CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Waste characterization in Sabak Bernam landfill

Waste composition in Malaysia depends very much on the source of solid waste generation. The wastes received in most of the landfills in Malaysia are co-mingled since organised waste sorting or pre-sorting facilities do not exist (Agamuthu and Khan, 1997). Based on visual observation, most of the wastes received in Sabak Bernam landfill were typical agro-based industrial wastes. Household wastes from the nearby town also contribute to the waste composition as shown in Table 4.1.

Table 4.1 Estimated composition (%) of the municipal waste in Sabak Bernam landfill.

Types of Wastes	% (volume)
Agro-waste	65
Municipal waste	20
Metal	2
Glass and ceramic	1.5
Paper	2
Textiles	0.5
Plastics and rubber	3
Others (bulky waste etc.)	6

It is observed that about 65% of the wastes in the landfill are agro-waste which comprises mainly of coconut, rubber and oil palm plantation wastes (Plate 4.1). This landfill also receives about 20% MSW which is mainly from small industries and household activities (Plate 4.2).

Plate 4.1 General view of Sabak Bernam landfill, showing the predominant agrowaste

Plate 4.2 Solid wastes disposed in Sabak Bernam landfill

4.2 Soil Studies

4.2.1 Introduction

Natural processes, as well as, environmental contamination continuously perturb the chemical composition of soil. The effect of the perturbation depends on the buffering capacity, as well as chemical characteristics of the soil and its specific compounds, for example, iron bind mainly to clay minerals, metal oxides and soil organic matter. The binding properties of these soil constituents differ significantly and are influenced by the environmental condition such as pH and ionic strength (Vander Zee and De Wit, 1993). The accumulation of the cations and the exclusion of the anions depend on the charge of the clay surface and the valency of the ions. Waste containing metals such as Cadmium (Cd), Nickel (Ni) and Zinc (Zn), etc. have for years been disposed of in dumps and landfills. The mobility of these heavy metals, and hence their potential risk to groundwater and surface water quality, depends on the complexing capacity of the organic matter leaching from the landfill waste. The subsequent migration of leachate away from landfill boundaries and its release to the adjacent environment is a serious environmental concern. The rate and amount of pollutant penetration through the soil is controlled by several factors including the physical and chemical properties of the pollutant and thickness and nature of the soil. Use of geotextile membrane in modern landfills has reduced or totally prevented heavy metal contamination of soil.

4.2.2 Physical characterization of soil

Soil Moisture content, Specific gravity and pH

The moisture content of soil samples from Sabak Bernam Landfill area at different depths from sites BH1, BH2 and BH3 are shown in Fig. 4.1a At

BH1, the moisture content ranged between 77 to 126% (dry weight basis), whereas at BH2 it was between 93 to 105% and at BH3 the moisture content ranged between 81 to 141%. At the sites BH1 and BH2, the moisture content variations do not indicate any particular trend with the depth. However, at the site BH3, the moisture content shows decreasing trend with increasing depth. The only metal which shows some degree of correlation with this trend is the metal Zn, but the trend is of a reverse nature meaning that the Zn concentration at the site BH3 generally indicates an increasing trend with increasing depth.

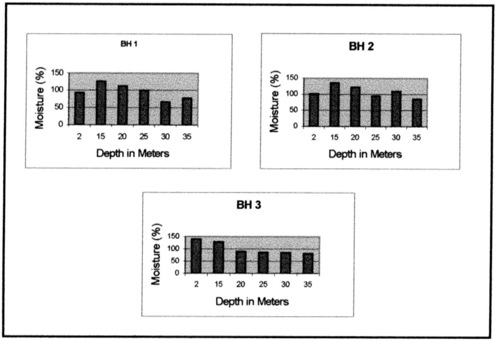

Fig. 4.1a Moisture content of the soil samples from different depths at the three boreholes

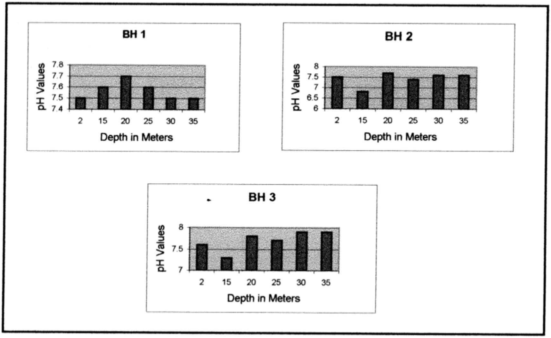

Fig. 4.1b pH of the soil samples from different depths at the three boreholes

The specific gravity of the soil samples varied between 2.39 to 2.55 (Table 4.2). The pH values of the soil samples at all the three sites ranged between 6.8 and 7.9, which can be attributed to the methanogenic condition of the landfill (Figure 4.1b). The pH values at all the three sites do not indicate any particular trend and the values ranged in a narrow band of 6.8 to 7.7. It is unlikely that these variations in the pH values will have any significant effect on metal contents at these three sites.

