

POLLUTE

Version 8

Example 1: Subtitle D Landfill



© 2021 GAEA Technologies Ltd.

GAEA Technologies Ltd,

*221 Laurel Street
Cambridge, Ontario
Canada
N3H 3Y6*

Tel: (613) 900-1950

*Email:
sales@gaeatech.com
support@gaeatech.com*

www.gaeatech.com

POLLUTE

Version 8

© 2021 GAEA Technologies Ltd.

All rights reserved. No parts of this work may be reproduced in any form or by any means - graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems - without the written permission of GAEA Technologies.

Products that are referred to in this document may be either trademarks and/or registered trademarks of the respective owners. GAEA Technologies makes no claim to these trademarks.

While every precaution has been taken in the preparation of this document, GAEA Technologies assumes no responsibility for errors or omissions, or for damages resulting from the use of information contained in this document or from the use of programs that may accompany it. In no event shall GAEA Technologies be liable for any loss of profit or any other commercial damage caused or alleged to have been caused directly or indirectly by this document.

Printed: September 2021 in Canada.

Description

This example illustrates the use of the program to model a U.S. RCRA Subtitle D landfill. The landfill consists of a composite liner and a primary leachate collection system. The composite liner is composed of a 60 mil (1.5 mm) geomembrane in good contact with a 0.9 m thick compacted clay liner. Small holes with an area of 0.1 cm² and a frequency of 1 per acre (2.5 per hectare) are assumed for the geomembrane. The method proposed by Giroud et al (1992) is used to calculate the flow (leakage) through the composite liner, these calculations are performed automatically by the program.

The landfill has a length (L) of 200 m in the direction parallel to groundwater flow in the underlying aquifer. Consideration is being given to a volatile organic contaminant with an initial source concentration of 1500 µg/L, which is assumed to remain constant with time over the time period being examined in this example. The leachate head on the composite liner is assumed to be constant at 0.3 m.

The flow in the aquifer must be established based on hydrogeologic data and is represented in terms of the horizontal Darcy velocity (the "Base Outflow Velocity") in the aquifer at the down-gradient edge of the landfill.

The parameters used for this example are listed below:

Property	Symbol	Value	Units
Geomembrane Contact		Good	-
Geomembrane Holes		Circles	-
Hole Area		0.1	cm ²
Hole Frequency		1	/acre
Source Concentration	c ₀	1500	µg/L
Source Type		Constant	-
Landfill Length	L	200	m
Leachate Head on Liner		0.3	m
Geomembrane Thickness		60	mil
Geomembrane Diffusion Coef.		3.0x10 ⁻⁵	m ² /a
Clay Thickness	H _s	0.9	m
Clay Diffusion Coef.	D	0.02	m ² /a
Distribution Coefficient	K _d	0.5	mL/g
Soil Porosity	n	0.35	-
Dry Density		1.9	g/cm ³
Aquifer Thickness	h	3	m
Aquifer Porosity	n _b	0.3	-
Base Outflow Velocity	v _b	10	m/a

For more information regarding:

- Leakage through composite liners - see Giroud et al (1992).
- Diffusion through geomembranes - see Hughes and Monteleone, (1987); Lord et al (1988).
- Diffusion, sorption, and effective porosity in clays (D, K_d, n) - see Rowe et al (1988)
- Modeling, hydrogeology, and engineering interaction - see Rowe (1992), Rowe et al, 1994.
- Theory used - see Rowe and Booker (1985, 1991), Rowe et al (1994)

Data Entry

Open the Examples project and open Case 1.

General Tab

General Information

Model Title: Case 1: Subtitle D Landfill with constant source concentration

Units: Metric Imperial

Waste
Collection System
Geomembrane
Clay Liner
Aquifer

Geomembrane
 Clay Liner
 Aquitard
 Aquifer

Laplace Transform Parameters

TAU: 7 N: 20 SIG: 0 RNU: 2

Run Parameters

Output Units
Time Units: a Depth Units: m Concentration Units: µg/L

All Depths Specified Depths

Concentrations at Specified Times Maximum Concentrations

Concentrations at Specified Times

+ Add X Delete

Time	Units
10	yr
20	yr
30	yr

On the General tab, the title and layers present in the model are specified as shown above. In this example there is a geomembrane, clay liner and aquifer. At the bottom of the tab the run parameters can be specified. The concentrations can either be calculated at specified times or the time of the maximum concentration can be found.

