of leakage on the secondary liner is very small, thus ensuring no or very little migration of contaminants through the secondary liner. This will help ensure protection of underlying soil and groundwater.

This guideline does not apply to single lined systems that may have been constructed in the past. It also does not apply to double lined systems where the primary liner is a clay liner.

Questions regarding this guideline should be directed to staff of the Industrial Waste and Wastewater Branch at Edmonton (403 427-5883) or Calgary (403 297-8054).

## 2. RECOMMENDATIONS FOR ACTION LEAKAGE RATES

An action leakage rate (ALR) must be developed for each double-lined wastewater or process liquids pond by the owner or operator. It is recommended that an ALR be developed in accordance with the liner performance method. The ALR is defined as the amount of leakage that would occur through the top liner of a double liner system, based on two holes per hectare, (see Section 3 for details) each with a diameter of 2 mm. In addition the ALR must be not be greater than the flow capacity of the leak detection/collection system (see Section 4).

A Response Action Plan (RAP) must be developed by the owner or operator which specifies monitoring, inspection, and corrective measures (Section 6.2) to be implemented if the action leakage rate is exceeded. Response when the ALR is marginally exceeded can be when convenient to the owner or operator, but generally within one year. Response when the flow capacity of the drainage layer or the pumping capacity of the leak detection sump is nearing exceedance must be immediate.

The liner performance method was originally developed by Giroud and Bonaparte (1989) and is based on liner performance with good installation and maintenance. From their preliminary survey's and later work by the U.S. EPA (1992a) it was found that a geomembrane lined facility installed with good construction quality assurance will have about 2 holes of 2 mm diameter per hectare. This number (two defects per hectare) is considered to not be overly low given that ponds installed with good construction quality assurance have shown virtually no leakage (EPA, 1992a and Bonaparte and Gross, 1990). In these surveys, five out of eight ponds with a single geomembrane as the top liner had no leakage occurring, one had leakage occurring at 0.4 litres per hectare per day, while in the other two, leakage was occurring at 27 to 80 litres per hectare per day.

For existing facilities with a bottom liner or leak detection/collection system of suspect quality (e.g. incompatible clay liner or drainage medium not meeting current specifications), increased diligence in monitoring with adjacent groundwater monitoring wells is recommended. Regular liner inspections will also be necessary.

### 3. BACKGROUND INFORMATION ON LINER LEAKAGE

Flow through holes in a single geomembrane liner can be calculated in accordance with Giroud and Bonaparte (1989) as follows. This equation applies to holes with a diameter approximately equal to or greater than the thickness of the geomembrane, and where the liner system has an underlying material (i.e. leak collection system) with a hydraulic conductivity higher than  $10^{-3}$  m/s (freely draining).

$$Q = C_b a (2 g h_w)^{1/2} \dots\dots\dots(1)$$

Q leakage rate (m<sup>3</sup>/s)  
a hole area (m<sup>2</sup>)  
C<sub>b</sub> dimensionless coefficient, 0.6 for sharp edges (default value)  
h<sub>w</sub> liquid depth (m)  
g gravity (m/s<sup>2</sup>)

Equations to predict leakage due to *permeation or diffusion* can be found in Giroud & Bonaparte (1989). Permeation is a small component of leakage and is not normally considered when developing action leakage rates due to its low value in comparison to that of leakage through defects. To illustrate this, permeation through an 80 mil HDPE liner with 3 metres of liquid is calculated to be 1.2 m<sup>3</sup>/ha/mo.

The above equation (1) is for the primary geomembrane liner of a double liner system. Empirical equations to predict the rate of leakage through a hole in a composite liner have been developed based on analytical studies and model tests (Giroud et al, 1992). A composite liner consists of a geomembrane placed in close contact with a low-permeability soil liner. These equations are not presented in this document due to their complexity and as most facilities have a single geomembrane as the primary liner. For the purpose of calculating a reasonable action leakage rate, the use of equation (1) is acceptable.

The collected leakage should be analysed regularly for parameters indicative of the pond contents and the leakage volumes should be measured or estimated by recording the quantity collected or the quantity pumped back to the pond. By reviewing the leakage volumes, and comparing the leakage chemistry to that of the liquids in the pond, one can estimate how much is actual leakage, including any trends. Reviewing the chemistry is important as the leakage volumes may inadvertently contain other waters such as construction water, compression water from granular drainage systems, clay consolidation water, and groundwater infiltration (Bonaparte and Gross, 1990).

