Environmental Impact of Landfill on Groundwater Quality and Agricultural Soils in Nigeria

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Abstract: Physical, chemical and bacteriological analyses were carried out of water samples from three boreholes located near a landfill, and or soil samples at Akure, Nigeria, to ascertain the effect of the dumpsite on the groundwater and soil quality. The samples from borehole locations with radial distances of 50, 80, and 100 m, respectively, away from the landfill and twelve soil samples collected at distances 0 (dump centre), 10, 20, and 30 m away from the refuse dump were analysed. The parameters determined were the turbidity, temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), total iron, nitrate, nitrite, chloride, calcium and heavy metals like copper, zinc, and lead. Most of these parameters indicated pollution but were below the World Health Organization (WHO) limits for consumption. The pH ranged from 5.7 to 6.8 indicating toxic pollution, the turbidity values were between 1.6 and 6.6 NTU, and the temperature ranged from 26.5°C to 27.5°C. The concentrations of iron, nitrate, nitrite and calcium ranged from 0.9 to 1.4, 30 to 61, 0.7 to 0.9, and 17 to 122 mg/l, respectively. Out of heavy metals, zinc ranged between 3.3 and 5.4 mg/l and lead ranged from 1.1 to 1.2 mg/l. Soil water holding capacity, porosity, pH, organic matter, organic carbon and organic nitrogen ranged from 38 to 54, 44 to 48, 6.9–7.5, 2.44–4.27, 1.42–2.48, and 0.12–0.21%, respectively. Statistical analyses indicated significant differences at 95% level. The results showed that all the boreholes were not strongly polluted but require treatment before use while the soil is absolutely unsuitable for the crop production. Re-designing of sanitary landfills to prevent leachate from getting to the water table, adoption of clean technology for recycling greenhouse gases and a sustainable land management programme for reclamation are recommended.

Keywords: chemical land use; parameters; pollution; wastes; water

Groundwater is a valuable resource often used for industry, commerce, agriculture and most importantly for drinking. Often, the raw water used for domestic purposes is vulnerable to contamination due to the human influence resulting in pollution. Groundwater pollution is mainly due to the process of industrialisation and urbanisation that has progressively developed over time without any regard for environmental consequences (Longe & Balogun 2010). In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. Leachate migration from wastes sites or landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to the groundwater resources if not adequately managed (Ikem *et al.* 2002). Groundwater protection is a major environmental issue. Open dumps are the oldest and most common way of disposing solid wastes, and although in recent years thousands of them have been closed, many are still being used (Al Sabahi *et al.* 2009). The frequently used municipal solid waste disposal methods include: composting, sanitary landfill, and pyrolysis, reuse recovery and recycling (USEPA 2007). Waste management has become increasingly complex due to the increase in human population, industrial and technological revolutions while the processes that control the fate of wastes in the soil are complex and many of them are poorly understood. Issues such as nutrients and other chemicals release rates, leaching of nutrients and metals through macropores as suspended solids, and sludge organic matter effects on the sorption degradation are often not understood by many researchers (Mohammed *et al.* 2009). The leaching of hydrophobic organics, long term bioavailability, and fate of metals fixed by soil organic matter need to be studied to gain a better approach in groundwater pollution handling (Ikem *et al.* 2002). Toxic chemicals that have high concentrations of nitrate and phosphate derived from the waste in the soil can filter through the dump and contaminate both the ground and surface water. Insects, rodents, snakes, scavenger birds, dust, noise, or bad odour are some of the aesthetic problems associated with sanitary landfills. Emissions of methane (CH_4) and carbon IV oxide (CO_2) and leachate contamination of ground water and soil are the environmental issues connected with the landfill. The volume of solid waste generated in Akure, South western Nigeria has increased significantly over time from the estimated quantity of 60 000 metric tons per year in 1996 to 75 000 metric tons in 2006 because of the increasing population as well as the industrial and economic development. While the population of Akure was about 283 108 in 1996, it increased to approximately 353 211 in 2006. The total assessment revealed that about 80% of the total waste is organic in nature, followed by 15.72% of plastic/nylon, and about 1% of metal (Olanrewaju & Ilemobade 2009). The increasing waste generation and disposal resulted in increased groundwater pollution and unsuitability of the use of soils within the area for agricultural productivity purposes. To what extent this pollution has affected this area is unknown and hence needed to be determined. The objectives of the study therefore were, to assess the effect of the landfill on the degree of pollution of groundwater in Akure, and to analyse the soil properties at the dumpsite for the productivity viability.