Source & Hydraulic Heads Tab

The screenshot displays a software interface with a menu bar at the top containing 'Run', 'Auto', 'On', 'Off', 'Save', and 'SaveAs'. Below the menu bar is a tabbed interface with the following tabs: 'General', 'Source & Hydraulic Heads', 'Geomembranes', 'Clay Liners', 'Aquifer', 'Special Features', and 'Subsurface Model'. The 'Source & Hydraulic Heads' tab is active and contains two sections: 'Source' and 'Hydraulic Heads'.
The 'Source' section includes:
- 'Concentration: 1500 µg/L' (with a dropdown arrow)
- 'Landfill Length: 200 m' (with a dropdown arrow)
- 'Landfill Width: 0' (with a dropdown arrow)
- 'Source Type' with radio buttons for 'Constant Concentration' (selected) and 'Finite Mass'.
The 'Hydraulic Heads' section includes:
- 'Leachate Head on Primary Liner: 0.3 m' (with a dropdown arrow)
- 'Groundwater level relative to top of Aquifer: 0 m' (with a dropdown arrow).

On this tab the Source Type, Source Concentration and Landfill Length are specified. In this example, the source type is constant concentration. If the source type was finite mass additional information for the source would need to be entered as discussed in Case 4.

The Hydraulic Heads is used to specify the leachate head on the primary liner and the groundwater level relative to the top of the aquifer. These heads are used to calculate the Darcy velocity through the liner.

Geomembranes Tab

Run Auto On Off Save SaveAs

General Source & Hydraulic Heads Geomembranes Clay Liners Aquifer Special Features Subsurface Model

Geomembrane

Name: Geomembrane

Change Symbol

Leakage Method

LEAK, Rowe et al 2004

Giroud & Bonaparte 1992

Equivalent K

Number of Sublayers: 1

Thickness: 60 mil

Diffusion Coef: 3E-5 m²/a

Phase Parameter: 1

Giroud & Bonaparte, 1992

Contact

Good

Poor

Hole Type

Circle

Long

Permeation

Yes

No

Hole Frequency: 1 acre

Hole Area: 0.1 cm²

Calculate Leakage Darcy Velocity

On this tab the Name, Thickness, Diffusion Coefficient, Phase Parameter, and method to calculate the leakage through the geomembrane is specified. If the method is Rowe et. al. 2004 or Giroud & Bonaparte 1992, an additional tab will be displayed to enter the hole parameters. If the method is equivalent K, then the Hydraulic Conductivity of the geomembrane can be entered on this tab. In this example the leakage method used is Giroud & Bonaparte 1992. Using this method the parameters for the holes in the geomembrane are specified. These parameters include the Type of Contact, Hole Type, Use of Permeation, and Hole Frequency. If the type of holes is Circles then the Hole Area can be specified, if the type is Long then the Hole Length and Width can be specified.

At the bottom of the tab, the Calculate Leakage button can be used to calculate and display the Darcy velocity (leakage) through the primary liner.

Clay Liners Tab

The screenshot shows the 'Clay Liner' configuration tab. At the top, there are buttons for 'Run', 'Auto', 'On', 'Off', 'Save', and 'SaveAs'. Below these are tabs for 'General', 'Source & Hydraulic Heads', 'Geomembranes', 'Clay Liners', 'Aquifer', 'Special Features', and 'Subsurface Model'. The 'Clay Liner' tab is active and contains the following fields:

- Name:
- Change Symbol button
- Number of Sublayers:
- Thickness: m
- Density: g/cm³
- Conductivity K: cm/s
- Diffusion Coef: m²/a
- Distribution Coef: mL/g
- Porosity:

The Clay Liners tab below is used to specify the properties of the clay liner below the geomembrane. These properties include the Name, Symbol, Thickness, Density, Hydraulic Conductivity, Diffusion Coefficient, Distribution Coefficient, and Porosity.