Table 4.2 Specific gravity of the soil samples from different depths of the three boreholes

BOREHOLE NO.	DEPTH (M)	SPECIFIC GRAVITY
BH 1	2	2.46
	15	2.41
	20	2.40
	25	2.42
	30	2.42
	35	2.39
BH 2	2	2.50
	15	2.54
	20	2.53
	25	2.51
	30	2.56
	35	2.54
BH 3	2	2.50
	15	2.54
	20	2.52
	25	2.52
	30	2.55
	35	2.55

Sieve Analysis:

Based on soil composition results, soil samples from boreholes BH1, BH2 and BH3 are classified as silty clay. In this study, the soil samples collected from different boreholes were found to contain clay (42-57%), silt (37-48%) and (0-14%) sand. The results of the sieve analyses of the soil samples from different boreholes at different depths are shown in the Figs. 4.2a,b, and c. It was observed that the respective particle sizes of sand, silt and clay at all the three sites do not vary significantly. It was also noticed that the percentage of clay at site BH1 (Fig.4.2a) decreased with depth. The percentage of silt was found to be increasing with depth at BH1 and BH2.

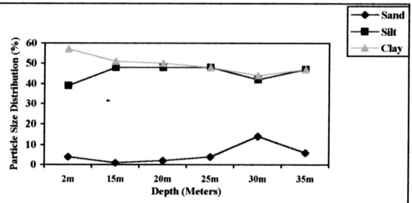

Fig. 4.2a Particle Size Distribution at site BH1

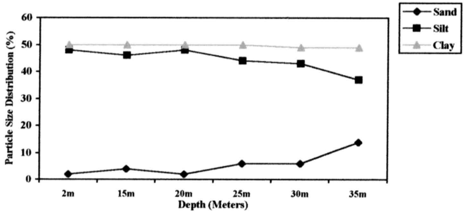

Fig. 4.2b Particle Size Distribution at site BH2

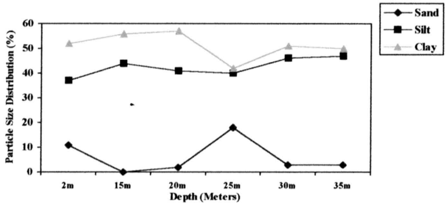

Fig. 4.2c Particle Size Distribution at site BH3

4.3 Concentration of heavy metals at different depths (Vertical distribution)

The concentration of heavy metals in the soil samples from various depths at the three borehole sites viz. BH1, BH2, and BH3 are given in Tables 4.3, 4.4 and 4.5. The results given are averages of three replicates.

Table 4.3 Heavy metal concentrations in soil at various depths from site BH1 (within landfill)

Heavy Metal		Depths					
mg/L		2m	15m	20m	25m	30m	35m
Ca	Mean	19.1674	10.2451	16.4428	14.8235	17.2620	11.4846
	Std.Deviation	±0.0800	±0.3330	±0.1100	±0.2300	±0.2200	±0.2300
Pb	Mean	0.5610	0.1722	0.2324	0.3440	0.1808	0.1208
	Std.Deviation	±0.021	±0.002	±0.0021	±0.0064	±0.0022	±0.0012
Fe	Mean	17.0132	15.2087	22.1221	24.6633	25.0327	23.7016
	Std.Deviation	±0.3030	±0.1300	±0.0700	±0.2600	±0.1300	±0.1000
Cu	Mean	0.0100	0.0121	0.0129	0.0103	0.0105	0.0111
	Std.Deviation	±0.0008	±0.0015	±0.0007	±0.0014	±0.0007	±0.0015
Zn	Mean	0.1866	0.2537	0.2125	0.2413	0.3189	0.3513
	Std.Deviation	±0.0049	±0.0038	±0.0025	±0.0011	±0.0054	±0.0007
Ni	Mean	0.0580	0.0206	0.0343	0.0216	0.0304	0.0343
	Std.Deviation	±0.0022	±0.0004	±0.0008	±0.0005	±0.0005	±0.0012
Cd	Mean	0.0100	0.0108	0.0101	0.0124	0.0129	0.0108
	Std.Deviation	-	±0.0010	±0.0008	±0.0005	±0.0003	±0.0086

Table 4.4 Heavy metal concentrations in soil at various depths from site BH2 (ex-landfill)