MATERIAL AND METHODS

Study area

The study area was the dump site (landfill) of the Ondo State Waste Management Authority Yard situated along Igbatoro Road, Akure in Ondo State, located in the South Western part in Nigeria. Akure, the capital of Ondo state of Nigeria, is located between latitude 9°17'N and longitude 5°18'E. It has a tropical humid climate with two distinct seasons, a relatively dry season from November to March and a rainy season from April to October. The average annual rainfall ranges between 1405 mm and 2400 mm of which the rainy season accounts for 90% while the month of April marks the beginning of rainfall (Akinbile 2006). The towns bordering Akure are; Ikere in the north, Ondo in the south, Owo in the east and Igbaraoke in the west. The predominant soil in Akure is sandy-loam. The population of Akure in 1992 and 2002 grew from 2 312 535 to 2 983 433 and the projected figures for 2012 and 2022 are 3 856 469 and 4 984 900 people respectively (Olanrewaju & Ilemobade 2009).

Water analyses

Three existing 6'' diameter boreholes with the average depth of 40 metres in the basement formation located within the distance of 50, 80, and 100 m radially away from the centre of the landfill were used as the sampling points for groundwater quality testing. For each borehole, 15 l of the groundwater samples were collected in 600 ml sterilised polyethylene bottles, stored at the temperature of 4°C and analysed. The analyses covered physical, chemical, and bacteriological parameters of the water samples from each borehole. The qualitative analyses were carried out at the water laboratories of the Ondo State Water Corporation and the Federal University of Technology, Akure (FUTA) Chemistry Department. The physical parameters tested included: odour, taste, colour, turbidity and temperature. Chemical parameters analysed were pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness (TH), total iron, nitrate, nitrite, chloride, calcium and heavy metals such as copper, zinc, and lead. The pH was determined using a Mettler Toledo (Schwerzenbach, Switzerland) pH meter by direct measurement, analog mercury thermometer was used for temperature measurements, and a Hach 2100A turbidimeter was used for turbidity determination. The samples were also analysed in the water laboratories for total dissolved solids, total hardness, iron, nitrate (NO_3), nitrite (NO_2), calcium, and chloride using standard methods for the examination of water (APHA 2005). The concentrations of heavy metals such as copper, zinc, and lead in the water samples were determined with flame atomic absorption spectrophotometer. Also, bacteriological assay was used for the determination of thermotolerant coliform bacteria and *Escherichia coli.* All the results were compared with the World Health Organization (WHO 2004) and the Nigerian Standard for Drinking Water Quality (NSDWQ 2007) values.

Soil sampling and analysis

The soil samples were collected from the landfill (dumpsite) of Ondo State Waste Management Authority, Akure. 100 grams of the soil samples taken at the depths 10, 20, and 30 cm, respectively per sampling point were collected at four different locations at a distance of 10 m from one another. The samples were collected at specified depths using a soil auger. They were air dried, sieved using a 2 mm mesh, and stored in sampling bags for analysis.

The following constituents were analysed in the soil samples taken from the landfill site, the pH, organic content (OC), nitrogen (N), phosphorus (P), sodium (Na), calcium (Ca), magnesium (Mg), cyanide (Cn), copper (Cu), lead (Pb), silver (Ag) and mercury (Hg). The soil particle size analysis was carried out using apparatuses such as the mechanical stirrer, stop watch, analytical balance, hydrometer, thermometer, and reagents: calgon as the dispersing agent, 50 g sodium hexametaphosphate plus 7 g anhydrous sodium carbonate dissolved in 1000 ml distilled water. This was done using the standard laboratory procedures and analytical methods (APHA 2005). The pH was measured using a pH meter while the soil organic content was determined in the laboratory using a muffle furnace to burn the soil at 440°C during 24 h. The soil porosity and other constituents such as N, P, Na, Ca, Mg, Cn, and metals such as Cu, Pb, Ag, and Hg were determined in the laboratory using standard procedures by AOAC (2000). The values were compared with the Food and Agriculture Organization (FAO) of the United Nations (UN) values.

