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

Christopher O. Akinbile, Ph.D.

School of Civil Engineering, Universiti Sains Malaysia, 14300, Nibong Tebal, Pulau Penang, Malaysia.
Department of Agricultural Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.

E-mail: cecoakinbile@eng.usm.my
cakinbile@yahoo.com
coakinbile@futa.edu.ng

ABSTRACT

Physical and chemical analyses of water samples from three boreholes located near a landfill and soil samples were carried out to assess the effect of dumpsite on groundwater quality and soil. The parameters determined included dissolved oxygen, iron, nitrate, nitrite, calcium, and heavy metals. Most of these parameters indicated pollution but were below the World Health Organization (WHO) limit for consumption. The results showed very poor sanitation and damaging effects to health of users which also implied that groundwater contamination was more dependent on proximity to dump sites. Concentrations of iron, nitrate, nitrite, and calcium ranged from 0.9 to 1.4 mg L^{-1}; 30 to 61 mg L^{-1}; 0.7 to 0.9 mg L^{-1}; and 17 to 122 mg L^{-1}, respectively. Soil organic matter and organic carbon ranged from 2.44- 4.27% and 1.42- 2.48%. Statistical analyses indicated significant differences at 95% level. Treatment of water before use and landfill redesigning are suggested.

(Keywords: Akure, landfill, environmental pollution, soil; wastes; ground water, contamination)

INTRODUCTION

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 industrialization and urbanization that has progressively developed over time without any regard for environmental consequences [1]. In recent times, the impact of leachates on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental importance. Leachates migration from wastes sites or landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to groundwater resource if not adequately managed [2].

Protection of groundwater is a major environmental issue. Open dumps are the oldest and most common way of disposing of solid wastes, although in recent years, thousands have been closed, many are still being used [3]. The frequently used municipal solid waste disposal methods include: composting, sanitary landfill, and pyrolysis, reuse recovery and recycle [4].

Waste management has become increasingly complex due to the increase in human population, industrial and technological revolutions and the processes that control the fate of wastes in the soil is complex and many of them are poorly understood. Issues such as nutrients release rate and other chemicals, leaching of nutrients, metals through macropores as suspended solids and sludge organic matter on the sorption degradation are often not understood by many [5]. Leaching of hydrophobic organics and long term bioavailability and fate of metals fixed by soil organic matter needed to be studied to have a better approach in handling groundwater pollution [2].

Toxic chemicals that have high concentration of nitrate and phosphate derived from waste in the soil can filter through a dump and contaminate both ground and surface water. Insects, rodents, snakes and scavenger birds, dust, noise, and bad odor are some of the aesthetic problems associated with sanitary landfill. Emissions of methane (CH_4) and carbon dioxide (CO_2) and leachate contamination of ground water and soil are the environmental issues connected with landfill.

The volume of solid waste generated in Akure, South western Nigeria has increased significantly over time from an estimated quantity of 60,000 metric tons per year in 1996 to 75,000 metric tons in 2006 because of the increasing population, 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 plastic/nylon, 15.72% and about 1% metal [6]. Increasing waste generation and disposal resulted in increase groundwater pollution and unsuitability in the usage 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 landfill on the degree of pollution of groundwater in the Akure and to analyze soil properties at the dumpsite for productivity viability.

MATERIALS AND METHODS

Study Area

The study area was the dump site (Landfill) of Ondo state Waste Management Authority Yard situated along Igbatoro Road, Akure in Ondo State, located in South Western part in Nigeria. Akure, capital of Ondo state of Nigeria located between latitude $9^{0}17^{1}$N and Longitude $5^{0}18^{1}$E. It has a tropical humid climate with two distinct seasons.

Akure has a relatively dry season from November to March and a rainy season from April to October. Akure has an average annual rainfall within the range of 1405mm and 2400mm of which rainy season accounts for 90% and the month of April marks the beginning of rainfall [7].

The cities that shared boundaries with Akure include; Ikere in the north, Ondo in the south, Owo in the east and Igbara-oke 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 [6].

Water Analyses

Three existing 6” diameter boreholes with average depth of 40 meters in basement formation located within the distance 50m, 80m, and 100m radially away from the centre of the landfill were used as sampling points for groundwater quality testing. For each borehole, 15 liters of the groundwater samples were collected in 600 mL sterilized polyethylene bottles, stored at 4^{0}C and analyzed.

The analyses covered physical, chemical and bacteriological parameters of 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 for included: odor, taste, color, turbidity and temperature. Chemical parameters analyzed were pH, Dissolved oxygen (DO), total dissolved solids (TDS), Total Hardness, Total Iron, Nitrate, Nitrite, Chloride, Calcium and heavy metals such as Copper, Zinc and Lead.

The pH was determined using a Mettler Toledo (GmbH 8603 Schwerzenbach) pH meter by direct measurement, analog mercury thermometer was used in making temperature measurements and a Hach 2100A turbidimeter was used for turbidity determination. The samples were also analyzed for total dissolved solids (TDS), total hardness, iron, nitrate (NO_3), nitrite (NO_2), calcium, chloride were carried out in the water laboratories using standard methods for the examination of water [8]. The concentrations of heavy metals such as copper, zinc, and lead in water samples were determined with flame atomic absorption spectrophotometer. Also, bacteriological assay was used in the determination of thermotolerant coliform bacteria and *Escherichia Coli.* All the results were compared with the World Health Organization [9] and the Nigerian Standard for Drinking Water Quality [10] values.

