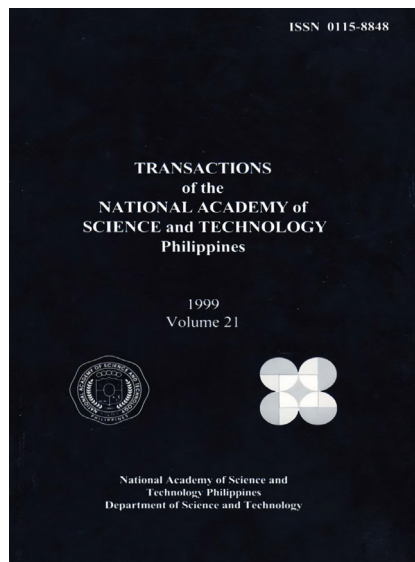


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Metals and Total Organic Levels in the San Mateo Landfill Leachate and Its Receiving Water Systems

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METALS AND TOTAL ORGANIC LEVELS IN THE SAN MATEO LANDFILL LEACHATE AND ITS RECEIVING WATER SYSTEMS

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ABSTRACT

The San Mateo landfill has been discharging leachate into the Bosoboso River since it started operating in 1991. The effluent being discharged may potentially deteriorate the receiving water systems in the area. This study, which was conducted from August to December 1998, was aimed at assessing the impact of the San Mateo landfill on its receiving water systems as well as the receiving waters of the Bosoboso rivers using the following parameters: volume of discharge, conductivity, pH, turbidity, dissolved oxygen (DO), Chemical Oxygen Demand (COD), iron, copper and zinc in the landfill leachate.

The results of the study revealed the following. High conductivity readings were obtained in the landfill (highest value of 8.32 mS/cm) in comparison with other sites (0.291 mS/cm) indicating a high ion content in the leachate. The pH of all samples taken from the sites (pH range = 7.69 - 8.39) met the standard pH range of 6.00 - 9.00 for effluent waters as specified in the DENR Administrative Order 35. No significant differences in turbidity were observed among the sampling sites throughout the study. However, DO measurements showed very low values for the landfill site in comparison to the other sites, which is indicative of the presence of very high levels of organic matter. Very high values were observed for COD (3,910 ppm) in the landfill leachate. On the other hand, copper (0.252 ppm) and zinc (1.147 ppm) were found to be within the effluent limits.

The high COD level was found to be one major cause for the deteriorating water quality of the Bosoboso River. In the light of proposals to tap this river system as a source of drinking water for Metro Manila, these results highlight the need to implement a Water Quality Management Program to prevent further degradation of the river.

Keywords: San Mateo Landfill, Bosoboso River, Leachate, River Pollution, River Sampling, Chemical Oxygen Demand (COD), Iron (Fe), Copper (Cu), Zinc (Zn), Pollution load.

INTRODUCTION

The San Mateo Landfill (SML) was constructed in February 1991 within the 279.3-hectare Marikina Watershed, and presently covers a total surface area of about 106 hectares (Culibao, 1998). It currently receives an estimated 5,500 to 6,000 cubic meters of garbage daily from Metro Manila and four Rizal towns. Its leachate goes through a series of seven lagooning ponds that process its wastewater before being discharged onto a leachate stream which eventually merges with the Bosoboso River.

The Bosoboso River is connected to the Wawa River, which functioned as the primary source of Metro Manila's drinking water supply during 1909 - 1968. The Wawa Dam was closed by the Philippine Inter-Agency Committee in 1968 due to structural instability (Ubac, 1997). After three decades of the Wawa Dam's closure, water shortage problems have risen sharply within Metro Manila; thus, proposals to reopen the Wawa Dam have been made (Ubac, 1997). However, concerns had been raised on the possible effect of landfill leachate on the quality of the water. Hence, an immediate need to closely monitor the water quality of the Bosoboso-Wawa River system arises. This was carried out in this study through the assessment of the following parameters: discharge and the physico-chemical parameters of temperature, conductivity, pH, turbidity, dissolved oxygen (DO), COD, Iron (Fe), Copper (Cu), and Zinc (Zn) in four selected sampling sites from August to December 1998 (Figure 1).

