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Physicochemical and Microbial Characteristics of Leachate-Contaminated Groundwater

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Abstract: The biochemical effect of leachate (using Odo Iya Alaro landfill located in Ojota, Kosofe local government of Lagos State as a case study), on the quality of surrounding groundwater was assessed. Water samples were collected from two hand dug wells and two boreholes at about 2 km radius to the landfill. The physicochemical and microbial characteristics of the leachate-contaminated groundwater samples were determined. Compared to the tapwater, the leachate-contaminated groundwater samples and the simulated leachate showed significantly ($p<0.05$) higher concentrations of heavy metals such as Pb, Cd and Cr. Coliform bacteria such as *E. coli*, *Shigella* sp. and *Salmonella* sp. were present in the leachate-contaminated groundwater samples and simulated leachate. Overall, the data revealed that consumption of leachate-contaminated groundwater may lead to, among other things, heavy metal toxicity such as impaired renal function and possibly cancer. The evidences from this study, therefore, suggest that consumption of leachate-contaminated groundwater is hazardous and therefore should be discouraged.

Key words: Landfill, leachate, groundwater, coliform, heavy metal toxicity

INTRODUCTION

In Nigeria today, the use of groundwater has become an agent of development because the government is unable to meet the ever increasing water demand, inhabitants have had to look for alternative groundwater sources such as shallow wells and boreholes (Azzeez, 1972; LAWMA, 2000)

Until recently, groundwater had been considered a dependable source of uncontaminated water. It has, however, been realized that this source of water is in serious danger of being contaminated as any liquid that finds its way into the ground can eventually enter the groundwater supply (Bagchi, 2004). Although the soil and other materials do naturally purify most of the water as it strains through an aquifer, some harmful materials are allowed to pass through (Monroe, 2001). Any addition of undesirable substance to groundwater caused by human activities is considered to be contamination (Speidel *et al*., 1988).

The quality of groundwater is affected by the characteristics of the media through which the water passes on its way to the groundwater zone of saturation (Raji and Alagbe, 1997). In aquatic systems, waste sediments may be both a carrier and a possible source of pollutants (Forstner, 1989).

Many studies have been conducted on the effect of leachate-polluted groundwater on living systems. Two of the studies reported increase in the recurrence of bladder cancer and leukemia (Albion, 1995; Dolk, 1999). Birth defects were also reported in children born of mothers consuming leachate-polluted water (Dolk, 1999). The common birth defect reported is low birth weight and that children tend to be shorter than those who do not consume leachate polluted water (Dolk, 1999). Impaired locomotion and reduced spleen weight was also reported in mice after consuming leachate-contaminated water (Radi *et al*., 1987).

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In Nigeria, groundwater contamination is one of the least recognised environmental problems. This may be due to lack of awareness because groundwater problems are not readily detected and pathways for contamination are not as noticeable as those affecting surface water.

To avoid possible contamination of groundwater, Dolk (1999) reported that groundwater should not be located within 7 km radius to a landfill. The present study is focused on hand dug wells and boreholes that are located within 1.5 km radius of Odo Iya Alaro landfill in Ojota, Lagos, Nigeria. These groundwater sources are being used for domestic purposes with little or no knowledge of the potential risk of the contaminant leachate on public health. In this study, the physicochemical and microbial characteristics of the groundwater samples were determined for the dry and raining seasons with a view to encouraging or discouraging their use for domestic purpose.

MATERIALS AND METHODS

Chemicals and solvents are of analytical grade and are products of Sigma-Aldrich Inc, St. Louis, USA. The experimental water for the study was collected from the residential areas located within the vicinity of Odo Iya Alaro landfill in Ojota, Lagos, Nigeria (Fig. 1).