Heavy Metal		Depths					
mg/L		2m	15m	20m	25m	30m	35m
Ca	Mean	9.5920	7.8100	4.6223	4.9117	4.4632	4.1900
	Std.Deviation	±0.2000	±0.1000	±0.0700	±0.0300	±0.0400	±0.0300
Pb	Mean	0.6100	0.2580	0.2110	0.1119	0.1030	0.1123
	Std.Deviation	±0.0700	±0.0030	±0.0040	±0.0005	±0.0078	±0.0100
Fe	Mean	9.9200	12.5710	24.7689	25.0267	26.3091	16.4800
	Std.Deviation	±0.3000	±0.1340	±0.3300	±0.3500	±0.0007	±0.3500
Cu	Mean	0.0170	0.0111	0.0153	0.0147	0.0129	0.0140
	Std.Deviation	±0.0007	±0.0010	±0.0040	±0.0006	±0.0002	±0.0004
Zn	Mean	0.1980	0.1732	0.3212	0.4316	0.6369	0.1800
	Std.Deviation	±0.0007	±0.0006	±0.0170	±0.0020	±0.0020	±0.0010
Ni	Mean	0.0570	0.0227	0.0187	0.0383	0.0402	0.0280
	Std.Deviation	±0.0008	±0.0002	±0.0006	±0.0003	±0.0006	±0.0010
Cd	Mean	0.0001	0.0005	0.0006	0.0001	0.0001	0.0001
	Std.Deviation	-	±0.0001	±0.0002	-	-	-

Table 4.5 Heavy metal concentrations in soil at various depths from site BH3 (future cell)

Heavy Metal	**Depths**						
mg/L		2m	15m	20m	25m	30m	35m
Ca	Mean	8.8132	4.3257	2.2681	3.5573	4.5660	4.0694
	Std.Deviation	±0.0900	±0.0300	±0.0030	±0.1100	±0.0600	±0.0110
Pb	Mean	0.1980	0.1377	0.1215	0.0172	0.0947	0.1205
	Std.Deviation	±0.0086	±0.0019	±0.0063	±0.0009	±0.0037	±0.0041
Fe	Mean	12.8900	20.2978	8.8784	8.0170	7.5048	7.2692
	Std.Deviation	±1.0300	±1.0000	±0.2000	±0.2000	±0.0170	±0.0440
Cu	Mean	0.0151	0.0103	0.0130	0.0137	0.0126	0.0124
	Std.Deviation	±0.0005	±0.0009	±0.0012	±0.0004	±0.0006	±0.0006
Zn	Mean	0.1925	0.2236	0.1555	0.2724	0.4100	0.4146
	Std.Deviation	±0.0100	±0.0090	±0.0014	±0.0020	±0.0040	±0.0040
Ni	Mean	0.0570	0.0363	0.0228	0.0127	0.0471	0.0589
	Std.Deviation	±0.0040	±0.0016	±0.0012	±0.0005	±0.0009	±0.0003
Cd	Mean	0.0003	0.0006	0.0001	0.0069	0.0022	0.0009
	Std.Deviation	-	±0.0002	±0.0001	-	-	-

It is observed that the concentrations of Ca and Pb at all three borehole sites decreases with increasing depths while that of Fe, Zn and Ni increases with increasing depths. The concentration of Cu at all three borehole sites appears to be almost constant at all depths.

Calcium

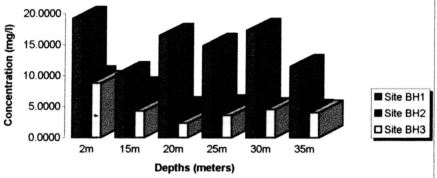

Fig. 4.3a Calcium Distribution by Site and Depth

In Figure 4.3a, the concentration of Ca at the three-borehole sites is presented as a function of the soil depths. Very large concentration of Ca (10-20 mg/L), far exceeding the Malaysian guide levels of 7.5 mg/L (Tong, 1997) was found at the landfill site BH1. Similar Ca pattern was reported by Mohd. Nazan Awang and Mohd. Abdul Karim (1998) and Haji Saffen Baharuddin (1992).

The concentration of Ca was found to be generally higher than 7 mg/L at all three borehole sites within the upper soil layer of 2 to 15 m depth except at BH3. The high concentration of Ca in the soil samples from the upper layers could be attributed to the biomass from the agrowaste (Ghestan and Barmond, 1998). The concentration of Ca at all three borehole sites indicated a generally decreasing trend with increasing depth.