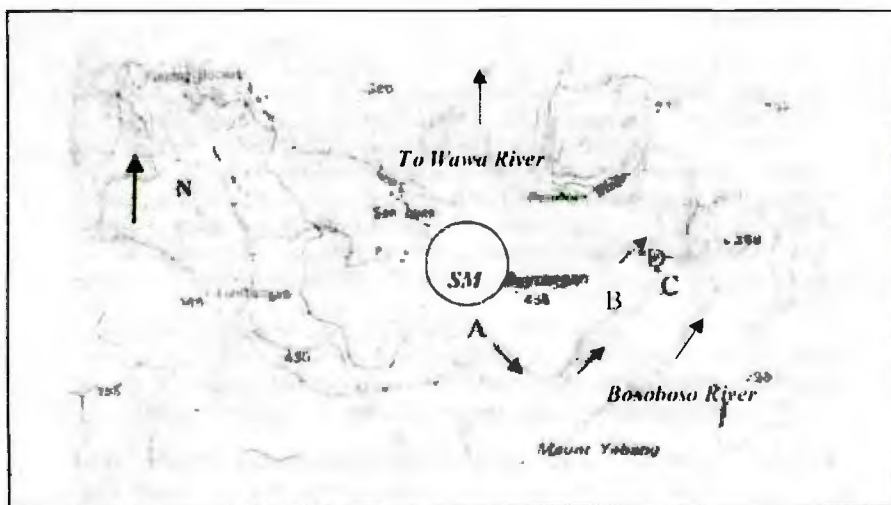


Figure 1. Topographical map of the study area. Letters indicate the sampling sites. Arrows show the direction of flow of the rivers and streams.

MATERIALS AND METHODS

Description of Sampling Sites

Site A: San Mateo Landfill (SML) -

The San Mateo Landfill is located on top of Mount Baytangan at an altitude of about 455 m above sea level. The linear distance from Site A to the Bosoboso River junction is about 1.1 km. However, the leachate stream takes the path of an arc to get to the junction; thus, the estimated distance to the junction along stream path is about 1.5 km.

Site B: Leachate Stream - 20 meters before merging with the Bosoboso River -

Site B is situated on an unnamed creek that receives the effluent discharge from the sanitary landfill. Its riverbanks were mostly vegetated with tall grass, and its substrate was composed of either soft mud, or mud with rocks.

Site C: 400 meters upstream of the Bosoboso River -

Site C had riverbanks with a muddy substrate and heavy vegetation.

Site D: 300 m downstream of the Bosoboso River -

The area surrounding Site D had varying physical characteristics along its river banks. The first 250 m stretch from the junction was muddy and had a lot of vegetation. However, the next 50 m span had very little vegetation and the substrate was mostly rock.

Sample Collection and Preservation

COD, Fe, Cu, and Zn were the major chemical parameters chosen in this study. Preliminary studies conducted revealed the presence of relatively high concentrations of organics. Furthermore, among the metals analyzed, detectable levels of Fe, Cu, and Zn were obtained from the samples of the San Mateo Landfill leachate.

Water samples for COD, Fe, Cu, and Zn analyses were obtained at mid-depth. Polyethylene bottles were used for storage. For COD analysis, two 500-ml bottles were used to make two replicates. These samples were then preserved by adding of concentrated sulfuric acid until the pH was below 2. For metal analysis, two 1000-ml replicates were collected per site. The samples were preserved by adding concentrated nitric acid until the pH was below 2.

Major Parameters

The COD levels for all samples were determined using the Open Reflux Method as described in *Standard Methods* (Eaton et al, 1995). However, a deviation from standard procedure was made for Site C whose COD values were all under 50 ppm. This was corrected by analyzing additional pairs of Site C samples spiked with a KHP equivalent of 10.0 mg O₂/L.

Iron (Fe), Copper (Cu), and Zinc (Zn) were analyzed using the Direct Air-Acetylene Flame Atomic Absorption Spectroscopy Method as described in *Standard Methods* (Eaton, Clesceri and Greenberg, 1995). However, Zn analysis entailed the use of a third degree calibration curve due to inadequate sample volume.

Minor Parameters and River Dynamics

Minor parameters such as temperature, conductivity, pH, turbidity, and DO were measured on site using the Horiba U-10 water quality checker. River dynamics involved determining of the water body's surface velocity, width and depth. Surface velocity was obtained through the use of a styrofoam ball float, a stopwatch, and a calibrated nylon string. Depth and width were measured using a calibrated pole and string.

