Groundwater quality at two landfill sites in Selangor, Malaysia

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Abstract: The groundwater quality in and around two landfills sites in the state of Selangor, Malaysia is studied to evaluate levels of contamination around an unengineered site and an engineered site. The two landfill sites are Ampar Tenang and Bukit Tagar. Data were obtained through site sampling from available boreholes. In addition results from published data and reports of previous works are used for analysis. The data indicate serious groundwater contamination in and around unengineered landfill sites. Analytical data include quality of groundwater, leachate and surface water in which many parameters were above the regulatory limits. Whereas, at the engineered site, contamination was generally below the standards. The findings serve to warn waste management industry stakeholders in Malaysia that for sustainability, unengineered landfills must be closed and cleaned up.

Keywords: landfill, groundwater quality, leachate, Selangor

INTRODUCTION

Solid waste disposal by landfill poses a threat to groundwater and surface water quality through the formation of polluting liquids known as leachate. Leachate can percolate through the base of the landfill and enter the groundwater system. Fully engineered landfills that are equipped with compacted clay and geomembrane liner can prevent this seepage from occurring. Leachate can also enter surface water system and affecting its quality. The information and analyses provided in this paper is part of a larger study to evaluate the effects of landfill leachate on the surface water and groundwater quality at all landfill sites in the state of Selangor, Malaysia.

The landfills in Selangor (and Malaysia in general) can be classified into 4 categories (NAHRIM, 2009):

i. Landfills operating at critical stage without any control to prevent pollution into the environment. These landfills will be closed once a new landfill starts to operate.
ii. Landfill sites (open dumpsites) that have capacity receiving waste and will be allowed to continue accepting waste, but need to be upgraded to manage leachate and methane gas.
iii. Landfills that were already closed (ceased operation) but do not have prepared any safety closure plan.
iv. Landfills with up-to-date technologies.

Two landfills discussed in this paper are Ampar Tenang, which is unengineered (category ii) and Bukit Tagar (engineered landfill, caterogy iv). The quality of groundwater were evaluated based on their comparison with the following documents:

- Guidelines for Raw Drinking Water Quality Benchmark for Groundwater Quality. Ministry of Health Malaysia (MOH, 2000),
- Malaysian Environmental Impact Assessment Guidelines for Groundwater and/or surface Water Supply Project (DOE, 1995), and
- The background data from EIA before the development.

The DOE (1995) document is also known as the Interim National Water Quality Standards for Malaysia (INWQS). Another important document used is the Malaysian Environmental Quality Act (EQA, 1974) which is the first law approved in the Malaysian Parliament relating to the prevention, abatement, control of pollution and enhancement of the environment, and for other purposes connected with the environment. The background data prior to landfilling activity were also used to compare with the current water quality status. These data were collected from EIA reports.

STUDY AREA

Ampar Tenang Landfill

Ampar Tenang Landfill site is located approximately 4 km to the south of Dengkil town about 40 km southeast of Kuala Lumpur, the capital city of Malaysia (Figure 1). The landfill site is bounded mainly by oil palm plantation. The surrounding area is now being developed particularly for housing projects. The southern area of the site is located about 20 m from Sg. Labu.

The site is an active open tipping (started operation in year 2000), and receives about 100 tons domestic waste per day. It was first operated by the Majlis Perbandaran Sepang before it was transferred to the management of Alam Flora Sdn Bhd (a private company that dominates the solid waste management in Selangor). The site was then upgraded from open dump to a controlled waste disposal site. However, there was no proper liner system.

Geologically, the landfill is sited on top of the river alluvium consisting mainly of silt (50-70%), clay (<25%)

Figure 1: Locations of the landfill sites.

and sand (<25%). The site is more clayey near the ground surface but more silty to sandy in deeper layers, representing the shallow confined aquifer. Ampar Tenang landfill site is situated on the most eastern part of the confined Langat Basin alluvial aquifer. The area is underlain by unconsolidated alluvium sediments of thickness ranging between 15 m and 26 m, sitting on bedrock of Kenny Hill Formation. A clay layer forms the top 5 m to 12 m of the alluvium. The minimum thickness of the clay beneath the landfill site is approximately 4 to 5 m. The clay is underlain by an aquifer layer of sand and silty sand with the thickness of 8 to 15 m. However, the bottom portion of this aquifer layer consists of interbedded layers and lenses of clayey silt and gravel of variable thicknesses.