RESULTS AND DISCUSSIONS

Water analyses

The results and comparison of the sample parameters with the World Health Organization and the Nigerian Standard for Drinking water quality are presented in Tables 1, 2, and 4. The temperature, turbidity, colour and odour of the samples are shown in Table 1. The presence of colour was an indication of pollution and confirmed leachate infiltration into the wells (Ogedengbe & Akinbile 2004; Mohamed *et al.* 2009). The temperatures which ranged from 26.5°C and 27.5°C were found

Table 1. Physical characteristics of the borehole water samples analysed

Sample	Colour	Odour	Turbidity (NTU)	Temperature (°C)
W_1	not clear	mild	6.6	27.5
W_2	clear	mild	3.5	27.6
W_3	not clear	mild	1.6	26.5

NTU – nephelometric turbidity unit

Table 2. Chemical constituents in the boreholes and their comparison with the WHO Standard (in mg/l)

Sample	Distance (m)	pH	DO	TDS	TH	Ca	NO_3	NO_2	Cl^-
NSDWQ		6.5–8.5	NS	500	200	75	50	3	250
WHO		6.5–8.5	NS	500	200	75	50	3	250
W_1	50	5.68	0.9	342	140	83	61	0.9	122
W_2	80	6.20	1.9	221	138	71	42	0.8	20
W_3	100	6.82	2.4	18	136	69	30	0.7	17

DO – dissolved oxygen; TDS – total dissolved solids; TH – total hardness outside the range of the WHO standard of 4°C for domestic water, hence indicating the presence of foreign bodies. A similar view was reported by Jaji *et al*. (2007) in his studies. Pollution from a nearby abattoir, especially W_1, may also be responsible for the high values recorded for both colour and temperature in the water samples analysed. The turbidity readings of the samples were above the WHO and NSDWQ standards with samples W_1, W_2, and W_3 having average turbidity values of 6.6 nephelometric turbidity unit (NTU), 3.5 NTU, and 1.6 NTU, respectively. Similar high turbidity values were also reported by Shyamala *et al*. (2008) indicating that the wells might be unlined, hence the high values. Soil particles may have found their way into the wells from the unstable side walls thereby increasing the water turbidity. A similar observation was made by Akinbile (2006) and the reasons adduced for the observation were as mentioned above. The WHO (2004) recommended a value of 5 NTU as the maximum above which disinfection is inevitable. The observed turbidity value in sample W_1 was slightly higher than the recommended value and might be due to the proximity to the landfill indicating a higher sediment flow when compared with others. All the values were, however, lower than the ones reported in (Jaji *et al*. 2007). Samples W_1 and W_2 were close; hence they needed to be treated before the use. The chemical characteristics of the samples analysed were as shown in Tables 2 and 3. The pH ranged from 5.68 to 6.82 which is acidic and indicated the presence of metals in the samples, particularly toxic metals. Metals such as zinc, those from damaged battery cells (lead, mercury, and alkaline), and improperly disposed of used cans of aerosols and other disinfectants deposited in the landfill as waste may after exposure to air and water, found their ways to the well-water levels through seepage to give the toxic, acidic nature it currently has. It was remarked that though pH 7.0 is neutral and may be tolerated up to 9.2, provided microbiological monitoring indicated no deterioration in bacteriological quality (WHO 2004). In this case, all indicators showed deterioration in bacteriological quality (as shown in Table 4) and deserve urgent attention to avert the imminent catastrophe its continued existence in both the soil and water bodies will pose to the end users of these resources. The pH findings from this study agreed with the values obtained by (Ikem *et al*. 2002; Akinbile 2006; Longe & Balogun 2010) but did not agree with the opinions of (Jaji *et al*. 2007; Shyamala *et al*. 2008).

