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Leaching of Chemical Contaminants from a Municipal Landfill Site

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In a vast majority of cases solid municipal wastes are disposed through sanitary landfill operations. However, as water percolates through such wastes, it dissolves inorganic and organic components thereby producing contaminated leachates which may constitute a large pollution potential. The actual composition of a leachate is governed by several factors such as a) original solid waste composition b) climate c) hydrological conditions at the landfill site and d) the age of the landfill site. Several workers have examined leachates and found that they contained toxic inorganic (heavy metals) and organic (PCB, PAH) materials. Studies by Johansen and Carlson (1976) show that organic acids account for 90% of the total organics in high strength leachates, while the same are also contaminated with heavy metals (Fe, Zn, Cu, Ni, Cr, Pb and Cd) in varying concentrations. Harmsen (1983) has examined the composition of the organics in leachates from a waste dump, while Murray et al. (1981) have tried to evaluate the degree of ground water contamination through sanitary landfill leachates. Robinson and Maris (1983) have studied the chemical composition of the adjacent ground or surface waters. Wilson et al. (1982) have examined the release of cadmium from pigmented plastics in landfill sites.

Such studies show that the organic contaminants emanate at high concentrations during active stages of decomposition and decrease with time as fill stabilizes but the inorganic contaminants on the other hand continue to leach for decades from a site.

It is therefore pertinent that the release of chemical contaminants from each municipal landfill operation be established and documented. Such an information in turn can be valuable in the design and long term use of a landfill site. A proper design can assure minimum leaching of contaminants to the environmental water bodies of public use.

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The metropolitan area of the City of Moncton comprises a population base of over 100 000 people and is situated on the bank of the Petitcodiac River. The sanitary landfill practices were introduced in the City as far back as 1940. The landfill sites located on the river bank are apt to deliver their chemical contaminants into the river. This may influence the aquatic life and also constitue a potential health hazard for the public at large. However, no documented information is available that characterizes the emanation of chemical contaminants from these landfill operations.

The present report describes the physico-chemical data of the leachates of these landfill sites, their inorganic contents and in particular the heavy metals. The nature of the organic contents shall be reported separately. In addition to leachate analysis, water and sediment samples from the river have also been analyzed for comparison.

MATERIALS AND METHODS

The City has three sanitary landfill sites marked as A, B and C on Figure 1. Site C is still active while the other two were closed several years ago. Randomly in total 20 sampling stations were selected from the three sites. The sampling stations were chosen at points where leachate formation was suspected and each station was sampled in duplicate. A clean one litre plastic bottle with a screw cap was used for sample collection. Water samples from the Petitcodiac River upstream (station 12) and downstream (station 19) served as controls. In addition, sediments in the river bed were collected at sations 12, 19 and 20 to assess the degree of adsorption of the contaminants.

The analytical procedures for various parameters were those of Environment Canada (1979). The physico-chemical parameters such as pH, conductivity, total alkalinity, total organic carbon (TOC), total inorganic carbon (TIC), hardness, chemical oxygen demand (COD), nitrite-nitrate, chloride, and sulfate were measured soon after sample procurement. Samples were filtered appropriately when required. An aliquot of each sample was preserved in 0.1M HCl for heavy metals analyses. Except for Hg and As, all metals were analyzed by flame atomic absorption spectrophotometry. The former were analyzed by flameless atomic absorption spectroscopy. In each case atomic absorption standards supplied by Fisher Scientific Company were employed for calibration purposes.

