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Parametric fate and transport profiling for selective groundwater monitoring at closed landfills: A case study

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ABSTRACT

Monitoring contaminant concentrations in groundwater near closed municipal solid waste landfills requires long term monitoring program which can require significant investment for monitoring efforts. The groundwater monitoring data from a closed landfill in Florida was analyzed to reduce the monitoring efforts. The available groundwater monitoring data (collected over 20 years) were analyzed (i.e., type, concentration and detection level) to identify the trends in concentrations of contaminants and spatial mobility characteristics of groundwater (i.e., groundwater direction, retardation characteristics of contaminants, groundwater well depth, subsoil characteristics), to identify critical monitoring locations. Among the 7 groundwater monitoring well clusters (totaling 22 wells) in landfill, the data from two monitoring well clusters (totaling 7 wells) located along direction of groundwater flow showed similarities (the highest concentrations and same contaminants). These wells were used to assess the transport characteristics of the contaminants. Some parameters (e.g., iron, sodium, ammonia as N, chlorobenzene, 1,4-dichlorobenzene) showed decreasing trends in the groundwater due to soil absorption and retardation. Metals were retarded by ion exchange and their concentration increased by depth indicating soil reached breakthrough over time. Soil depth did not have a significant effect on the concentrations of volatile organic contaminants. Based on the analyses, selective groundwater monitoring modifications were developed for effective monitoring to acquire data from the most critical locations which may be impacted by leachate mobility. The adjustments in the sampling strategy reduced the amount of data collected by as much as 97.7% (i.e., total number of parameters monitored). Effective groundwater sampling strategies can save time, effort and monitoring costs while improving the quality of sample handling and data analyses for better utilization of post closure monitoring funds.

1. Introduction

Contamination of groundwater due to transport of leachate from closed landfills can be a major environmental concern (Singh et al., 2008; Yusoff and Al-Hawas, 2008). Especially at unlined landfills, leachate can contaminate the groundwater with potentially hazardous chemicals at concentrations above the drinking water standards (Reyes-López et al., 2008). Lined landfills also pose a threat on groundwater quality as the liners fail over time. After contaminants reach the groundwater, pollutants in leachate can mix with the aquifer. The contaminants in groundwater can undergo a series of reactions by interaction with soil and minerals present in the soils. For the organic compounds, the reactions with soils include sorption, biodegradation, hydrolysis, redox reactions and volatilization. For metals, the principal reactions involve sorption, ion exchange, precipitation and redox reactions (Christensen et al., 2001; Eganhouse et al., 2001; Kjeldsen et al., 2002).

The Subtitle D (40 CFR §258.61(b)) of The Resource Conservation and Recovery Act (RCRA) requires a post closure care period (PCC) of 30 years for non-hazardous wastes in landfills. The length of the PCC period can be extended or shortened by the governing regulatory agency on a site-specific basis. The PCC activities at landfills include cap maintenance; water quality monitoring; maintenance and monitoring of the gas collection/control system, leachate collection system, groundwater monitoring wells, surface water management system and general site maintenance (Sizirici et al., 2011). Among the PCC activities, the cost of water quality monitoring is one of the highest long-term expenses at a landfill (over 90% of total cost). Monitoring requires to identify hydrogeology, to characterize groundwater quality, and to evaluate the leachate contaminants and its by-products' possible impact on groundwater quality. Groundwater monitoring costs include all