All the ions were below the WHO and NSDQW limits but still require a treatment before being useful for domestic purposes. The values above 250mg/l for chloride would result in detectable taste while the values above 200 mg/l for total hardness do not have any associated adverse health-related effects on humans but are an indication of Ca and/or Mg ions deposits. Their presence will disallow water from forming lather with soap, thereby preventing economic management of water resources. Chloride ranged from 17 to 122 mg/l and though being below the WHO and NSDWQ levels, its presence indicates pollution requiring a treatment before use. This agrees with the findings of (Igbinosa & Okoh 2009). For manganese, WHO recommended a value of 0.1 mg/l which is still tolerable, while above 0.5 mg/l, manganese will impair potability. Though not detected in all the samples, it was remarked that its excessive concentration would result in taste and precipitation problems (Longe & Balogun 2010). This agrees with the findings of Ogedengbe and Akinbile (2004). Calcium levels though low (with the exception of W_1), which ranged from 69 to 83 mg/l, still portend the danger of water hardness and are slightly higher than the values of (Chauhan & Rai

Table 3. Heavy metal contents in the boreholes and their comparison with the WHO Standard (in mg/l)

Sample	Distance (m)	Fe	Pb	Zn	Cu	Mn	Cr^{3-}
NSQDW		0.5–50	0.01	3.0	1.0	0.2	0.05
WHO		0.5–50	0.01	3.0	1.0	0.1	0.05
W_1	50	1.20	1.21	5.4	ND	ND	ND
W_2	80	1.0	1.11	3.3	ND	ND	ND
W_3	100	0.9	ND	ND	ND	ND	0.25

ND – not detected

2010). The implication is that forming lather with soap will be a major challenge for domestic users (Akinbile 2006). The value of 0.9 mg/l was an indication of oxygen depletion (DO) in W_1 sample, the closest one to the landfill, which also inferred the presence of pollutants that use up oxygen in water. The high DO by the pollutants were noticed and showed that the wells water was unsafe for consumption. The other two wells revealed DO of 1.9 and 2.4 mg/l which, though still low, indicated an indirect impact of the landfill on them. Similar results were reported in Chauhan and Rai (2010) and Akinbile (2006) underlining the presence of pollutants in appreciable quantities. DO is an important factor used for water quality control and similar values were reported by Igbinosa and Okoh (2009) and Jaji *et al*. (2007). The total dissolved solids (TDS) ranging from 18 to 342 mg/l, though being lower than the WHO and NSDWQ values, still indicated pollution, hence the suspension that was evident during analysis. Nitrate, the most highly oxidised form of nitrogen compounds, is commonly present in surface- and groundwaters because it is the end product of the aerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain only minute quantities of nitrate. The nitrate values in the study ranged from 30 to 61 mg/l, showing an appreciable presence of pollutants in all the water samples. Nitrite ranged from 0.7 to 0.9 mg/l and all this agreed with the observations made by Chauhan and Rai (2010) and Igbinosa and Okoh (2009) in their respective studies despite being below the WHO and NSDWQ values for potable water. From Table 3, most heavy metals tested for were not detected with the exception of iron, lead, zinc, and chromium which indicated the presence of toxic wastes coming perhaps from disposed off battery cells, used aerosol cans, and other materials with a certain degree of toxicity. Iron and lead ranged from 0.9 to 1.2 mg/l and 1.11 to 1.2 mg/l, respectively, which is a clear manifestation of the presence of toxic wastes in the landfill. Zinc ranged from 3.3 to 5.4 mg/l which also indicated pollution. A similar result was reported by Ikem *et al*. (2002) and agreed with the findings of Shyamala *et al*. (2008) and Longe and Balogun (2010). The WHO (2004) report indicated that a range of values of 1 to 3 mg/l is permissible for iron metals in water above which an objectionable and sour taste in mouth is observed. It was also remarked that the formation of blue baby syndrome in babies and goiter in adults are the results of consumption of water containing iron above the specified quantity (Akinbile 2006; Shyamala *et al*. 2008). The results of other tests carried out on cyanide and other metals such as mercury and silver were negative. However, the presence of chromium (0.25 mg/l) in the sample at 100 metres distance from the landfill may suggest pollution from a nearby abattoir and not from the landfill site. Similar view is shared by Chauhan and Rai (2010).