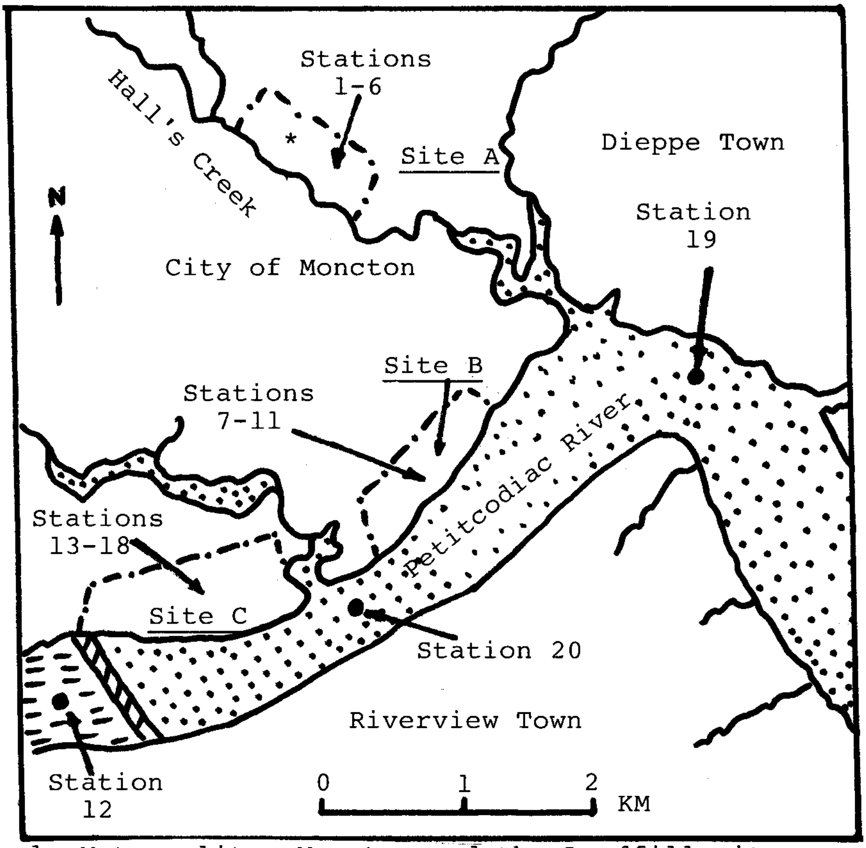

Figure 1. Metropolitan Moncton and the Landfill sites.

RESULTS AND DISCUSSION

Nearly 300 landfill sites have been identified in the maritimes provinces (Estey and Lutz 1982, Anonymous 1983), of these the active ones are potentially dangerous, particularly when such disposal sites are located in proximity of high population density areas.

The results of water quality parameters determined for sites A, B and C in this study are shown in Tables 1-3. For site A which is closed now, the experimental data are similar to those of the control stations (1 and 6) except for station 4 where certain parameters show higher values. However, for site B, also inoperative, the data at all stations for 6 parameters are significantly superior to those of the control stations (12 and 19). One observes higher values at station 19 compared to 12. This is to be expected since the former is located downstream and should reflect the effects of the released contaminants from the leachates formed within the landfill site zones. Nonetheless it is apparent that some chemical contamina-

Table 1. Water Quality Parameters - Site A

Parameter	Sampling stations 1*	2	3	4	5	6
pH	6.57	6.51	6.50	6.51	6.59	6.69
Conductivity (uS/cm)	994	310	295	1800	425	846
Acidity	32.0	46.2	12.0	70.3	8.0	48.5
Alkalinity	50.3	119.5	79.7	297.2	119.5	48.7
Hardness	138.9	660.4	368.4	1257.6	787.6	212.1
Nitrites-nitrates	11.3	18.5	9.7	30.9	8.4	7.3
Sulfates	10.38	6.68	24.99	14.82	3.1	12.96
Chlroides	12.6	13.8	11.2	28.5	17.3	12.2
T.O.C.	11.8	22.2	12.6	11.2	3.1	13.7
T.I.C.	19.5	20.5	15.0	71.0	24.5	17.2
C.O.D.	20.0	17.1	15.5	25.4	10.0	10.2