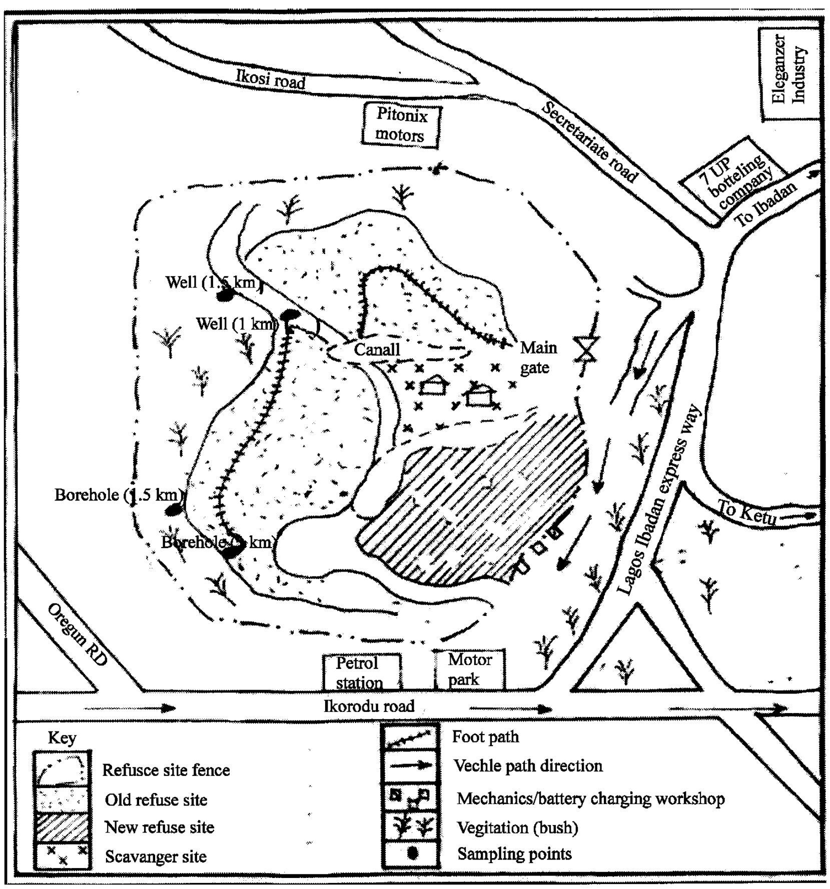

Fig. 1: Location of Odo Iya Alaro landfill, Ojota, Lagos

The experimental water samples were obtained from two different wells located at about 1 and 1.5 km, respectively from the landfill and two boreholes located at about 1 and 1.5 km, respectively from the landfill. The water samples were collected using stainless steel buckets.

Solid wastes were collected at the Odo Iya Alaro landfill located in Ojota, Lagos, Nigeria in December, 2004. Leachate simulation was carried out following the ASTM method (Perket *et al*., 1982). The physicochemical properties of all the water samples were carried out following standard method (APHA, 1985) and Atomic Absorption Spectrophotometer (Buck 210VGP) was used for the determination of heavy metals. Microbial analysis involves isolating and identifying the bacteria in the leachate-contaminated groundwater samples after appropriate culturing. The procedure described by Olutola *et al*. (2002) was followed.

RESULTS AND DISCUSSION

Physicochemical characteristics of the groundwater samples for dry and raining seasons are presented in Table 1 and 2, respectively. The BOD and COD of the leachate-contaminated groundwater samples were found to be higher in the dry season than in the raining season; however, total bacteria in the groundwater samples were more in the raining season than in the dry season. Compared to the tap water, the leachate and groundwater samples contain high amounts of metals e.g., iron, copper, zinc, nickel etc., although at concentrations within tolerance limit. However, the two well samples contain cadmium at a concentration higher than the tolerance limit. All the groundwater samples studied as well as the leachate contain Pb, BOD and COD at concentrations higher than the recommended level.

The observed physicochemical characteristics of the leachate-contaminated groundwater samples may be associated with the heavy rainfall that occurs during raining season which might encourage the leaching of the pollutants into the groundwater. McGraw-Hill Encyclopedia

Table 1: Physicochemical characteristics of the leachate and groundwater samples collected in the dry season (December, 2004)