Different layers of alluvial sediment in the area are characterised by different values of hydraulic conductivity (K). JICA & MGDM (2002) quantified the K parameters of sediments at various places in Langat Basin. It can be generalized that K values for the clay layers are between 1.2 x 10^{-8} m/s and 6.0 x 10^{-5} m/s and for sand layers are between 1.20 x 10^{-7} m/s and 1.13 x 10^{-3} m/s.

The piezometric levels at Ampar Tenang landfill denoted that groundwater in the landfill site flow towards the southwest, into Sg Labu. Out of the seven monitoring wells installed, only three remain. The rest were covered by waste as they were installed within the active landfill area. One of the remaining wells is, however, not usable.

Bukit Tagar Landfill

The Bukit Tagar landfill is situated on parts of Lots 25, 36 and 37 of Ladang Sg. Tinggi in Mukim Sg. Tinggi, Daerah Ulu Selangor. It is a sanitary landfill and it started operation in 2007. The development of the Bukit Tagar waste disposal facility was meant to overcome the problems associated with the closure of existing landfills at Taman Beringin in Kepong and Air Hitam in Puchong. The landfill received its first load of waste on 1 April 2005 and now handles 3,000 tons of waste per day. This facility has a capacity of 1,000 m^3/day and has been designed and developed to allow modular expansion up to 3,000 m^3/day. The plant is fully automated with sophisticated SCADA control systems whereby operator intervention requirements are minimized. The treatment process includes extensive reed beds polishing and land irrigation of treated leachate to achieve zero discharge of treated leachate from the site. The storage ponds, aeration ponds and the treatment plants have comprehensive secondary containment and monitoring system.

The landfill site occupies a total land area of 1,700 acres. It is approximately 50 km north of Kuala Lumpur and 5 km west of the North-South Expressway. The site is situated within two stream valley systems surrounded by high ridges on all sides except for areas to the west and northwest. It is drained by two small streams which flow northwesterly and converges to drain westwards. The two stream valleys are separated by low hills which act as a natural divide between the two valleys. The landfill site is characterized by undulating to hilly terrain with elevations ranging between 20 and 210 m above mean sea level.

Geologically, the area is characterized by thin layer of young alluvium deposit, mostly in the stream channels, underlain by bedrock of metasandstone and shale/slate/ phyllite. The alluvium generally is formed by recent deposits from soil eroded from the surrounding areas. The bedrock that characterizes most of the area and intense weathering have resulted in thick soil profile over the terrain. Geological structures within the bedrock are mainly foliation and folds, in the north-northwest trend and in parallel to the regional structures. The on-site soils generally comprise 4 to 12 m thick veneer of loose to medium dense yellowish brown sandy silt and clayey silt, overlying dense to very dense light grey clayey silt and sandy silt. The permeability (hydraulic inductivity) of the natural soils is lower than 1 x 10^{-7} m/s or better.

The landfill site was previously agricultural land and was cultivated with oil palm and rubber trees. Agricultural activities remain in the surrounding area. There are approximately 6 estate settlements near the landfill area. The nearest settlement is the Ladang Mary quarters which is about 1.5 km away. The biggest settlement is the Ladang Sg. Tengi which is 3 to 6 km to the south.

The landfill site was located within the catchment area of Sg. Tengi and adjacent to the North Selangor Peat Swamp Forest (NSPSF). This peat swamp forest occupies some 750 km^2 of the north-western part of Selangor and extends just west of the landfill site to the coast some 40 km away. Drainage from the site is towards the west to the NSPSF and ultimately into Sg. Tengi. However, an alienation of swamp forest land for agriculture has resulted in the development of man-made channels that run north-south and east-west. These drainage channels are for draining the swamp so as to make it suitable for agriculture. In doing so, drainage from southern part of the Sg. Tengi catchment which, is likely to include drainage from the landfill site, has been directed to flow southward to Sg. Selangor catchment. The flow from these channels drains into Sg. Air Hitam and ultimately into Sg. Selangor. Within the landfill site, there are two valley systems drained by two unnamed streams. The catchment area is approximately 3.26 km^2, comprising an area of 1.36 km^2 in the northern valley and 1.88 km^2 in the southern valley.