Bacteriological characteristics

The bacteriological characteristics of the samples tested are as reported in Table 4. The *Escherichia coli* and thermotolerant coliform bacteria contentswere high and greater than one in all the samples analysed being an indication of faecal pollution of human wastes from the landfill. The variance from the WHO was also more than 50 % (with the exception of *E. coli* in W_3) which further confirmed bacteriological pollution, not limited to human sources and coming perhaps from the remains of dead animals or even a grave yard nearby. It was remarked that the probability

Table 4. Bacteriological constituents in the boreholes and comparison with WHO Standard (in 1/100 ml)

Sample	Bacterial constituent	Water sample result	Variance from WHO
W_1	total coliform bacteria	> 1.7	+ 0.7
	Escherichia coli	> 1.6	+ 0.6
W_2	total coliform bacteria	> 1.5	+ 0.5
	Escherichia coli	> 1.5	+ 0.5
W_3	total coliform bacteria	> 1.2	+ 0.2
	Escherichia coli	> 1	0

of packing faeces from the public disposal systems due to the lack of functional sewage systems in some parts of Akure was high (Akinbile 2006). These results showed that the three samples did not satisfy the WHO requirements for bacteriological characteristics in human consumption. The WHO and NSDWQ standards were 1 in 100 ml but all the samples analysed showed values over 1/100 ml. A thorough treatment of water from these wells would be required before its domestic consumption.

Soil analyses

Tables 5 and 6 show the physical and chemical properties of soil at the landfill site. From Table 5, the pronounced soil class is sandyclayloam using the USDA textural class triangle which was about 87% of the total soil samples analysed. The proportion of sand was between 58–60%, of silt 12–14%, and of clay 28–30%. Sand content decreases farther away from the dump site indicating the reduction in organic matter with the increasing distance away from the site. Ibitoye (2001) made similar observations in his study which indicated a decrease in sand within the refuse dump area as the soil depth increased. He also reported that the lower level of sand within 0–10 m may be the result of the organic matter binding effect. The higher level of clay within 10–15 m may have occurred due to erosion which removed loose particles from the surface. The mean moisture content of soil ranged from between 34 and 43% and it decreased with the increase of the distance away from the refuse dump. This resembles the observations reported by Silva and Kay (1997) and Moura *et al.* (2009) in their studies. The moisture content within the refuse and dump (centre) was higher as this was associated with the increased activity of organisms and high organic matter (Zhang *et al.* 2007). Water holding capacity (WHC) mean values ranged from 38 to 54%. It decreased with the increase of the distance away from the refuse dump. Water holding capacity was high as a result of high organic matter within the dump and clay content distribution. Porosity ranged from 31 to 56% in all the locations and depths

The mean porosity values decreased with the increase of the distance from the refuse dump. They ranged from 44 to 47% and are an indication of a high percentage of the clay content and of a lower sand proportion; this was also observed by (Ibitoye 2001). The observed colours of the soil samples were dark. It was noticed that the

Table 5. Physical properties of soil class (using USDA textural triangle) (in %)

Locations	MC	WHC	Porosity	Sand	Clay	Silt
A	43	54	48	59	29	12
B	36	47	47	68	29	13
C	36	47	47	60	28	13
D	34	38	44	58	30	13

A, B, C, D – locations (points) from the centre of the dump site measured horizontally away from the dump (0, 10, 20, 30 m); MC – moisture content, WHC – water holding capacity

Table 6. Chemical properties of soil samples at various locations within the landfill site