Data Analysis

Discharge was calculated using the equation of Gordon, McMahon and Finlayson (1992) shown as follows:

$$Q = V_1A_1 + V_2A_2 + \dots + V_nA_n$$

where: Q = discharge
V_i = velocity
A_i = area

Analysis of Variance (ANOVA, p = 0.95) was used to determine significant differences due to monthly and geographic variation. Pollution load (P), expressed as tons of O₂/day for COD, and as kg/day for metals, was computed using the following equation:

$$P = kQC$$

where: k = the unit conversion factor equivalent to 0.0864 for COD and 86.4 for metals
Q = discharge (m³/s)
C = concentration (ppm).

The results were then subjected to Paired Sample t-Tests, p=0.95, (Pena-Muralla, 1995) to determine whether significant differences in pollution load levels exist between the final landfill leachate (Site A) and the water in the leachate

stream (Site B). Moreover, linear regression was performed to determine the pollution load contributions at Site B in cases where the alternative hypothesis was accepted. The same technique was also adopted to determine if there exists significant differences between the sites upstream (Site C) and downstream (Site D) of the Bosoboso River.

RESULTS AND DISCUSSION

Minor Parameters and River Dynamics

Sites C and D had significantly higher discharge values compared to Sites A and B. This finding was expected since Sites C and D were located along the Bosoboso River, while Sites A and B were situated at the outlet of the leachate pond and the leachate stream respectively. Values ranged from a minimum of 0.005 m³/s during the months of September, November, and December at Site A, to a maximum of 7.74 m³/s during December at Site C (Table 1).

As expected, the temperature in December was significantly lower than the other months as cool Siberian winds enter the country during this time. Values ranged from a minimum of 25.0°C at Site A during December, to a maximum of 31.6°C at Site D during August (Figure 2).

Significant differences in conductivity were observed between sampling sites. The values ranged from a minimum of 0.291 mS/cm in Site C during December to a maximum of 8.32 mS/cm at Site A of the same month (Figure 2). Data is indicative of high ion content within the landfill's wastewater (Site A) and the leachate stream (Site B), since the reference value of 0.05% sodium chloride is already 1.000 mS/cm.

pH on site ranged from a minimum of 7.69 during December at Site A, to a maximum of 8.39 at Site B of the same month (Figure 2). All samples passed the allowable pH range of 6.00 to 9.00 for effluent, and 6.5 to 8.5 for ambient waters as specified by Department of Environment and Natural Resources Administrative Order 35 and 34 (DAO 35 and 34 (1990)), respectively. The ANOVA results show that there exist significant pH variation for both month and geographic location. The month of October had pH levels significantly more acidic than September. However, samples taken in September were significantly more acidic

Table 1. Discharge values measured from August to December 1998 (m³/s). Indicates the volume of water that is released per unit time.

	August	September	October	November	December
Site A	-	0.005	0.01	0.005	0.005
Site B	0.03	0.01	0.21	0.08	0.13
Site C	1.40	2.72	5.53	3.71	7.74
Site D	1.13	2.61	6.00	3.57	-