As mentioned earlier, the landfill site is characterized by widespread of thin layer Quaternary deposit overlying predominantly low grade metamorphic bedrock. Groundwater conditions in the area are essentially associated with and influenced by fracture systems in the bedrock. The permeability of the bedrock carried out during soil investigation prior to landfill development (DOE, 2004) is in the order of 10^{-8} m/sec to 10^{-7} m/sec. Groundwater levels monitored at 7 monitoring standpipes during the soil investigation were measured between 16 m and 27 m below the ground level, particularly in the hilly terrain. Groundwater levels near rivers were much shallower and lower in elevation, signifying that groundwater flows from high topographic elevation towards valleys and rivers. Regional groundwater flow in the area is apparently from the highland of the landfill site towards the west.

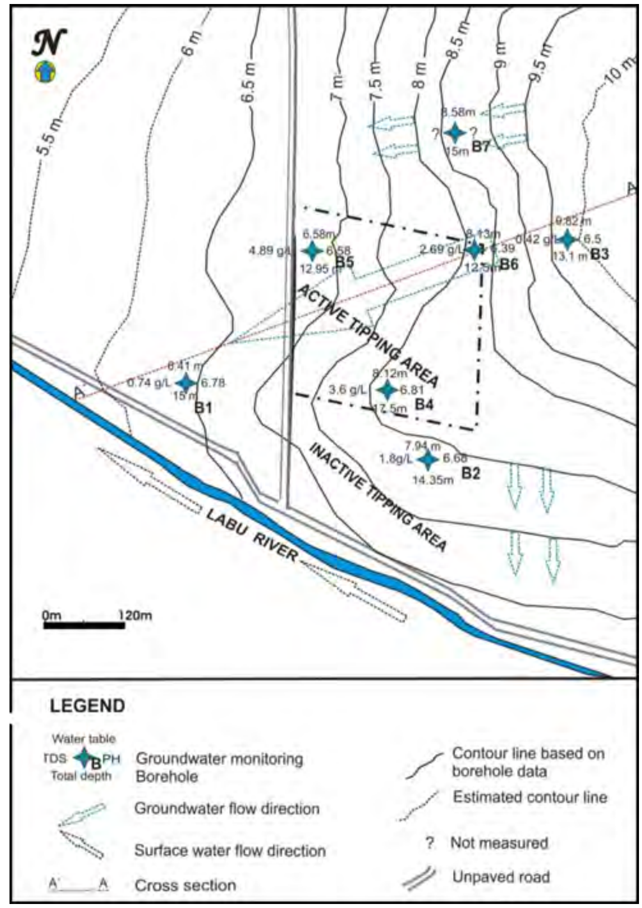

Figure 2: Location of boreholes at Ampar Tenang.

RESULTS AND DISCUSSION

Ampar Tenang Landfill

There are a total of 7 boreholes at this site (Figure 2), but 5 wells were damaged and/or collapsed due to landfilling activities in this area. Groundwater was sampled from the remaining 2 boreholes to generate new set of groundwater chemical data. Extensive studies were previously conducted and reported at this site (Bahaa, 2005; Esmail, 2006; Umi Kalsum, 2009).

New groundwater data (BH1 & BH2) in Table 1 revealed that the groundwater in BH1 is contaminated with organic pollutants indicated by COD values, ranging from 3931-11357 mg/l (COD level permitted in Standard B of the Malaysian Environmental Quality Act [EQA 1974] is 100 mg/l). High COD value in groundwater may indicate that the leachate had already penetrated the ground and contaminated the groundwater. It is also possible that raw leachate from the landfills could have flowed directly into the wells through surface drainage during rainy periods. The COD values previously recorded by Bahaa (2005) were in the range of 4589-8197 mg/l. Most developed countries such as US, Germany (and EU) and Australia did not have standards for COD for source water quality. However, compared with available standards (Chang *et al*., 2005) for countries like Japan (5 mg/l limit) and Taiwan (25 mg/l limit), the values at Ampar Tenang are quite alarming.