Lead

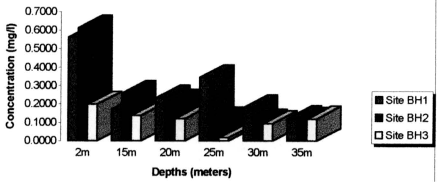

Fig. 4.3b Lead Distribution by Site and Depth

Significant amount of Pb was found at sites BH1 and BH2 at 2m depth (Figure 4.3b). The highest Pb concentration (0.5610mg/L) was generally found in the upper level (1m-2m) at site BH1 and BH2. At 35m depth, the lead concentration was the same (0.1000mg/L) at all three sites because of the very low mobility of lead in deeper soils. Since, Sabak Bernam is an agricultural area, the elevated levels of Pb could be attributed to the application of agro-chemical pesticides, animal manure and fertilizers

(Chen *et al*, 1997). Lead could also be contributed from old batteries disposed from households. From Fig. 4.3b, it is observed that the total concentration of Pb in the soil samples increased from the lower depth to the topsoil layers. This pattern of specific elements being retained in the upper level, has also been reported by Bergkvist (1987).

Iron

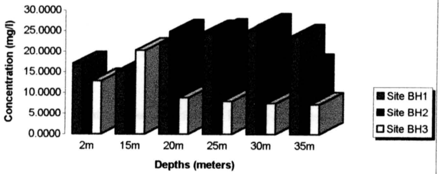

Fig. 4.3c Iron Distribution by Site and Depth

Figure 4.3c shows that the concentrations of Fe in the landfill site at different depths vary from 7.3 to 26.3 mg/L. It was observed that the Fe concentration was higher at depths ranging from 20-30m in sites BH1 and BH2, compared to site BH3. This could be because BH1 is the landfill site while the BH2 is ex-landfill site.

Copper

Figure 4.3d shows the distribution of Cu for all the three sites and the concentration of Cu was found in between 0.01 to 0.017 mg/L. It is found from the Figure 4.3d that Cu concentration does not show much difference at different depths of the soil.

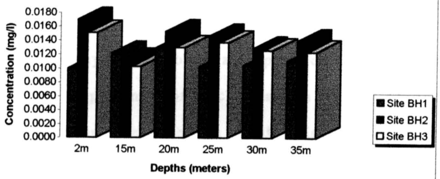

Fig. 4.3d Copper Distribution by Site and Depth

Zinc

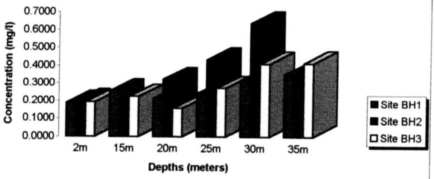

Fig. 4.3e Zinc Distribution by Site and Depth

Figure 4.3e shows the Zn concentrations at various depths of all the three sites. It was found that the mean Zn concentration of the soil samples ranged between 0.1 to 0.6 mg/L. The depth distribution profiles of Zn in soil sample shows generally enrichment at the deeper levels (Figure 4.3.e). The results obtained for Zn from the different sites showed increasing trend, similar to Fe and Ni. It has been established that heavy metal in the soil is retained by different reactions such as precipitation, forming carbonates and hydroxides or by adsorption on clay (Tack *et al.*, 1993). The relative importance of each reaction is determined by differences in the reaction kinetics of the metal. This is due to its much higher total content and also to the higher solubility of Zn as compared to other metals (Tack *et al*, 1993). The high Zn concentration in the landfill is due to agricultural activity going on around Sabak Bernam area and the Zn could be from other sources like materials discarded from homes and some commercial activities such as household fittings, audio-visual electronics, kitchen equipment and used batteries etc.

Nickel

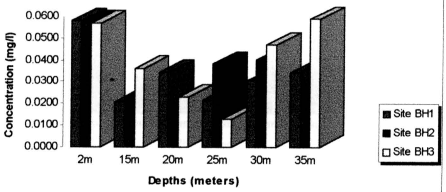

Fig. 4.3f Nickel Distribution by Site and Depth

The concentrations of Ni from the soil at 3 different sites were found to be in the range of 0.01 to 0.06mg/L (Fig. 4.3f). In the upper portion of the soil (2m), Ni content was comparatively higher than the deeper anoxic zone.

The amount of Ni found in the soil samples might be because of anthropogenic activity. The results obtained for Ni at different levels could be correlated with interaction with other soil component (Vander Zee and De Wit, 1993).

Cadmium

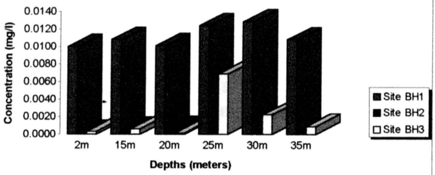

Fig. 4.3g Cadmium Distribution by Site and Depth

Cd concentration ranges from 0.0001 to 0.015mg/L (Fig. 4.3g). The concentration of Cd at the landfill site (BH1) was exceptionally high compared to the neighboring sites BH2 and BH3, but all the sites contained Cd below the EQA, 1974 limit. Contribution of Cd in the landfill site is due to material discarded from homes and some commercial activities such as electronic items, used batteries, etc.