Aquifer Tab

The screenshot shows the 'Aquifer' configuration tab. At the top, there are buttons for 'Run', 'Auto', 'On', 'Off', 'Save', and 'SaveAs'. Below these are tabs for 'General', 'Source & Hydraulic Heads', 'Geomembranes', 'Clay Liners', 'Aquifer', 'Special Features', and 'Subsurface Model'. The 'Aquifer' tab is active and contains the following fields:

- Name:
- Change Symbol button
- Thickness: m
- Porosity:

Below the configuration fields, there are two sections:

- Outflow in Aquifer:**

The minimum outflow velocity in the Aquifer that will fulfill the conditions of continuity of flow is: 0.002619 m/a

Outflow Velocity: m/a
- Calculated Results:**

Darcy Velocity:

Leachate Head on Primary Liner:

The Aquifer tab is used to specify the Name, Symbol, Thickness and Porosity of the Aquifer. At the bottom of the tab the Outflow Rate in the Aquifer can be specified. This rate should be at greater than or equal to the minimum calculated by the program. In this example, the minimum is 0.002619 m/a.

Model Execution



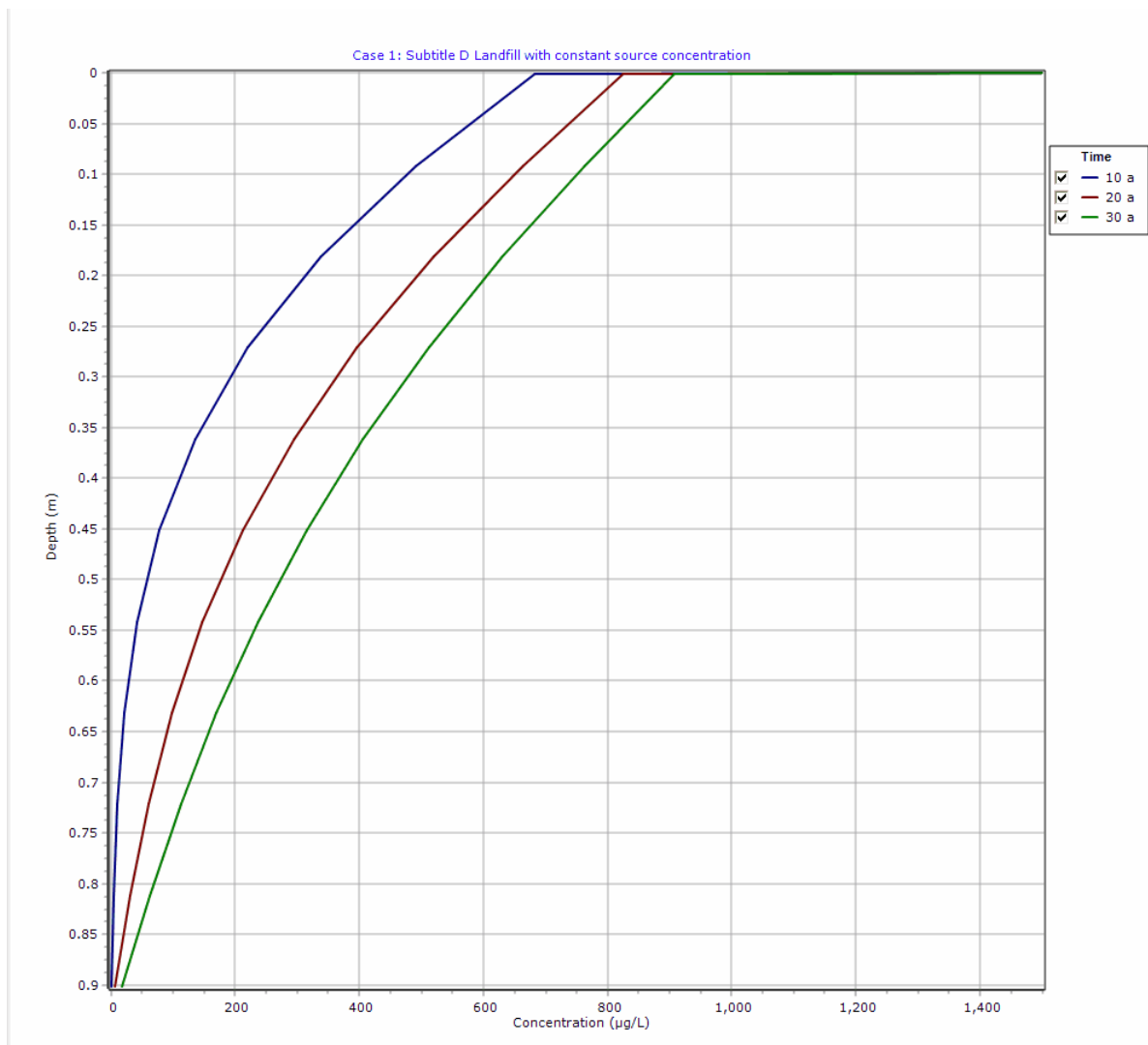
To run the model and calculate the concentrations press the Run button on the toolbar.