#### 4. CAPACITY OF THE LEAK DETECTION/COLLECTION SYSTEM

This is calculated according to the following equations (U.S. EPA, 1992a) using the method of flow originating from two holes per hectare. It is based on a maximum head allowable on the secondary liner of 0.3 m. For either case a factor of safety of 2 should be incorporated as well.

##### Granular Drainage Layer Case

$$Q = k h \tan \alpha B_{\text{avge}} \quad (2)$$

- Q flow rate in the leak detection system per hectare  
 k hydraulic conductivity of the drainage medium (e.g.  $1 \times 10^{-1}$  cm/s)  
 h head on the bottom liner (e.g. 0.3 metres, the design number)  
 $\alpha$  slope of the leak detection system in degrees  
 $B_{\text{avge}}$  width of flow in the leak detection system, perpendicular to flow (e.g. 100 feet or 30.5 metres), where  $B_{\text{avge}} = D/\sin \alpha$  and  $D \approx h$   
 D drainage layer thickness (m)

##### Synthetic Drainage Layer (Geonet) Case

$$Q = 2\theta_d h \text{ with } \theta_d = k_d D \dots\dots\dots (3)$$

- Q flow rate in the leak detection system per hectare  
 $\theta_d$  hydraulic transmissivity of the drainage medium (e.g.  $3 \times 10^{-4}$  m<sup>2</sup>/s)  
 $K_d$  in plane hydraulic conductivity of the drainage medium (m/s)  
 D drainage layer thickness (m)  
 h head on the bottom liner (e.g. 0.3 metres, the design number)

The solution to these equations for a pond meeting all of EPA's minimum technical requirements, incorporating a factor of safety of two, and adjusting the number to reflect two holes per hectare, yields in the order of 10,000 litres per hectare per day for ponds and 1000 litres per hectare per day for landfills.

## 5. EXAMPLE POND CALCULATIONS

Given: Double Lined Pond with a Leak Detection/Collection System in Between the two Liners (2 cases evaluated).

Pond Surface Area = 2 ha

Average Liquid Depth = 3m

Geonet Case:  $\theta_d = 3 \times 10^{-4} \text{ m}^2/\text{s}$  and  $h = 0.3 \text{ m}$

Granular Drainage Layer Case: Slope = 1% ( $\sin\alpha = 0.01 = \tan\alpha$ )

$k = 0.001 \text{ m/s}$  and  $h = 0.3 \text{ m}$

ALR Calculation:

$$\begin{aligned} \text{Leakage Rate per hole } Q &= C_b a (2 g h_w)^{1/2} \quad (\text{equation (1)}) \\ &= 0.6 (\pi 0.001^2) (2 \times 9.81 \times 3)^{1/2} \\ &= 1.446 \times 10^{-5} \text{ m}^3/\text{s} \\ &= 37.5 \text{ m}^3/\text{month} \end{aligned}$$

$$\begin{aligned} \text{ALR} &= \text{leakage rate per hole} \times 2 \text{ ha} \times 2 \text{ holes/ha} \\ &= 37.5 \times 2 \times 2 = 150 \text{ m}^3/\text{month} \end{aligned}$$

Geonet Case: Calculation of the Capacity of the Leak Detection/Collection System

$$\begin{aligned} Q &= 2\theta_d h \quad (\text{equation (3)}) \\ &= 2 \times (3 \times 10^{-4} \text{ m}^2/\text{s}) \times 0.3 \text{ m} \\ &= 466.6 \text{ m}^3/\text{mo. per hole} \end{aligned}$$

$$\begin{aligned} Q_{\text{cap}} &= 466.6 \times 2 \text{ holes/ha} \times 2 \text{ ha} \\ &= 1867 \text{ m}^3/\text{month} \\ &\approx 900 \text{ m}^3/\text{month after applying a factor of safety of 2.} \end{aligned}$$