4.4 Horizontal distribution of heavy metals at Sabak Bernam landfill

4.4.1 Heavy metal concentration in topsoil at different sites

In Table 4.6, the elements lead, cadmium, copper and calcium show higher metal contents at the subsoil. Such a distribution is usually explained by the anthropogenic influences, which lead to the accumulation of metals in the subsoil (Chen *et al.*, 1997).

Table 4.6 Heavy metal concentration (mg/L) in subsoil at different sites

Heavy Metals	Site BH1 (Landfill)	Site BH2 (Ex-landfill)	Site BH3
Pb	0.70	0.75	0.27
Cd	0.001	0.001	0.0001
Cu	0.11	0.116	0.05
Ca	28.2	23.54	20.5
Zn	1.02	0.56	0.50

* All concentrations are in mg/L.

In comparison with the standard B(EQA, 1974), lead concentrations are found to be higher at sites BH1 and BH2 whereas, zinc concentration was higher in the landfill site BH1 than at sites BH2 and BH3. In the agriculture sector, inputs by fertilizers, pig slurry (zinc) and plant treatment products (lead) can be considered as a possible source of lead and zinc. Copper is mainly brought in soils by agricultural practice (Chen *et al.*, 1997).

4.4.2 Lateral distribution of heavy metal among the 3 study sites

Fig. 4.4(a-f) shows the lateral distribution of calcium among the three sites. It was observed from Fig. 4.a that the Ca concentration was almost double (19.96mg/L) at the landfill site BH1 than at the sites BH2 and BH2, specially at 2m depth. In sites BH2 and BH3, the calcium concentration was found to be in the range of 4 to 8 mg/L (15–35m). Although, the Ca concentration at site BH1 decreased with depth, it was always higher compared to the other two sites.

The lead concentrations, however did not show the same trend shown by Ca, since at sites BH2 and BH3 the lead concentration was higher at different depths compared to the site BH1 (Fig. 4.5).

The concentration of iron at 2m depth at site BH1 was higher compared to the other two sites as shown in Fig. 4.6a. It was also found that the concentration of iron, at depth 15m, was comparatively higher at sites BH1 and BH3 than at site BH2 (Fig. 4.6b). However, at 20m depth, the concentration of iron was higher at site BH2 compared to the sites BH1 and BH3 (Fig. 4.6c). At 30m depth, the iron concentration at site BH2 was higher than at the sites BH1 and BH3 (Fig. 4.6e). At 35m depth, the site BH1 indicated higher iron concentration than at the sites BH2 and BH3 (Fig. 4.6f).

Except for 20m and 25m depths, the copper concentration showed a reverse trend in that the landfill site had lower copper concentration than at sites BH2 and BH3 (Fig. 4.7). However, the overall concentration of copper was generally low at all sites.

Concentration of Zn at all three sites was found to be almost the same at all sites at 2m depth. At 15m, zinc concentration is higher at the landfill (site BH1) and site BH3 compared to site BH2. It was also observed from the Fig.4.8 (c-e), that at site BH2, the concentration of zinc was comparatively higher at the level range 20m-30m than at site BH1. In site BH3, on the other hand, concentration of Zn at all levels except at 35m were comparatively lower than the other two sites.

Concentrations of Ni at 2m-35m in all three sites were showing almost the same as shown in Fig. 4.9(a-f). At site BH3, Ni concentration was exceptionally high at the level 35m compared to the other two sites.

From the Fig. 4.10(a-f), the Cd concentration in landfill site BH1 was high at all depth, except at 30m, compared to the other two sites.