Parameter ($mg\ L^{-1}$)	Tap water	Leachate	Well (1 km)	Well (1.5 km)	Borehole (1 km)	Borehole (1.5 km)
Colour * (HU)	6±0.1	610±5.0	66±2.0	64±2.1	31±1.4	27±1.01
pH*	7.2±0.1	8.3±0.1	6.0±0.1	6.7±0.1	6.9±0.1	7.1±0.01
BOD	-	6,270±6.0	3,427±2.0	2,120±3.0	120±1.0	40±1.00
COD	-	4,740±5.0	1700±3.0	680±1.0	14±2.0	2.7±0.03
Total hardness	26±2.0	1000±4.0	780±2.0	675±4.0	140±0.7	137±1.00
Total solids	270±4.0	8,170±6.0	1,370±5.0	1,080±3.0	680±2.0	545±2.00
Total dissolved solids	147±2.0	7,070±14.0	573±6.0	405±4.0	165±0.8	120±1.00
Chlorides	23.7±0.6	504±4.0	365±2.0	243±2.0	170±1.0	121±2.00
Ammonium	0.01±0.00	850±3.00	96±1.00	10±0.40	13±0.60	0.22±0.01
Nitrates	0.24±0.01	30±0.50	6.37±0.20	5.76±0.20	5.29±0.04	0.26±0.00
Nitrites	nd	4±0.09	0.98±0.05	0.39±0.02	0.23±0.01	0.06±0.00
Calcium	18.0±1.0	167.5±0.6	36.4±0.3	32.4±0.5	31.1±0.2	25.05±0.2
Magnesium	7.0±0.6	246±2.0	46.40±1.5	29.35±0.8	17.58±0.7	16.10±0.6
Sodium	14±0.9	157±3.0	54±2.9	36±2.2	28±2.4	2600±0.9
Potassium	6±0.4	364±7.4	52±2.8	47±1.4	27±0.8	1900±0.9
Iron	0.2±0.01	12.7±0.40	0.8±0.01	0.7±0.01	0.4±0.01	0.04±0.01
Copper	nd	16.0±0.5	0.12±0.02	0.12±0.01	0.08±0.01	0.05±0.00
Manganese	nd	0.11±0.00	0.08±0.00	0.06±0.00	0.04±0.00	0.02±0.00
Zinc	nd	312±6.2	1.78±0.9	1.07±0.6	0.82±0.01	0.54±0.01
Lead	nd	6.1±0.03	0.13±0.01	0.11±0.01	0.09±0.01	0.05±0.01
Cadmium	nd	2.2±0.01	0.02±0.00	0.01±0.00	n.d	nd
Chromium	nd	9.4±0.04	0.50±0.01	0.41±0.01	n.d	nd
Nickel	nd	0.56±0.00	0.16±0.00	0.13±0.00	0.02±0.00	nd
Total bacteria	nd	460±4.0	216±3.00	140±3.0	nd	nd

*Not in $mg\ L^{-1}$, ND: Not Detected

Table 2: Physicochemical characteristics of the leachate and groundwater samples collected in the raining season (April, 2005)

Parameter (mg L^{-1})	Tap water	Well (1 km)	Well (1.5 km)	Borehole (1 km)	Borehole (1.5 km)
Colour * (Hu)	6±0.1	86±3.0	70±2.0	24±2.0	12±0.5
pH*	7.2±0.1	6.3±0.5	6.9±0.2	6.9±0.1	7.2±0.1
BOD	-	3,170±7.0	1,870±7.0	96±4.0	34±2.0
COD	-	1,250±10.0	560±8.0	10±1.0	1.8±0.5
Total hardness	26±2.0	800±4.0	690±5.0	145±2.0	140±2.0
Total solids	270±4.0	1200±6.0	970±4.0	520±1.0	500±2.0
Total dissolved solids	147±2.0	580±4.0	420±4.0	180±3.0	129±2.0
Chlorides	23.7±0.6	391±3.0	257±2.0	184±2.0	131±1.0
Ammonium	0.01±0.00	81.4±0.9	8.16±0.5	10.9±0.2	0.16±0.2
Nitrates	0.24±0.01	0.51±0.05	5.94±0.04	6.04±0.50	24±0.90
Nitrites	nd	0.92±0.02	0.40±0.01	0.17±0.00	0.06±0.00
Calcium	18.0±1.0	51.4±0.9	46.2±1.0	38.5±0.8	30.4±0.6
Magnesium	7.0±0.6	45.70±1.5	30.11±2.0	8.01±0.9	5.91±0.5
Sodium	14±0.9	65±2.0	42±1.0	30±1.0	29±0.5
Potassium	6±0.4	62±3.0	58±3.0	32±2.0	27±1.0
Iron	0.2±0.01	1.00±0.01	0.84±0.01	0.54±0.01	0.50±0.01
Copper	nd	0.16±0.00	0.11±0.00	0.10±0.00	0.08±0.00
Manganese	nd	0.09±0.00	0.08±0.00	0.04±0.00	0.03±0.00
Zinc	nd	2.41±0.01	1.81±0.01	1.02±0.01	0.76±0.01
Lead	nd	0.14±0.01	0.09±0.01	0.09±0.00	0.05±0.00
Cadmium	nd	0.09±0.01	0.07±0.01	nd	nd
Chromium	nd	0.52±0.01	0.53±0.01	nd	nd
Nickel	nd	0.19±0.01	0.14±0.01	0.02±0.01	nd
Total bacteria	nd	271±2.0	157±2.0	88±1.0	4±0.5