Most other parameters were below (better) the Raw Drinking Water Standard of Ministry of Health, Malaysia (MOH) except for Hg, Cd, Pb and Fe. Data from Umi Kalsum (2009) in showed that groundwater samples from two boreholes were not contaminated. All parameters were lower than the groundwater standard except for Fe in BH1 (downstream). The parameters in BH1 were slightly higher compared to BH2. This justifies that BH1 is located downstream of the groundwater flow and its water quality was slightly affected by the plume migration of leachate.

Table 2 shows results of groundwater study by Bahaa (2005) for six boreholes. The parameters were compared with groundwater standards by Ministry of Health (MOH 2000) and Department of Environment (DOE, 1995). The results showed that the TDS values in BH2, BH4, BH5 and BH6, nitrate in BH2, BH5 and BH6, Fe in all boreholes, Cu and Pb in BH1, BH2, BH3, BH4 and BH5, Ni and Cd in BH2, BH4, and BH5 exceeded the groundwater standards.

In addition surface water and leachate composition data generated from the current study are also available. Surface water was compared to class III INWQS (DOE 1995) while leachate was compared to Standard B Parameters Limits in the Environment Quality Act (EQA 1974). The data showed that most parameters for surface water from Sg. Labu were lower (better) than the Class III INWQS standard. Therefore, it can be classified as Class II indicating the water can be used as water supply source with conventional treatment required. However, leachate data showed that only 4 parameters were over the standard i.e. COD, As, Cr and Fe.

Bahaa (2005) also collected 3 surface water samples from Sg. Labu. He discovered that all parameters were

Table 1: Groundwater parameters from Ampar Tenang landfill (new data).

Parameter	BH1 (downstream)			BH2 (upstream)	MOH (2000)
Well depth (m)	12	NA	NA	13.64	NA
Water Table (m)	1.4	NA	NA	0.3	NA
pH	6.78	NA	NA	6.47	NA
Electrical Conductivity (EC) (µs/cm)	788	NA	NA	301	NA
Temperature (ºC)	27.6	NA	NA	25.7	NA
Dissolve Oxygen (DO)- mg/l	0.68	NA	NA	1.05	NA
Total Dissolve Solids (TDS) - mg/l	734.2	NA	NA	193	1000
Nitrate	8.56	7.59	8.51	0.45	10
Sulphate	3.76	3.77	3.82	1.5	250
Carbonate	0.53	0.52	0.55	NA	NA
Bicarbonate	12.04	12	12	NA	NA
Chloride	17.91	18.25	18.4	NA	250
Sulphide	5.39	5.42	5.4	NA	NA
Biochemical Oxygen Demand (BOD)	2.64	0.87	1.34	NA	NA
Chemical Oxygen Demand (COD)	11357	3931	6552	10	NA
Mercury (Hg)	0.003	0.004	0.004	NA	0.001
Cadmium (Cd)	0.058	0.095	0.082	ND	0.003
Chromium (Hexavalent)	0.039	0.039	0.038	0.00538	0.05
Chromium (Trivalent)	0.058	0.056	0.06	0.01298	NA
Arsenic (As)	0.0004	0.0004	0.0004	0.00091	0.01
Lead (Pb)	1.179	1.181	1.18	0.0008	0.01
Copper (Cu)	0.203	0.202	0.2	0.00259	1
Manganese (Mn)	0.011	0.02	0.016	0.19862	0.1
Nikel (Ni)	0.028	0.026	0.023	0.00907	NA
Tin (Sn)	0.255	0.256	0.254	0.0002	NA
Zink (Zn)	0.13	0.181	0.14	0.0613	3
Iron (Fe)	1.03	1.04	1.04	0.17455	0.3
Selenium (Se)	0.005	0.002	0.007	1.79928	0.01
Oil and Grease	0.02	0.03	0.05	NA	NA
Coliform (MPN)	ND	ND	ND	NA	NA
Total Suspended Solid (TSS)	59	61	62	NA	NA

All parameters are in mg/l unless indicated otherwise. ND=Not detected; NA = Not available. The values in shaded box indicate that the levels exceeded the national guidelines for raw drinking water quality benchmark for groundwater quality (MOH, 2000).