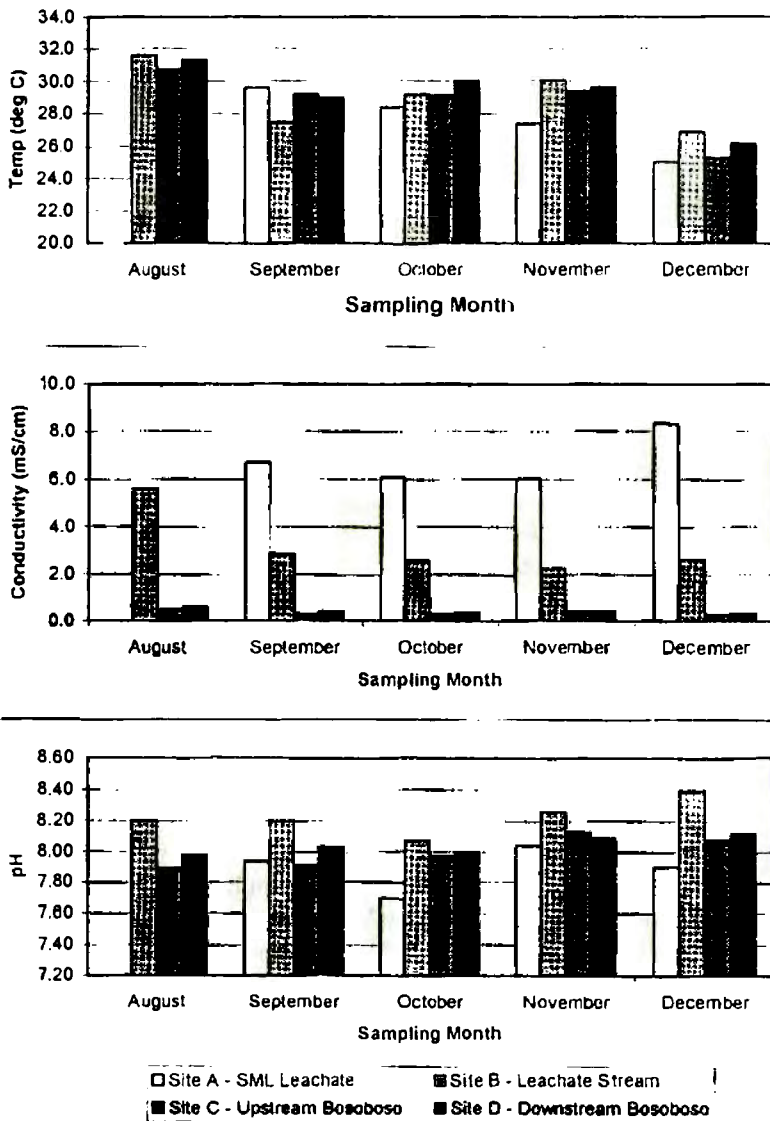


Figure 2. Temperature, conductivity, and pH variation from August to December 1998.

*no measurement available.

than those taken in November and December. All sampling sites had significantly different pH levels. The order of magnitude in decreasing acidity were as follows: Site A > C > D > B. Significantly low pH at Site A is indicative of anaerobic microbiological activity within the leachate ponds. This is because anaerobic decomposition of organic matter produces byproducts such as organic acids and carbon dioxide (Qasim and Chiang, 1994).

Turbidity on site ranged from a low of 26 NTU during November at Site D, to a high of 480 NTU during September at Site B (Figure 3). No significant

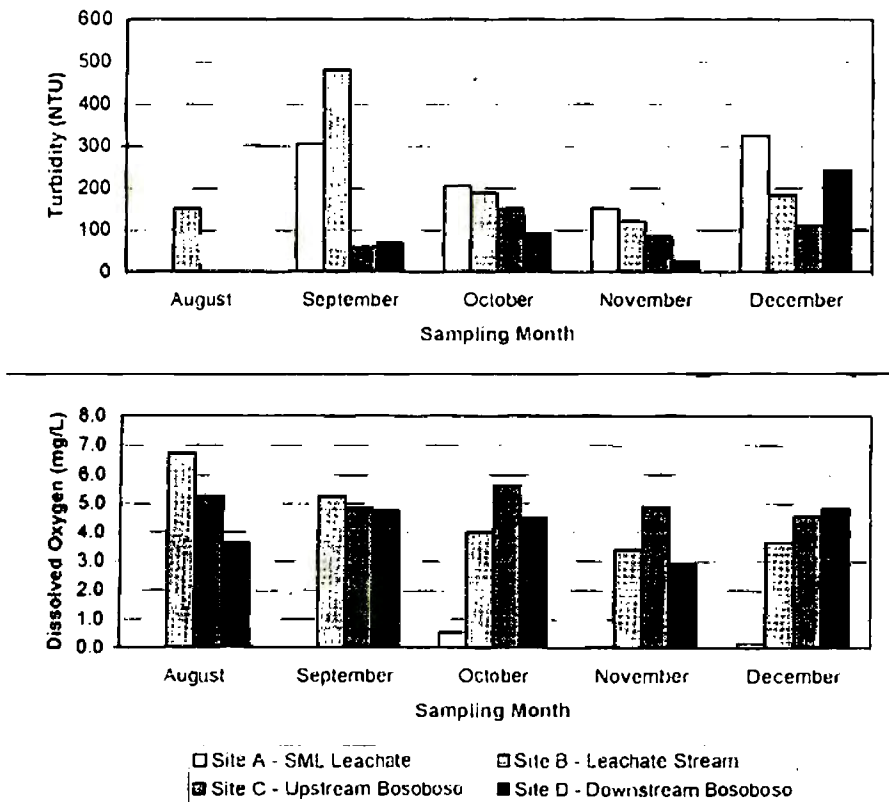


Figure 3. Turbidity and Dissolved Oxygen variation from August to December 1998.