* Control Stations

Table 2. Water Quality Parameters - Site B

Parameter	Sampling stations 7	8	9	10	11	12*	19*
pH	6.69	6.72	6.92	6.85	6.98	7.39	7.52
Conductivity	2000	38000	29000	31250	25500	701	5927
Acidity	76.3	66.3	112.5	10.0	92.4	39.1	20.0
Alkalinity	817.6	474.4	447.7	379.7	543.8	44.8	89.3
Hardness	393.8	6097.5	3925.3	4382.5	4375.6	240.6	1385.3
Nitrites-nitrates	23.8	38.1	38.4	39.0	29.8	10.9	13.4
Sulfates	10.14	1161.40	894.01	1018.22	879.51	29.07	363.88
Chlorides	83.4	4309.2	3337.2	3747.6	3078.0	15.9	905.3
T.O.C.	52.6	24.2	12.2	7.1	32.4	13.2	14.4
T.I.C.	207.4	106.4	80.1	90.2	130.6	6.4	15.5
C.O.D.	65.1	145.6	840.0	115.2	120.6	28.3	20.0

*Control stations

Table 3. Water Quality Parameters - Site C

Parameter	Sampling stations 13	14	15	16	17	18
pH	7.28	6.98	7.92	7.75	7.29	7.54
Conductivity	600	1060	13600	19000	35500	25600
Acidity	148.7	68.3	74.3	72.3	48.2	74.3
Alkalinity	126.6	789.9	1286.9	1162.6	670.4	870.0
Hardness	216.0	868.9	1915.6	4763.5	7431.3	5970.0
Nitrites-nitrates	16.1	36.9	42.3	47.6	39.0	38.3
Sulfates	116.90	165.30	526.08	422.48	830.94	777.53
Chlorides	43.2	734.4	1717.2	2430.0	2894.4	3818.0
T.O.C.	128.3	231.3	88.9	93.0	24.2	48.0
T.I.C.	50.8	134.8	320.5	251.0	122.6	211.9
C.O.D.	105.0	175.0	165.0	85.0	185.5	110.0

Control stations 12 and 19 as in Table 2.

tion is emanating from this abandoned landfill site B. The data from the active landfill site C (Table 3) further show that leachates are contributing chemical contaminants into the Petitcodiac River. In this case also the values are significantly higher than those of the controls. In addition total organic carbon values are greater than those at the other two sites. This is in conformity with observations of Johanson and Carlson (1976) that quantities of organic matter released from active sites are greater than those from discontinued landfill sites.

Increased conductivity of the leachates is indicative of the ionic species and inorganic ions in particular. In this study conductivity values of 35000 to 38000 uS/cm have been recorded for sites B and C, whereas values for natural waters range between 50 - 1500 uS/cm (Anonymous 1983). Alkalinity represents the capacity of a body of water to neutralize acidic contaminants and is indicative of the presence of CO_3^{2-}, HCO_3^- and OH^- in water. Normal levels of natural waters range in the vicinity of 500 mg/L $CaCO_3$, whereas the data show that leachates at the landfill sites exceed this limit in many cases. The water hardness is a measure of water quality and reflects the levels of calcium and magnesium ions in a water body. A value exceeding 200 mg/L $CaCO_3$ is regarded as excessive in terms of water quality. This study shows that this value is practically exceeded in all the leachate samples examined.

Sulfates and chlorides occur naturally in the waters. The former may arise through natural bacterial oxidation of sulfur compounds or anthropogenic depositions. A concentration up to 500 mg/L is considered acceptable. The analytical data show that both chloride and sulfate ions occur at levels significantly higher than natural levels at sites B and C, though abandoned site A appears to make little contribution in this respect.

The data on heavy metal contents of the leachates are presented in Table 4. For site A control data have

Table 4. Average heavy metal contents of the leachate sample

Element	Site A Control (1 and 6)	Site A Samples (2 - 5)	Sites B and C Control (12)	Sites B and C Samples B (7-11)	Sites B and C Samples C (13-18)	Sites B and C Control (19)
As (ug/L)	1.0	1.6	0.4	2.36	4.66	4.8
Hg (ug/L)	0.02	N.D.	N.D.	0.044	0.012	0.05
Cr (mg/L)	N.D.	0.18	0.03	0.14	0.23	0.32
Cd (mg/L)	0.013	N.D.	N.D.	0.001	0.009	N.D.
Pb (mg/L)	0.03	0.02	N.D.	0.03	0.046	N.D.
Sb (mg/L)	N.D.	0.01	N.D.	0.01	0.01	N.D.
Co (mg/L)	0.01	0.033	N.D.	0.029	N.D.	N.D.
Fe (mg/L)	1.42	11.86	1.00	4.83	13.13	0.38
Cu (mg/L)	0.046	0.054	0.042	0.045	0.12	0.33
Ni (mg/L)	0.045	0.028	N.D.	0.033	0.041	0.023
Zn (mg/L)	0.055	0.102	0.055	0.056	0.064	0.013
Al (mg/L)	1.02	0.46	10.10	2.52	1.23	2.69