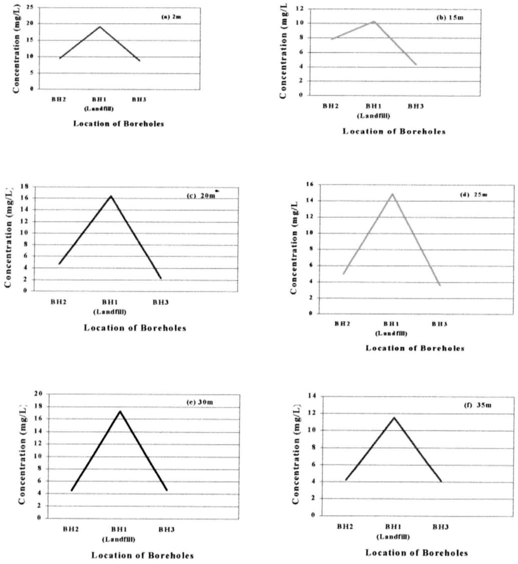

Fig. 4.4 Lateral distribution of Ca among the sites BH1, BH2 and BH3

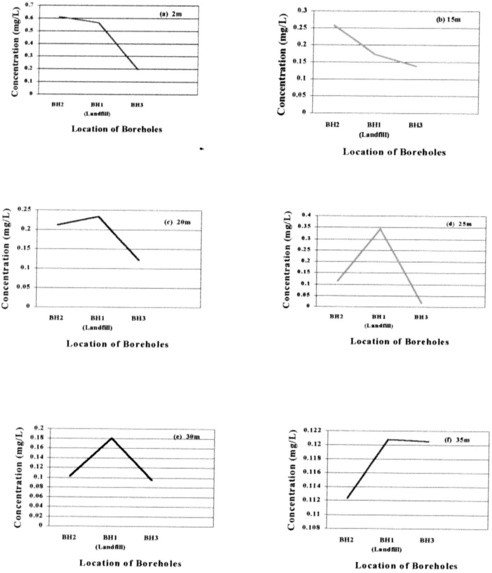

Fig. 4.5 Lateral distribution of Pb among the sites BH1, BH2 and BH3

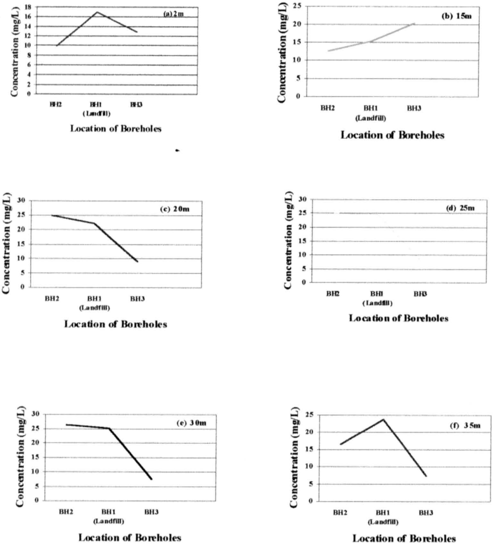

Fig. 4.6 Lateral distribution of Fe among the sites BH1, BH2 and BH3

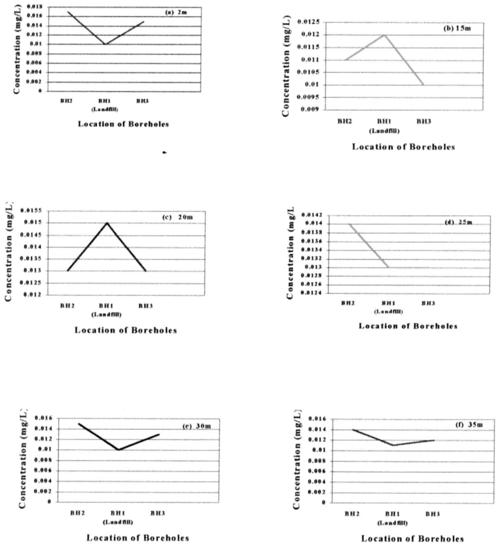

Fig. 4.7 Lateral distribution of Cu among the sites BH1, BH2 and BH3

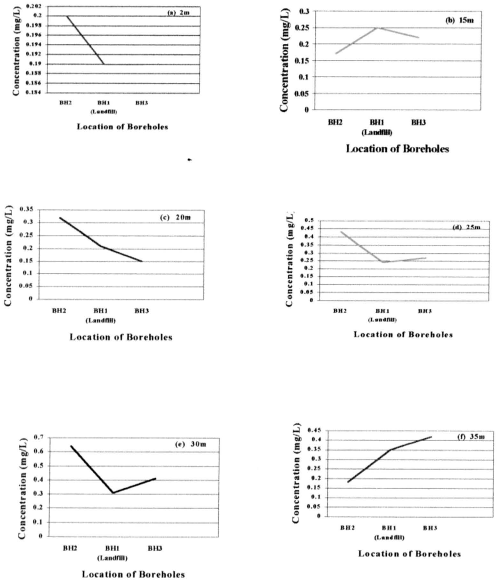

Fig. 4.8 Lateral distribution of Zn among the sites BH1, BH2 and BH3

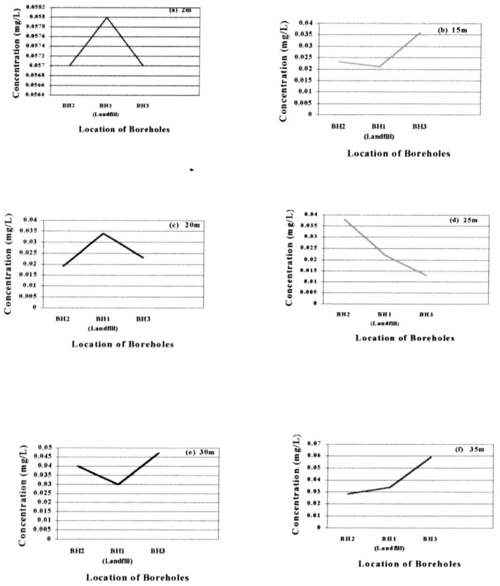

Fig. 4.9 Lateral distribution of Ni among the sites BH1, BH2 and BH3

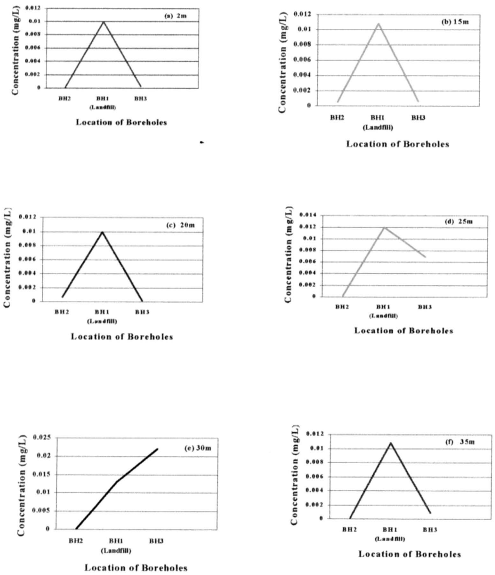

Fig. 4.10 Lateral distribution of Cd among the sites BH1, BH2 and BH3

4.5 Leachate Studies

4.5.1 Introduction

Landfilling is at present the most economical means for disposing of municipal solid waste, sludge and liquid concentrates of pollutants. Infiltration of water into a landfill plus decomposition of the solid waste results in the production of landfill leachate —a noxious mineralized liquid with a high content of organic substances that may move out of the landfill and pollute the ground water.

Pollutants in leachate from poorly designed or badly located dumps or landfills have contaminated water resources and in some places such pollution could cause severe economic and environmental consequences. Although several factors are involved in the retention and concentration of pollution from landfill leachate, two of the more important factors are adsorption and retention of the pollutants by soils and clay minerals thus limiting environmental degradation.

The complex chemical and biological reactions that take place in a landfill make it very difficult to predict leachate quality at any given landfill site. The variability in leachate composition is due to factors such as: quality and composition of solid wastes, landfill age, degree of compaction and amount of rainwater infiltration. Landfill leachate often contains high concentrations of toxic heavy metals, and many of these metals can form strong complexes with biomolecules. Landfill leachates contain many organic and inorganic complex ligands, particularly Cl, which determine, to a large extent, the forms of metals in solution (Tack *et al*, 1993) These complexes will have an impact on the mobility and thus possible toxic effects of the metals in the soil.