*no measurement available.

variation in turbidity among the different sampling months and sites were observed.

Significant differences in DO levels were found between sampling sites. The values ranged from a minimum of 0.00 ppm during September at Site A, to a maximum of 6.74 during August at Site B (Figure 3). Significantly low DO values at Site A are indicative of the anaerobic decomposition of very high levels of organic matter within the leachate ponds.

Major Parameters

Chemical Oxygen demand (COD) –

Mean COD values ranged from a low of 2.83 ppm during October at Site C, to a high of 3910 ppm during August at Site B. Site A exceeded the maximum allowable COD level for effluent discharge of 100 ppm in the months of September to December (DAO 35, 1990) (Figure 4). All sampling sites were significantly different from each other. The order of magnitude in decreasing order were as follows: Sites B> A> D> C.

Mean pollution load levels ranged from a low of 0.5289 tons of Oxygen needed to oxidize organic matter per day during November at Site A, to a high of 38.84 tons of Oxygen per day during October at Site B (Table 2). Site B yielded a significantly higher COD pollution load than Site A as determined from the Paired Sample t-Test. At the Bosoboso River, Site D had a significantly higher COD pollution load when to Site C.

Iron (Fe) -

Mean Fe values ranged from a low of 0.067 ppm during November at Site C, to a high of 9.41 ppm during September at Site B. During the months of September to December, Site A discharged Fe above the 2.0 ppm standard set by the U.S. Public Health Service (USPHS) (Lund, 1971) (Figure 5). Site B possessed a significantly higher Fe concentration when compared to Site A. However, Site A was significantly higher than Sites C and D.

Mean pollution load levels ranged from a low of 0.880 kg of Fe per day during November at Site A, to a high of 1927 kg of Fe per day during December at Site C (Table 3). Site B carried a significantly higher Fe pollution load level compared to Site A as determined from the Paired Sample t-Test. At the Bosoboso River, there was no significant difference in Fe pollution load levels between Sites C and D.

Copper (Cu) -

Mean Cu values ranged from a low of 0.002 ppm during November at Sites C and D, to a high of 0.252 ppm during September at Site D. During the months of September to December, Site A was discharging Cu within the standard set by the USPHS at 0.5 ppm (Lund, 1971). On the other hand, mean Cu levels in the ambient waters of the Bosoboso River were within the allowable standard of 0.05