Location	pH	OC	OM	N	P	K	Na	Ca	Mg	Cu	Pb
				(%)					(mg/kg)		
A	7.5	2.48	4.27	0.21	33.52	1.21	1.02	11.77	6.23	101.9	54.2
B	7.4	2.46	4.24	0.21	20.15	1.02	0.99	11.73	5.53	81.0	59.7
C	7.3	2.11	3.64	0.18	15.15	0.95	0.76	11.50	5.43	63.7	43.2
D	6.9	1.42	2.44	0.12	11.36	0.93	0.65	10.27	4.97	31.7	24.7
FAO	7		3	0.15	20	0.30	0.30	12	1.0	6	6

A, B, C, D – locations (points) from the centre of the dump site measured horizontally away from the dump (0, 10, 20, 30 m); OC – organic content; OM – organic matter soil within the dump area was darker which was the result of the organic matter decomposition. As seen in Table 6, the mean pH values ranged between 6.9 and 7.5. They decreased slightly with the increasing distance from the refuse dump. This could be the result of a high exchangeable bases content around the refuse dump. The major effects of soil acidification on plants included the reduction in nutrients supply, increased concentrations of metal ions in solution, especially of aluminium, and including those of manganese, copper, zinc which may be toxic, nitrogen fixation by legumes may be reduced unless the Rhizobium strain is acid-tolerant (Dorraji *et al.* 2010).

Organic matter ranged between 2.44 and 4.27%. It decreased with increasing distance from the refuse dump. High organic matter discovered around the waste dump favours increased moisture content, water holding capacity, and permeability (Ibitoye 2001). The frequent addition of easily decomposable organic residues caused the synthesis of complex organic compounds that bind soil particles into structural units called aggregates. These aggregates helped in maintaining a loose, open and granular condition. Water is then able to enter and percolate downward through the soil with pollutants (Ibitoye 2001; Shepherd *et al.* 2002).

Organic carbon (OC) values in the landfill ranged between 1.42 and 2.48% (Table 6). The OC values decreased with the increase of the distance away from the centre of the dump. The increase of the values of organic carbon within the waste dump may be the result of the waste burning on the landfill. The effects of burning are numerous and have tremendous negative impacts on the environment. These include global warming and emissions of other greenhouse gases. Burning could also cause acid rain which occurs when sulphur IV oxide and nitrogen oxides are released into the atmosphere (Al Sabahi *et al.* 2009). Soil nutrients and essential elements are depleted during burning. Organic nitrogen ranged from 0.12 to 0.21%. The increase in the values of organic nitrogen within the waste dump was higher when compared with the (FAO 2004) standards. Organic nitrogen decreased with the increasing distance away from the waste dump site. Available phosphorus ranged between 11.36–33.52 mg/kg. It decreased with the increase in the distance. Phosphorus values were above 7–20 mg/kg, the FAO standards, with the exception of the measurements taken between the distances 20–30 m apart which had a mean value of 11.36 mg/kg. The high values of the available phosphorus in addition to organic matter may have resulted from the constituents of domestic wastes such as soaps and detergents present in the landfill. Exchangeable potassium, sodium, calcium, and magnesium values ranged between 0.93–1.21, 0.65–1.02, 10.27–11.77, and 4.97–6.23 cmol/kg, respectively. From Table 6, it was evident that the exchangeable bases were very high from the distances 0–10 m apart. The presence of heavy metals such as copper with means values ranging from 31.7–101.0 mg/kg, and lead ranging from 24.7–54.2 mg/kg is also indicated in the table which agrees with the results obtained by Shepherd *et al.* (2002). The pronounced presence of heavy metals was noticed between 0 and 10 m away from the refuse dump indicating toxic pollution. The Dutch standard for Soil Contamination Assessment concerning total concentration of heavy metals as well as those of industrialised countries state that the target and intervention (TI) values for copper are 36 and 190 mg/kg, respectively. The highest value for copper concentration in the landfill was 116.4 mg/kg, higher than the target value (36 mg/kg) but lower than the intervention value (190 mg/kg). The target and intervention values for lead are 86 and 530 mg/kg, respectively, indicating the presence of poison in the landfill. The highest value for lead concentration on the site was 58.7 mg/kg, lower than target value (85 mg/kg) and intervention value (530 mg/kg). Therefore, lead concentration on the site, though moderate, is dangerous if allowed to infiltrate towards the groundwater table.