4.5.2 Characterization of leachate from Sabak Bernam landfill

The chemical complexity and the heterogeneous nature of many wastes, not only make their characterization difficult (Chian and DeWalle, 1976), but also influences the quality of the landfill leachate. The composition of leachate also depends on the degree of waste stabilization. Other factors which contribute to the variation of the quality of the leachate are the size of the fill, the degree of compaction, moisture content, temperature, rainwater infiltration, sampling and the analytical methods (Chian 1977). The characteristics of leachate samples collected from Sabak Bernam landfill are listed in the Table 4.7. The presence of heavy metals is of major concern from an ecological point of view. It can be observed from the Table 4.7 that a significant quantity of heavy metals like iron, zinc, copper, cadmium, lead and nickel are found in the leachate samples which could be attributed to the wastes from industrial and agricultural activities. The mobility of these metals in the leachate is governed by the environmental factors like pH, rainfall, redox reaction, and microbiological activity and soil characteristics.

Table 4. 7 Composition of Landfill leachate from Sabak Bernam Landfill Site.

Parameter	Sabak Bernam Landfill (mean)	Kalana Jaya Landfill*	EQA 1974** Standard A	Standard B
BOD (mg/L)	726	20-180	20	50
COD(mg/L)	1250	70-515	50	100
pH	7.96	7.3-7.6	6.0-9.0	5.5-9.0
TSS(mg/L)	111.58	50-92	50	100
Specific Conductance μS	16.2	-	-	-
Alkalinity ($CaCO_3$) (mg/L)	1200	22-365	-	-
Hardness ($CaCO_3$) (mg/L)	850	109.9-360	-	-
Total P(mg/L)	5.76	-	-	-
Ortho P(mg/L)	103.39	-	-	-
NH_4-N(mg/L)	8.0	-	-	-
Calcium(mg/L)	437.86	17.93-211.60	-	-
Chloride(mg/L)	420	23-30	-	-
Sodium(mg/L)	1287	4.31-10944	-	-
Potassium(mg/L)	540	12.23-34.13	-	-
Sulfate(mg/L)	36	1-72	-	-
Magnesium(mg/L)	55.3	0.95-210	0.2	1.00
Iron(mg/L)	8.56	0.07-1.81	1.00	5.00
Zinc(mg/L)	1.36	-	0.20	1.00
Copper(mg/L)	0.02	-	0.20	1.00
Cadmium(mg/L)	0.001	-	0.01	0.02
Lead(mg/L)	0.03	-	0.01	0.50
Total C(mg/L)	2057	-	-	-