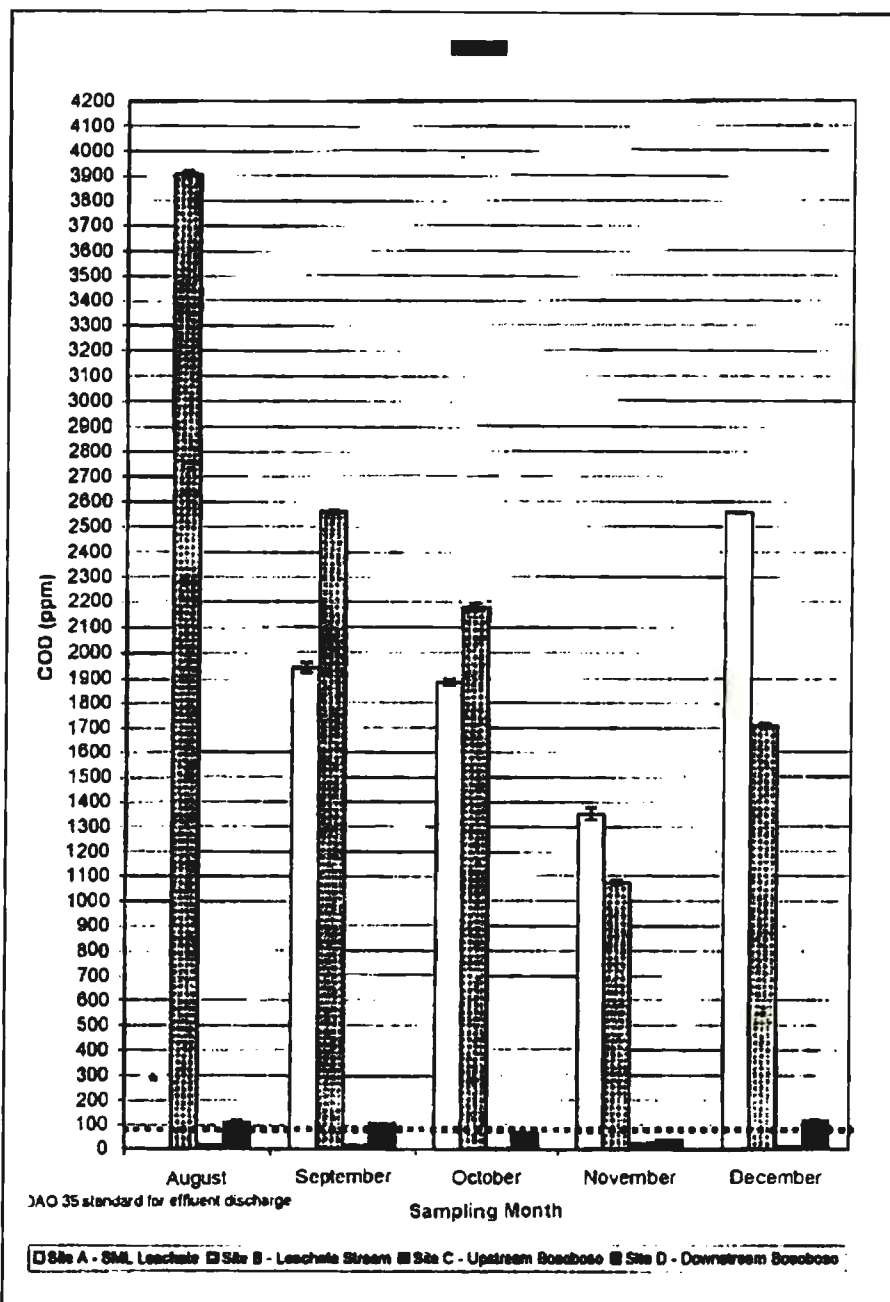


Figure 4. Average COD from August to December 1998 (n = 2)
 *no measurement available.

Table 2. COD pollution load from September to December.
Data Expressed as Mean \pm S.D. (tons O₂/day); n = 2

	Site A	Site B	Site C	Site D
Aug	–	11.04 \pm 0.04	2.10 \pm 0.13	10.78 \pm 1.61
Sept	0.81 \pm 0.02	2.35 \pm 0.01	3.52 \pm 0.56	23.96 \pm 0.04
Oct	2.08 \pm 0.03	38.84 \pm 0.47	1.35 \pm 0.08	37.18 \pm 0.54
Nov	0.53 \pm 0.02	7.27 \pm 0.09	7.75 \pm 0.25	12.16 \pm 0.54
Dec	1.12 \pm 0.00	18.61 \pm 0.22	8.65 \pm 2.88	–

Table 3. Fe pollution load from September to December.
Data Expressed as Mean \pm S.D. (kg Fe/day); n = 2

	Site A	Site B	Site C	Site D
Sept	1.68 \pm 0.23	8.64 \pm 0.20	210.49 \pm .55	432.42 \pm 34.29
Oct	2.48 \pm 0.35	154.13 \pm 0.78	581.47 \pm 5.18	619.84 \pm 67.57
Nov	0.88 \pm 0.12	58.58 \pm 0.29	390.36 \pm 3.48	368.61 \pm 40.18
Dec	1.39 \pm 0.00	80.01 \pm 2.25	1928 \pm 58.00	–

ppm (DAO 34, 1990), except during September at Site D (0.252 ppm) (Figure 5). The month of September showed a significantly higher Cu concentration compared to December. However, December was significantly higher than the months of October and November.

Mean pollution load levels ranged from a low of 0.0039 kg of Cu per day during November at Site A, to a high of 56.9 kg of Cu per day during September at Site B (Table 4). Site B had significantly higher Cu pollution load compared to Site A as determined from the Paired Sample t-Test. No significant difference in Cu pollution load was obtained between Sites C and D.