*Not in mg L^{-1}, ND: Not Detected

(1997) reported that the concentration of the leachate pollutant increases considerably with rainfall and affects groundwater quality adversely. The present observation indicates that the groundwater samples are indeed polluted when compared with the WHO (1989) standard. Additionally, the extent of the pollution of the groundwater increases with decreasing distance from the landfill. This submission is evident as the level of organic and inorganic pollutants in the water sample for first well (1 km) was found to be higher than that of the second well (1.5 km). Similarly, the first borehole (1 km) water sample showed higher pollutant concentrations than the second borehole (1.5 km) water sample. Generally, the well water samples studied showed higher concentration of pollutants than the borehole water samples studied. This may be due, in part, to the selective migration and percolation of pollutants down the soil based on their sizes and shapes. Inorganics and heavy metals have been reported to be retained at a lower level than organic chemicals and pesticides (Brenaam, 2000). Johnson *et al*. (2000) also reported that the concentrations of pollutants in leachates vary with depth of groundwater and the distance from the landfill.

The bacteria isolated are *E. coli*, *Streptococcus faecalis*, *Pseudomoas*, *Shigella* sp. and *Salmonella* sp (Table 3). None of these bacteria were found in the tap water whereas the leachate and the first well (1 km) water samples contained all the bacteria. *Pseudomonas* was absent in the second well (1.5 km) water sample (Table 4) while the first borehole (1 km) contained *Shigella* sp. Generally, the total bacteria population of the groundwater samples are higher in the wet season than the dry season. This observation compares favourably with the study conducted by Hammond and Beliles (1980) and in a separate study by McGraw-Hill Encyclopedia (1997). The presence of Coliform bacteria in the leachate-contaminated groundwater samples, as observed in this study is a source of concern. These bacteria have been associated with a number of health problems such as cholera, vomiting and diarrhoea (Barlaz *et al*., 1989; Prescott *et al*., 2002). The use of leachate-contaminated groundwater for domestic purposes may cause several pathological diseases as indicated earlier.

The physicochemical and microbial characteristics carried out on Odo Iya Alaro landfill in Ojota, Lagos, Nigeria showed that the leachate collected there-from contaminates surrounding groundwater.

Table 3: Characteristics of bacterial isolated from leachate-contaminated groundwater

Culture morphology	Gram stain	Catalase	Coagulase	Oxidase	Urease	Glucose	Lactose	Sucrose	Mobility	Indole	Probable identity
Flat, circular colonies	Negative, rod	ND	ND	-ve	+ve	+ve	+ve	+ve	-ve	-ve	*E. coli*
Smooth, circular colonies	Positive, cocci in chain	-ve	+ve	ND	ND	ND	ND	ND	ND	ND	*Streptococcus faecalis*
circular colonies	Negative, rod	ND	ND	-ve	+ve	+ve	+ve	+ve	-ve	-ve	*E. coli*
Creamy, smooth, circular colonies	Positive, cocci in chain	-ve	+ve	ND	ND	ND	ND	ND	ND	ND	*Streptococcus faecalis*
Metallic, sheen colonies	Negative, rod	ND	ND	-ve	+ve	+ve	+ve	+ve	-ve	-ve	*E. coli*
Whitish, pin point	Negative, rod	ND	ND	-ve	+ve	+ve	+ve	+ve	+ve	+ve	*Pseudomonas*
Convex, circular colonies	Negative, rod	+ve	ND	-ve	+ve	+ve	-ve	+ve	-ve	+ve	*Shigella* sp.
Flat, circular colonies	Negative, rod	+ve	ND	-ve	+ve	+ve	-ve	+ve	+ve	+ve	*Salmonella* sp.

ND: Not Determined, +ve: Positive, -ve: Negative

Table 4: Bacteria isolated from leachate-contaminated groundwater samples

	Water samples					
Bacteria	Tap water	leachate	Well (1 km)	Well (1.5 km)	Borehole (1 km)	Borehole (1.5 km)
Streptococcus faecalis	-	+	+	+	-	-
E. coli	-	+	+	+	+	+
Pseudomonas	-	+	+	-	-	-
Shigella sp.	-	+	+	+	+	-
Salmonella sp.	-	+	+	+	-	-

+ : Present, - : Absent

This is evident as the concentrations of heavy metals such as Pb and Coliform bacteria such as *E. coli.* were found to be higher than recommended permissible level in the groundwater samples studied. These findings revealed that the groundwater samples studied are not fit for consumption. We therefore advise the people living at about 3 km to Odo Iya Alaro landfill to stop using the wells and boreholes in their houses for domestic purposes as it could pose serious threat to their health. The authors recommend that groundwater sources in Kosofe local government of Lagos State should be routinely checked for the levels of pollutants and polluted water should be treated and channelled to industrial uses rather than domestic purposes.

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