## 5. EXAMPLE POND CALCULATIONS (cont'd)

### Granular Drainage Layer Case: Calculation of the Capacity of the Leak Detection/Collection System

$$\begin{aligned} B_{\text{avge}} &= D/\sin \alpha \text{ and } D \approx h \\ &= 0.3/(0.01) = 30 \text{ m} \end{aligned}$$

$$\begin{aligned} Q &= k h \tan \alpha B_{\text{avge}} \quad (\text{equation (2)}) \\ &= 0.001 \text{ m/s} \times 0.3 \text{ m} \times 0.01 \times 30 \text{ m} \\ &= 9.0 \times 10^{-5} \text{ m}^3/\text{s} \\ &= 233.3 \text{ m}^3/\text{month} \end{aligned}$$

$$\begin{aligned} Q_{\text{cap}} &= 233.3 \times 2 \text{ holes/ha} \times 2 \text{ ha} \\ &= 933 \text{ m}^3/\text{month} \\ &\approx 450 \text{ m}^3/\text{month after applying a factor of safety of 2.} \end{aligned}$$

## 6. ACTION LEAKAGE RATE DEVELOPMENT

- 6.1 Each operator shall develop an action leakage rate for each wastewater or process liquids pond with a double liner system, in accordance with this guideline.
- 6.2 Should the streams collected in the sump associated with the leak detection/collection system of the wastewater or process liquids ponds (and which originates from the pond itself) have a total flow per month greater than the action leakage rate (Section 6.1), then the operator shall implement a response action plan. A response action plan shall include:
- (a) notification to the Director of Air and Water Approvals within 7 days of the leakage;
  - (b) assessment of the source of leakage and possible location, size, and cause of any leaks,
  - (c) remedial actions to lower the leakage through the pond liner into the leakage detection/collection systems to below the action leakage rate, within a time period consistent with Section 2 or as otherwise authorized by the Director of Air and Water Approvals; and
  - (d) written monthly reporting to the Director of Air and Water Approvals summarizing the results of clauses (b) and (c), or as otherwise authorized by the Director.

## 7. MONITORING

- 7.1 Leakage streams collected in the liner sumps associated with the leak detection/ collection systems of the ponds, shall be returned to the ponds or an alternate location approved by the Director of Air and Water Approvals.
- 7.2 The operator shall monitor streams collected in the liner sumps associated with all leak detection/collection systems of the wastewater or process liquids ponds as specified in Table 7-1.

TABLE 7-1: LEAKAGE COLLECTION MONITORING

WATER CONTAMINANTS OR PARAMETERS TO BE MONITORED	FREQUENCY	SAMPLE TYPE
Total Flow (m <sup>3</sup> /month)	once/week	estimate
Parameters Characteristic of the Leakage	once/month	grab

- 7.3 In order to determine the average chemical concentration in each wastewater or process liquids pond, the operator shall collect a representative grab sample of each pond once per month, and have the sample(s) analysed for parameters characteristic of the pond contents. If it can be shown that the results are relatively stable, less frequent monitoring (i.e. twice per year) is acceptable.

## 8. LIST OF REFERENCES

Bonaparte, R. and Gross, B. A. 1990. Field Behaviour of Double Liner Systems. Proceedings of Waste Containment Systems: Construction, Regulation, and Performance, San Francisco, ASCE Geotechnical Special Publication No. 26, pp 52-83.

Giroud, J. P., Badu-Tweneboah, K., and Bonaparte, R. 1992. Rate of Leakage through a Composite Liner due to Geomembrane Defects. *Geotextiles and Geomembranes*, 11: 1-28.

Giroud, J. P., and Bonaparte, R. 1989. Leakage through Liners Constructed With Geomembranes-Part I. Geomembrane Liners. *Geotextiles and Geomembranes*, 8: 27-67.

Koerner, R. M., and Richardson, G. N. 1987. Design of Geosynthetic Systems for Waste Disposal. *ASCE Geotechnical Practice for Waste Disposal* 87, pp 65-86.

Matrecon, Inc. 1988. Lining of Waste Containment and other Impoundment Facilities. U.S. EPA, Office of Research and Development, Report No. EPA/600/2-88/052.

U. S. EPA. 1992a. Action Leakage Rates for Leak Detection Systems (Supplemental Background Document for the Final Double Liners and Leak Detection Systems Rule for Hazardous Waste Landfills, Waste Piles, and Surface Impoundments). pp 1-23.

U. S. EPA. 1992b. Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units; Final Rule. 40 CFR Parts 260, 264, 265, 270, and 271, January 29, 1992, pp 3462-3479.