Zinc (Zn) –

Mean Zn values ranged from a low of 0.119 ppm during August at Site D, to a high of 1.147 ppm during September at Site B. From the months of September to December, Site A discharged Zn below the 1.0 ppm critical level established by the USPHS (Lund, 1971) (Figure 5). All sampling months were significantly

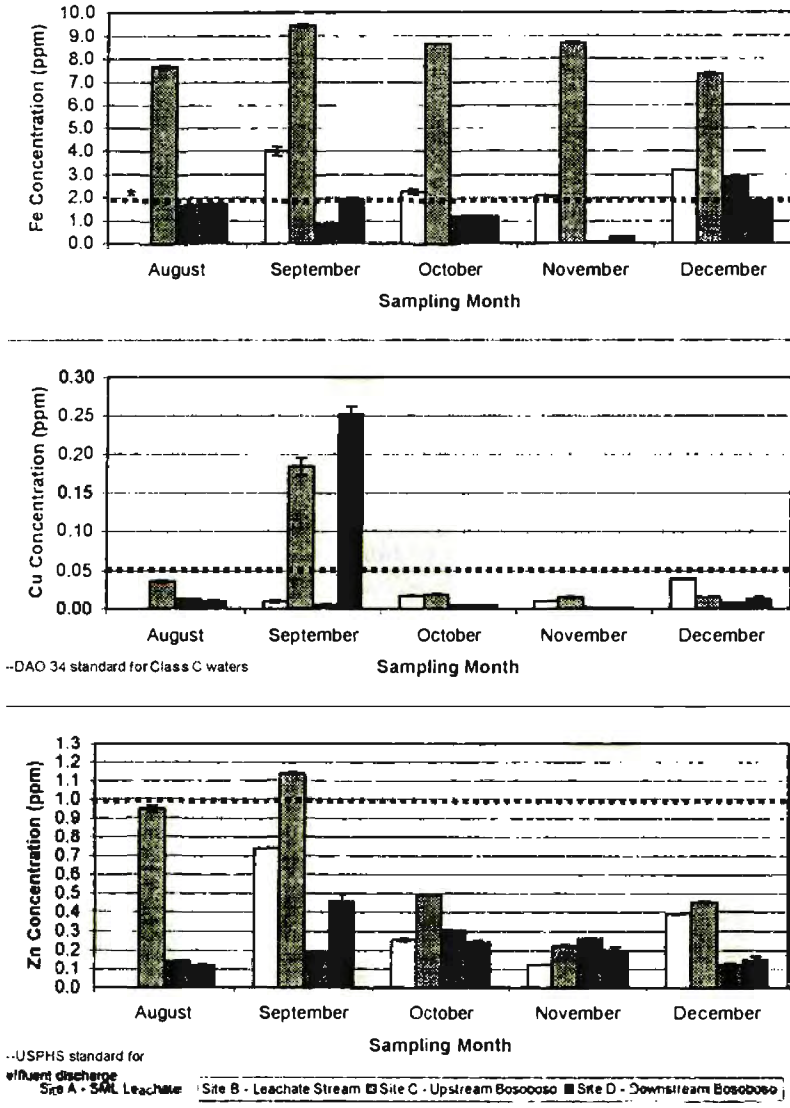


Figure 5. Mean Fe, Cu and Zn concentration from August to December 1998 (n-2).

*no measurement available.

Table 4. Cu pollution load from September to December.
Data Expressed as Mean \pm S.D. (kg Cu/day); n = 2

	Site A	Site B	Site C	Site D
Aug	-	0.100 \pm 0.014	1.63 \pm 0.00	1.12 \pm 0.06
Sept	0.005 + 0.002	0.169 \pm 0.028	1.40 \pm 0.13	56.90 \pm 6.44
Oct	0.018 + 0.001	0.332 \pm 0.010	2.46 \pm 0.27	2.67 \pm 0.29
Nov	0.004 + 0.000	0.102 \pm 0.023	0.76 \pm 0.00	0.73 \pm 0.00
Dec	0.017 + 0.000	0.173 \pm 0.000	5.30 \pm 0.00	-

different from each other. The order of magnitude in decreasing order were as follows: September, October, December, and November. Furthermore, all sampling sites were also significantly different from each other. The order of magnitude in decreasing order were as such: Sites B, A, D, and C.