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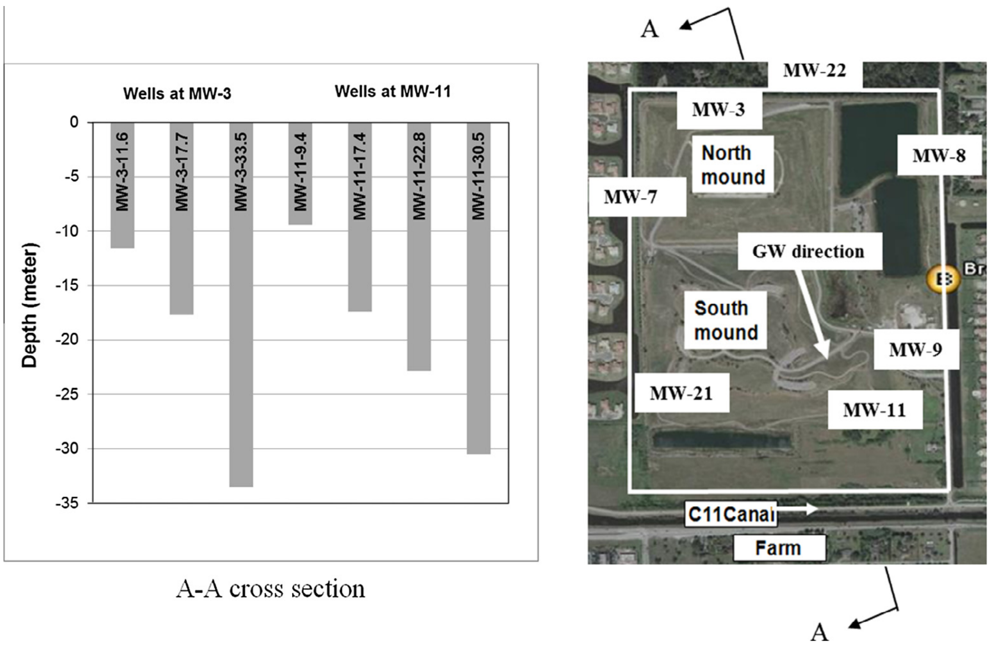

Fig. 1. Groundwater monitoring well clusters (MW) locations (Tansel et al., 2008).

Table 1
Monitoring wells and depths.

Well cluster no.	Depth monitored (m)
3	11.6, 17.7, 33.5
7	11.3, 18, 25.6
8	10.6, 18,22
9	11, 18, 28,3
11	9.4, 17.4, 22.8, 30.5
21	10.6,18.9, 25.9
22	10.4, 18.3, 27.7
Total monitoring depths	22

sampling, laboratory analysis, and reporting costs (Lawrence, 2008; Tuppan and Haynes, 1998).

Analysis of existing monitoring data can aid development of strategic sampling plans for effective use of sampling funds while reducing the monitoring program costs. The existing monitoring data can be evaluated to identify the number of monitoring wells needed based on characterization, the number of parameters, the number of wells, and the sampling frequency. The purpose of this study was to identify the mobility of leachate contaminants through groundwater system and to modify groundwater monitoring based on concentration and spatial mobility characteristics of groundwater.

2. Material and methods

2.1. Background

The case study landfill evaluated is located in South Florida, USA. This landfill was selected because of the extensive monitoring data availability. The availability of data over 20 years allows a comprehensive evaluation for the impact of leachate on groundwater and mobility of contaminants in groundwater to assess the groundwater monitoring strategy. The landfill has been closed since 1987. The site consists of 85 hectares that includes 19.5 hectares of Class I landfill (inert materials, north mound) and 27.5 hectares of Class III landfill (putrescible materials, south mound). The south mound was unlined and it was used to deposit incinerator ash, yard trash, and construction and demolition debris. The north mound was partially lined and had 14 cells. The cells 1–4 were lined with sprayed asphaltic liner and does not have a leachate collection system and cells 5–13 were lined with paved asphalt and have a leachate collection system. Cell 14 was constructed with a 60 mil high density polyethylene (HDPE) liner and has a leachate collection system. The north mound was used for disposal of municipal solid waste. The landfill is 525 m in length and 411 m in width. The potentiometric surface elevation of the underlying aquifer beneath the landfill ranges from approximately 1.22 m in the northwest section of the landfill to approximately 0.7 m in the southeast section. The groundwater flow is in a southeasterly direction. The regional groundwater gradient is reported as about 7.5×10^{-5}. The

Table 2
Parameters detected in leachate and groundwater.

Parameter	Leachate	Ground water[a]
Below MCL		
1,4-Dichlorobenzene	X	X (7.0%)
Chlorobenzene	X	X (18.2%)
Dichlorodifluoromethane	X	
Ethylbenzene	X	
Methylene chloride		X (1.8%)
Methyl-tert-butyl ether (MTBE)	X	X (2.7%)
Tetrachloroethene	X	
Toluene	X	
Xylenes	X	X (0.3%)
Total BTEX	X	
Cadmium		X (0.3%)
Chromium		X (1.8%)
Zinc		X (31.8%)
Above MCL		
Chloride	X	
Bicarbonate	X	
Sodium	X	X (100%)
Ammonia as N	X	X (100%)
Total iron	X	X (100%)
Benzene	X	
Vinyl chloride	X	X (3.0%)
Total dissolved solids (TDS)	X	X (100%)

[a] Detection frequency in groundwater wells is provided in parentheses.