Test of significance of the observed correlation coefficients

The significance of the observed correlation coefficients was tested by using *t*-test as shown in Table 7. Out of the total 28 correlations found between two parameters, 15 were found to be significant at 5% level ($R > 0.8$). The twelve negative correlations were found between pH and calcium ($R = -0.92$), pH and TH ($R = -1.0$), pH and TDS, pH and NO_3 ($R = -0.99$) and between pH and TH ($R = -1$). The same goes for pH and Cl^{-1} (–0.88), DO and TDS, TH, Ca, NO_3, NO_2, and Cl^{-1} had revealed negative correlation values ranging from –0.94 to –0.98 respectively. The DO and pH had negative correlations with all other parameters tested but positive between each other ($R = 0.98$). The positive correlations were observed between TH and Ca (0.92), Ca and NO_3 (0.97), and NO_3

Table 7. Correlation coefficient of different water samples physiochemical variables from the study data

Variable	pH	DO	TDS	TH	Ca	NO_3	NO_2	Cl^{-1}
pH	1	0.98	–0.99	–1	–0.92	–0.99	–1	–0.88
DO		1	–0.94	–0.98	–0.98	–0.99	–0.98	–0.95
TDS			1	0.99	0.86	0.96	0.99	0.80
TH				1	0.92	0.99	1	0.88
Ca					1	0.97	0.92	0.99
NO_3						1	0.99	0.93
NO_2							1	0.88
Cl^{-1}								1

DO – dissolved oxygen; TDS – total dissolved solids; TH – total hardness

and Cl^{-1} (0.93), respectively. Some of the highly significant correlations were discernible between TH and nitrite (R = 1), TH and nitrate (R = 0.99), and between nitrate and nitrite (R = 0.99). The trend was an indication that the pollutants presence in the test parameters is strongly interrelated and interdependence on one another with the co variability values is observed. For instance, DO dependence on TH, Ca, NO_3, NO_2, and Cl^{-1} indicated that the effect of oxygen depletion will be significantly felt on all the aforementioned parameters considerably. This would also be true with all other parameters of high R-values in all other constituents analysed in the study. In all the parameters tested using t-test correlation analysis, there were significant differences in all the parameters considered at 95% confidence interval also confirming the presence of pollutants at irregular concentrations in all the water samples.

Concluding remarks

The study revealed that the concentration of waste materials in the landfill site had systematically polluted the soil and groundwater over time. The effect of such pollution as determined from the study declined away from the polluting source. This implied that the contamination of the groundwater was more dependent on the proximity to the dump sites. Smaller dependence has been attributed to the influence of topography, type, state of waste disposal systems and, to some extent, hydrogeology of the area. However, the results indicated very poor sanitation and damaging effects to the health of both humans and animals if the surrounding well waters were used for domestic and agricultural purposes that require a certain degree of hygiene. As a result of the high levels of chemical and bacteriological contamination of the water from the boreholes, health problems such as typhoid fever or worm infestation are imminent when such water is consumed. It also follows from the study that the effect of the waste disposal on soils is damaging. This led to the destruction of several hectares of productive land and also altered the soil fertility. The dumping of industrial wastes and accumulation of heavy metals were considered the greatest hazard on the landfill site from the study. When these chemical elements are absorbed by soils, the toxins can pass into the food chain through grazing animals. The effects of incineration on the soil and emission of one major GHG-carbon IV oxide deplete the soil and destroy the aggregates. The impact on the environment includes; increased day-time temperature, global warming, increased incidences of crop abortion, and subsequent reduction in yield and productivity. Governmental policies on the waste disposal and management should be enacted and strictly enforced, citing of dumpsites far away from the residential areas to minimise the pollution of nearby well waters, streams and rivers, and waste sorting and treatment before the disposal are encouraged. Re-designing of sanitary landfill with clay or plastic liners to prevent leachate from getting to the water table, adoption of clean technology for recycling greenhouse gases emanating from the landfill, and a sustainable land management programme for reclamation are recommended.

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