Model Output

After the model has been executed, the output for the model will be displayed.

Concentration vs Depth

The Concentration vs. Depth chart can be displayed by selecting the Concentration vs Depth item for the Chart Type.



Output Listing

To display the output as a text listing that will show the calculated concentrations as numbers, click on the List tab.

POLLUTEv8

Version 8.00 Beta
 Copyright (c) 2021
 GAEA Technologies Ltd., R.K. Rowe and J.R. Booker

Case 1: Subtitle D Landfill with constant source concentration

THE DARCY VELOCITY (Flux) THROUGH THE LAYERS $V_a = 3.9284E-5$ m/a

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Geomembrane	60 mil	1	3E-5 m ² /a	1	0 cm ³ /g	950 kg/m ³
Clay Liner	0.9 m	10	0.02 m ² /a	0.35	0.5 mL/g	1.9 g/cm ³

Boundary Conditions

Constant Concentration

Source Concentration = 1500 µg/L

Fixed Outflow Bottom Boundary

Landfill Length = 200 m
 Landfill Width = 0 m
 Base Thickness = 3 m
 Base Porosity = 0.3
 Base Outflow Velocity = 10 m/a

Laplace Transform Parameters

TAU = 7 N = 20 SIG = 0 RNU = 2

Calculated Concentrations at Selected Times and Depths

Time a	Depth m	Concentration µg/L
10	0.000E+00	1.500E+03
	1.524E-03	6.823E+02
	9.152E-02	4.917E+02
	1.815E-01	3.370E+02
	2.715E-01	2.190E+02
	3.615E-01	1.345E+02
	4.515E-01	7.798E+01
	5.415E-01	4.254E+01
	6.315E-01	2.176E+01

	7.215E-01	1.028E+01
	8.115E-01	4.107E+00
	9.015E-01	3.970E-01
20	0.000E+00	1.500E+03
	1.524E-03	8.259E+02
	9.152E-02	6.636E+02
	1.815E-01	5.198E+02
	2.715E-01	3.966E+02
	3.615E-01	2.942E+02
	4.515E-01	2.117E+02
	5.415E-01	1.471E+02
	6.315E-01	9.768E+01
	7.215E-01	6.006E+01
	8.115E-01	3.082E+01
	9.015E-01	6.430E+00
30	0.000E+00	1.500E+03
	1.524E-03	9.082E+02
	9.152E-02	7.636E+02
	1.815E-01	6.309E+02
	2.715E-01	5.115E+02
	3.615E-01	4.062E+02
	4.515E-01	3.148E+02
	5.415E-01	2.365E+02
	6.315E-01	1.698E+02
	7.215E-01	1.126E+02
	8.115E-01	6.246E+01
	9.015E-01	1.675E+01

NOTICE

Although this program has been tested and experience would indicate that it is accurate within the limits given by the assumptions of the theory used, we make no warranty as to workability of this software or any other licensed material. No warranties either expressed or implied (including warranties of fitness) shall apply. No responsibility is assumed for any errors, mistakes or misrepresentations that may occur from the use of this computer program. The user accepts full responsibility for assessing the validity and applicability of the results obtained with this program for any specific case.