Table 2: Groundwater parameters of six boreholes at Ampar Tenang landfill (Bahaa, 2005)

Parameters	BH1	BH2	BH3	BH4	BH5	BH6	MOH (2000)	DOE (1995)
pH	6.64	6.82	6.38	7.08	6.81	6.51		
EC (µS/cm)	272	380	149	875	659	304		
TEMP	28.49	33.02	27.76	33.13	36.35	31.93		
DO	0.44	0.33	0.63	0.14	0.11	0.25		
TDS	737.2	1597.33	396.05	3238.67	5548.66	2666.7	1000	
Flourine	0.38	ND	0.15	0.06	0.62	0.03		
Chlorine	224.62	117.43	32.39	497.82	637.65	91.93		
Nitrite	1521	44.94	0.37	56.55	9.54	4.04		
Nitrate	8.56	41.85	0.04	1.01	16.87	10.02	10	
Phosphate	2.49	ND	0.003	ND	ND	0.04		
Sulphate	3.76	4.88	1.04	11.28	54.31	20.2	250	
Ammonia-N	10.3	22.64	2.16	25.19	53.15	22.79		
Carbonate	0.53	5.03	0.21	6.11	5.28	3.95		
Bicarbonate	12.04	31.03	25.85	36.13	35.05	27.96		
Fe	1.03	2.41	1.11	1.67	1.42	0.4	0.3	
Mn	0.06	ND	0.07	0.07	0.02	0.03	0.1	
Ca	1.25	4.9	1.36	3.53	3.42	10.08		
Na	34.83	434.56	17.26	922.54	847.43	247.94		
K	2.14	14.67	0.13	30.21	21.9	4.31		
Mg	15.24	42.25	14.4	59	164.17	52.93		
Cu	0.203	0.446	0.708	0.771	0.505	0.023		0.075
Cr	ND	ND	ND	0.039	0.001	0.0004		0.03
Ni	0.028	0.096	0.004	0.674	0.18	0.01		0.075
Zn	0.13	0.288	0.022	0.244	0.093	0.05		0.8
Cd	ND	0.058	0.003	0.098	0.077	ND		0.006
As	ND	ND	ND	0.002	0.002	ND		0.06
Pb	0.633	1.179	0.259	0.84	1.103	0.021		0.075

Note: 1) All units are in mg/l except stated. 2) The values in shaded box indicate the levels exceeded the Malaysian environmental impact assessment guideline for groundwater and/or surface water supply project 1995 and national guidelines for raw drinking water quality benchmark for groundwater quality, 2000

below (better than) Class II parameters of the INWQS except ammonia-nitrogen in two samples. Leachate composition showed that 3 parameters i.e. BOD, COD and chlorine were well above the Standard B.

A study by Umi Kalsum (2009) on surface water and leachate composition for 3 water samples from Sg. Labu showed that most parameters were higher (worse) than the Class II of INWQS, and thus the quality of the surface water could be in Class III or IV. The conductivity value was higher than Class II of INWQS in some samples due to its location near the leachate discharge point into Sg. Labu. BOD values were also higher in other samples (over the Class II classification). As far as metallic contamination is concerned, nitrate, As, Cu and Zn also exceeded the standard in some samples. In addition Mn, Fe and Pb were above the standard in all samples tested. Therefore, Sg Labu adjacent to Ampar Tenang landfill can be classified as Class III (polluted according to INWQS). These results differ from the findings of the current study due possibly to different weather conditions prior to sampling,

Umi Kalsum (2009) also collected and analysed 6 leachate samples collected at various points around the landfill site. All leachate parameters were below the Standard B except for certain heavy metals such as Cr, Fe and Zn.

Bukit Tagar Landfill

Comprehensive secondary data were collected from an EIA report (DOE, 2004) and 4 environmental monitoring reports (Table 3). It is also discovered that the numbers of parameters required to be tested and reported in Quarterly Monitoring Report for Bukit Tagar Landfill is 27 and this is higher than most landfills in Selangor. Table 3 shows the parameters of groundwater samples collected at different time intervals from October 2007 to March 2008. Overall, the quality of the environmental data was satisfactory and most parameters in all environmental classes are lower than the acceptable standards. Benchmarking these results with standards from DOE and MOH, it was found that only 1 parameter i.e. Fe that slightly exceeded the standard. Data from surface water analyses also show that none of the parameters are higher than the standards used. However, the nearby river water registered as Class III due to landuse activities not related to the landfill (DOE, 2004).