Mean pollution load values ranged from a low of 0.0476 kg of Zn per day during November at Site A, to a high of 146 kg of Zn per day during October at Site C (Table 5). Using Paired Sample t-Tests, it was shown that Site B possessed a significantly higher Zn pollution load when compared to Site A. No significant difference in Zn pollution load was recognized between Sites C and D.

Pollution Sources

All major parameters demonstrate that there exist significant pollution load differences between Sites A and B, with the latter having a greater value than Site A. This finding shows that other sources of pollution are present.

The first step in the analysis was to determine the percentage of pollutants contributed by the leachate ponds on the leachate stream. This was done by applying linear regression on the pollution load results of Sites A and B. Table 6 summarizes the results. It shows that among the four major parameters, only organic from the leachate ponds are consistently related to the organic load at the leachate stream. The COD pollution load contributed by Site A on Site B ranges from a low of 5.3% in September, to a high of 34% in October.

The next step was to determine the percentage of pollutants contributed by the unknown pollution sources at Site B. Pollution load of the unknown sources was obtained by subtracting the pollution load of Site A from Site B. Subsequently, linear regression was used to correlate the pollution load of the unknown sources with that of the leachate stream. The percent contribution made by the unknown sources on the leachate stream was then calculated by dividing the pollution load of the unknown sources by Site B. Table 7 summarizes the results. It shows that a

Table 5. Zn pollution load from September to December.
Data Expressed as Mean + S.D. (kg Zn/day); n = 2

	Site A	Site B	Site C	Site D
Aug	■	2.668 + 0.131	17.35 + 0.32	11.62 + 0.92
Sept	0.307 + 0.000	1.048 + 0.007	44.68 + 0.63	102.80 + 27.17
Oct	0.279 + 0.022	8.750 + 0.020	145.86 + 0.30	124.45 + 18.74
Nov	0.048 + 0.002	1.515 + 0.081	83.14 + 3.06	61.95 + 5.42
Dec	0.170 + 0.003	4.908 + 0.021	82.00 + 8.67	-

Table 6. Pollution Load Contribution of Site A at Site B from September to December 1998.

Parameter	r ²	Range of mean pollution load contribution of site A at site B
COD	0.9076	low of 5.3% in Oct to a high of 34% in Sept
Fe	0.3527	.
Cu	0.5596	.
Zn	0.1043	.

Table 7. Pollution load contribution of the unknown sources at site B from Sept to Dec 1998

Parameter	r ²	Percent contribution made by unknown sources on Site B	Standard Deviation
COD	0.9998	87%	13%
Fe	0.9999	94%	8.4%
Cu	0.9969	94%	2.9%
Zn	0.9990	90%	12.1%

very strong linear relationship exists for all major parameters between the unknown pollution sources and Site B. This implies that the pollution load at the leachate stream is highly dependent on the pollution load at the unknown sources. Furthermore, the amounts of organic, Fe, Cu, and Zn at Site B were mostly derived from the unknown pollution sources.

However, it must be mentioned that the pollution load percentages contributed by the unknown sources at Site B are estimates. The computations did not take into account certain pollution dynamics such as the deposition of pollutants unto the sediment, and the oxidation of organic matter within the leachate stream. Nevertheless, the deviations brought about by these pollution dynamics are most probably not very significant since all major parameters support the conclusion that the unknown pollution sources are the main contributors of pollution within the leachate stream.

CONCLUSIONS

In comparing Sites A and B for all major parameters, a significantly higher pollution load was found for Site B. This is strong evidence that the leachate ponds are not the only source of pollution for the leachate stream. Linear regression analysis of pollution loads, show that only COD had a strong correlation between the leachate pond discharge (Site A) and the leachate stream (Site B). However, the pollution load at Site B and the total load for the unknown pollution sources displayed strong correlation for all major parameters. Furthermore, pollutants found at the leachate stream were derived mostly from unknown sources. This implies that the quality of water at leachate stream is more dependent on the unknown pollution sources than on the leachate ponds. These unknown sources are most probably leaks within the landfill itself since there are no other known sources of pollution within the area.

As for the Bosoboso River, organic levels were significantly higher downstream (Site D) than upstream (Site C). This demonstrates that organic from the landfill and the unknown pollution sources significantly deteriorate the waters of the Bosoboso River.

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