* Source: (Mohd. Azlani, 1996),
** Environmental Quality Act 1974, Environmental Quality, (Swage Industrial Effluents), Regulations 1979.

The average pH value of the leachate samples was 7.96 and the average electric conductivity of the samples was 16.2μS. Landfill leachate is generally acidic in the earlier stages due to the generation of organic acids from the decomposition of the wastes at the early stage of the fill. Since the Sabak Bernam landfill is more than six years old, the alkaline pH value for the collected leachate samples could be because of the decrease in the acid and dissolution of calcium carbonate and other minerals (Chian and DeWalle, 1977b). The alkaline pH shows that the acid stage has been completed. The release of constituents from the solid waste is obviously governed by decomposition process, which is clearly reflected in the values of organic indicators like COD, BOD and TOC of the leachate samples. In this study, the average values of the BOD and COD in the leachate samples are found to be 726 and 1250 mg/L, respectively. The ratio of the BOD to the COD value is approximately 0.58 which is not too conductive for bio-degradation. This lower value of the BOD to COD ratio represents oxidized state of the organic carbon. These organic carbons are generally degradation products of microbial activity which increases with the age of landfill (Chian and Dewalle 1974). The average alkalinity of the leachate samples is 1200 mg/L. The presence of the carbonate, bicarbonate, ammonia, sulfides and phosphates in the leachate samples is the cause of this alkalinity. The large amount of the agro-waste and the industrial waste received by the Sabak Bernam landfill (Plate 4.1) could contribute to the high sodium, potassium, calcium, magnesium, chloride and sulfide ions in the leachate samples. Nitrogen and phosphorous are the macronutrients in the leachate samples. The concentration of NH_3-N (8.0 mg/L), total P (5.76 gm/L) and Ortho-P (103.39 gm/L) in the leachate were also investigated. The transformation of macronutrients depends on pH redox potential and microorganisms. Other mechanisms like adsorption and ion exchange also help to release this nutrient into the environment. The total carbon is high in the Sabak Bernam landfill leachate sample with a maximum value of 2057 mg/L, which could be from the fibrous agrowaste in the landfill. The leachate contains high amounts of total suspended solid (TSS), Mg, Fe and Zn which exceeded the effluent standards stipulated in EQA, 1974. For example Mg in the leachate was at 55.3mg/L, while the EQA limit was below 1mg/L. Similarly Fe concentration in leachate was 8.5mg/L, while the EQA limit was 5mg/L. The high heavy metals concentration in the leachate (Fe and Zn) seems to tally with the increased soil metal content, particularly at the landfill site, as observed in the earlier sections.

Some general observations can be made when comparing Sabak Bernam Landfill with one other published Malaysian data from Kelana Jaya Lanfill (Mohd. Azlani, 1996), (Table 4.7). The leachate from Sabak Bernam landfill contained higher concentrations of the major cations Ca (437.86 mg/L), Mg (55.3 mg/L), Na (1287 mg/L) and K (540 mg/L) than

Kelana Jaya landfill leachate. Also the leachate samples from Sabak Bernam landfill had higher Cl concentrations of (420 mg/L) compared to Kelana Jaya leachate (23-20gm/L). Cd concentration was found to be lower (0.001mg/L) in the Sabak Bernam landfill than data published for a typical 15 years old landfill (Chian and DeWalle, 1976 and 1977a). The leachate from Sabak Bernam landfill contained concentrations of sulfate at 36 mg/L, which is within the range reported by Tchobanoglous *et* al., (1993). The differences in the characteristics of landfill leachate from Sabak Bernam and Kelana Jaya could be attributed to the following factors: 1) Sabak Bernam, landfill basically contains more agrowaste whereas Kelana Jaya landfill in a residential area and contains little agrowaste and more of domestic and indusrtial wastes. 2) Sabak Bernam landfill is only about 6 years old while Kelana Jaya landfill is over 10 years old.

Sabak Bernam landfill leachate composition indicates lower concentration of heavy metals (Cd, Fe, Cu, Pb and Zn) compared to the leachate composition of other European countries. However, these differences are caused by important factors such as climate, age of landfill and composition of waste disposed.