been averaged since no significant difference was noticed in pre and post control stations. The elements As, Hg, Pb and Cd are considered toxic and are regarded as priority elements for environmental samples analyses (Environment Canada 1979). It appears that none of these elements at the moment occur in significant concentrations to warrant further studies, although some contamination from the landfill sites does occur. The levels of Cr, Cu and Fe appear higher than the other elements analyzed. Only Cr contamination needs to be watched since in the hexavalent state (Cr-VI) it is considered to be toxic for living beings.

Eventually the released contaminants through leaching are dispersed in the river water but some of them may be adsorbed by sediments. It was therefore of interest to analyze the river bed sediments for the same heavy metals to check for any build up. The data are presented in Table 5. In addition to collec-

Table 5. Analysis of metallic ions in sediment samples

Element	Stations 12 Petitcodiac Lake (mg/Kg)*	20 Coverdale Bridge (mg/Kg)*	19 Petitcodiac River (mg/Kg)*
As	1.160	2.462	5.540
Hg	0.150	0.031	0.045
Cr	371.5	777.4	441.1
Cd	4.86	14.20	8.63
Pb	N.D.	N.D.	N.D.
Sb	N.D.	N.D.	23.9
Co	N.D.	103.4	150.8
Cu	142.2	91.6	58.3
Fe	16,120	33,135	19,343
Ni	11.9	37.4	71.2
Zn	42.1	39.1	48.4
Al	7.9	36.7	12.0

N.D. = not detected * = dry weight

tion of sediment samples from the control station area (# 12 and # 19) one more station (# 20) at midpoint (between sites B and C) was selected. In general, levels of heavy metals remain higher at both station # 19 and # 20 compared to upstream station # 12.

One may infer from these data that sediments do adsorb some heavy metals in all samples. The levels of As, Cr, Cd, Sb, Co, Cu are fairly high and once again Cr appears to be an element of interest. Iron being of natural origin, it is expected to occur at significantly higher concentrations in any geological formation and sediments in this respect are no exception.

In conclusion it may be said that chemical contaminats are being released from the Mocnton City landfill operations but the levels, for the moment, are within acceptable range. However, periodic surveillance of the active and inactive sites for toxic contaminants is recommended to assure environmental protection.

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REFERENCES

Anonymous (1983) Preliminary field investigation of abandoned/closed land disposal sites, (Water Management Services Ltd) Environment New Brunswick, Fredericton, N.B., Canada, 91 pp.

Estey MK, Lutes RG (1982) Hazardous wastes in New Brunswick, Environment New Brunswick, Fredericton, N.B., Canada, 19 pp.

Environment Canada (1979) Analytical methods manual, Water Quality Branch, Inland Water Directorate, Ottawa, Ontario, Canada.

Harmsen J (1983) Identification of organic compounds in leachates from a waste dip. Water Res 17: 699-705.

Johansen OJ, Carlson DA (1976) Characterization of sanitary landfill leachates. Water Res 10: 1129-1134.

Murray JP, Rouse JV, Carpenter AB (1981) Ground water contamination by sanitary landfill leachates and domestic water in carbonate terrain. Water Res 15: 745-757.

Robinson HD, Maris PJ (1983) The treatment of leachates from domestic wastes in landfills. Water Res 17: 1537-1548.

Wilson DC, Young PJ, Hudson BC (1982) Leaching of cadmium from pigmented plastics in landfill sites. Environ Sc Technol 16: 560.

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