Thus analyses of the groundwater (and surface water)

Table 3: Groundwater monitoring data at Bukit Tagar sanitary landfill (Oct 2007-Mar 2008).

PARAMETERS	Unit	Oct-Dec 2007			Jan-March 2008			MOH (2000)	DOE (1995)
		GW1	GW2	GW10	GW1	GW2	GW10		
pH	-	7	6.8	5.7	5.9	4.3	6.8		
Temperature	°C	25.1	25	25	28.3	28.1	28.1		
Conductivity	µs/cm	89	89	25	35	35	91		
Bicarbonate	mg/l	40	46	5	8	1	32		
COD	mg/l	13	16	24	3	2	6		
Total petroleum hydrocarbons (TPH)	mg/l	0.04	0.04	0.04	0.04	0.04	0.04		
Lead	mg/l	0.001	0.001	0.001	0.004	0.013	0.002		0.075
Dissolved manganese	mg/l	0.001	0.001	0.001	0.005	0.015	0.001	0.1	
Total manganese	mg/l	0.001	0.001	0.001	0.011	0.018	0.087		
Dissolved iron	mg/l	0.005	0.005	0.005	0.397	0.128	0.007	0.3	
Total iron	mg/l	0.017	0.008	0.489	0.559	0.148	0.156		
Zinc	mg/l	0.005	0.005	0.005	0.036	0.074	0.044		0.8
Arsenic	mg/l	0.005	0.005	0.005	0.005	0.005	0.005		0.06
Cadmium	mg/l	0.005	0.005	0.005	0.001	0.001	0.001		0.006
Total chromium	mg/l	0.005	0.005	0.005	0.001	0.005	0.001		0.03
Copper	mg/l	0.005	0.005	0.005	0.014	0.026	0.002		0.075
Ammonia	mg/l	0.1	0.1	0.1	0.1	0.1	0.1		
Chloride	mg/l	1.4	1.9	3.3	4.8	4.8	1.4	250	
Sulphate	mg/l	3	3	1	8	2	2	250	
Sodium	mg/l	1,651	1,703	4,738	2,256	2,034	2,032		
Potassium	mg/l	1,704	1,724	3,659	1,033	0.736	1,813		
Calsium	mg/l	8,090	8,639	2,236	4,045	1,257	7,677		
Magnesium	mg/l	3,770	3,752	0.394	0.358	0.367	4.25		
Mercury	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
Boron	mg/l	0.005	0.005	0.005	0.012	0.009	0.001		
Nitrate	mg/l	1	1.6	0.1	0.2	0.9	1.3	10	
Water depth	m	5.1	16.5	26.6	3	17	10		

Note: 1) ND means Not Detected; 2) The values in shaded box indicate the levels exceeded the malaysia environmental impact assessment guidelines for groundwater and/or surface water supply project, 1995. SOURCE: 9th, 10th, 13th and 14th Quarter Environmental Monitoring Report, Bukit Tagar Sanitary Landfill (2006-2008)

showed environmentally favourable conditions at Bukit Tagar landfill. As mentioned earlier, the landfill operates on zero discharge policy. The leachate generated are treated in house until drinking water standards are achieved. The treated water is then used to irrigate the plants in the landfill compound. Although it was reported that Bukit Tagar Landfill was the reason for a smelly piped water incident in the Klang Valley in early 2006, the operator provided evidence to dispell this alegation (NST, 2006). Thus, the landfill has been used model landfill and has been a showcase for many visitors. Its technology is now being exported overseas.

CONCLUSIONS

The study mainly compares the state of groundwater at 2 landfill sites, i.e. Ampar Tenang (unengineered landfill) and Bukit Tagar (engineered landfill). Data obtained showed that at Ampar Tenang landfill, the groundwater is contaminated. Higher COD, Cd, Pb, and Fe were observed at the downstream side compared to upstream due to hydraulic flows. Leachate samples also showed high values As, Cr, Fe and Zn in some samples. Results at Bukit Tagar are generally well below (better) than the compared standard. Thus, in general, the overall observation made in this study is that groundwater quality is affected by landfill operation except for Bukit Tagar, which adopts a zero discharge target. The study also served to show with significant data that there are serious pollution around unengineered landfills.

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