Soil Sampling and Analysis

Soil samples were collected from the landfill (dumpsite) of Ondo State Waste Management Authority, Akure. Representative samples which were twelve were collected at four different aligned locations of 10 m distance with each location having three samples at various depths 0-10cm, 10-20cm, and 20-30cm in depth. Samples were collected with specification of pre-determined distances and depths using soil auger, air dried, sieved through 2mm mesh and stored in polythene bags for analysis.

Soil analysis was carried out on the samples to determine the composition of the following in the samples: pH, organic carbon (OC), nitrogen, (N), phosphorus, (P), sodium, (Na), calcium, (Ca), magnesium, (Mg), copper, (Cu), and lead, (Pb).

The soil particle size Analysis was carried out using apparatus such as the Mechanical stirrer, stop watch, Analytical balance, Hydrometer, Thermometer and Reagent: calgon as dispersing agent, 50g sodium hexametaphosphate plus 7g anhydrous sodium carbonate were dissolved in 1000ml distilled water. This was done using standard laboratory procedures and analytical methods [8]. The values were compared with the Food and Agriculture Organization [11] of the United Nations (UN) values.

RESULTS AND DISCUSSIONS

Water Analyses

The results and comparison of the sample parameters with the World Health Organization (WHO) [9] and the Nigerian Standard for Drinking water quality (NSDWQ) [10] were presented in Tables 1, 2, and 4. The temperature, turbidity, color and odor of the samples were shown in table 1. The presence of color was an indication of pollution and confirmed leachate infiltration into the wells [5, 12]. The temperatures which ranged from 26.5 and 27.5^{0}C were found outside the range of the WHO standard of 5^{0}C for domestic water hence indicating the presence of foreign bodies. Similar views were reported by [13] in their studies. Pollution from a nearby abattoir, especially W_1 may also be responsible for the high values recorded for both color and temperature in the water samples analyzed.

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 NTU, 3.5 NTU, and 1.6 NTU, respectively. Similar high turbidity values were also reported as in [14] indicating that the wells may be unlined hence the high values. Soil particles may have found their way into the wells from the unstable side walls thereby increasing turbidity of the water. A similar observation was made by [7] and the reasons adduced for the observation was as mentioned above. The [9] recommended a value of 5 NTU (nephelometric turbidity unit) as the maximum above which disinfection is inevitable. The observed turbidity value in sample W_1 was slightly higher than the recommended value and may be due to proximity to the landfill indicating higher sediment flow when compared with others. All the values were however lower than the ones reported in [13]. Samples W_1 and W_2 were close hence needed to be treated before usage.

The chemical characteristics of the samples analyzed were as shown in Tables 2 and 3. The pH ranged from 5.68 to 6.82 which is acidic and indicated presence of metals in the samples particularly toxic metals. Metals such as zinc, damaged battery cells (lead, mercury and alkaline) and improperly disposed used cans of aerosol and other disinfectants deposited in the landfill as waste, after exposure to air and water and may have found their ways to the well-water levels through seepage to give the toxic, acidic nature it currently has. It was remarked that though 7.0 is the neutral, up to 9.2 may be tolerated, provided microbiological monitoring indicated no deterioration in bacteriological quality [9]. 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 values obtained by [1, 2, 7] but did not agree with opinions of [13, 14, 15].

All the ions were below the [9] and [10] limits but still require treatment before being useful for domestic purposes. Values above 250mg/l for chloride would result in detectable taste while values above 200 mg/l for total hardness (TH) do not have any associated adverse health-related effects on humans but is an indication of deposits of Ca and/or Mg ions. Their presence will disallow water from forming lathe with soap thereby preventing economic management of water resources. Chloride ranged from 17 to 122 mg L^{-1} though below the WHO and NSDWQ levels, its presence connotes pollution hence require treatment before use. This agreed with the findings of [16].

Table 1: Physical Characteristics of the Borehole Water Samples Analyzed.

Sample	Color	Odor	Turbidity (NTU)	Temperature (^{0}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

Table 2: Chemical Constituents in the Boreholes and their Comparisons with the WHO Standards.

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
W1	50	5.68	0.9	342	140	83	61	0.9	122
W2	80	6.20	1.9	221	138	71	42	0.8	20
W3	100	6.82	2.4	18	136	69	30	0.7	17

The pH is dimensionless; except otherwise stated, all units are in mg/L

Table 3: Heavy Metal Contents in the Boreholes and their Comparisons with the WHO Standards.

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
W1	50	1.20	1.21	2.3	ND	ND	ND
W2	80	1.0	1.11	0.3	ND	ND	ND
W3	100	0.9	ND	ND	ND	ND	0.25

Except otherwise stated, all units are in mg/L

Table 4: Bacteriological Constituents in the Boreholes and Comparison with WHO Standards.

Sample	Bact. Constituent	Water Sample Result	Variance from WHO
W1	T. coliform bacteria Escherichia coli	>1.7 >1.6	+0.7 +0.6
W2	T. coliform bacteria Escherichia coli	>1.5 >1.5	+0.5 +0.5
W3	T. coliform bacteria Escherichia coli	>1.2 >1	+0.2 0

For manganese, WHO recommended a value of 0.1mg/l which is still tolerable, above 0.5mg/l, manganese will impair potability. Though not detected in all the samples, it was remarked that its excessive concentrations would result in taste and precipitation problems [1]. This agreed with the findings of [12]. Calcium levels though low (with the exception of W_1), which ranged from 69 to 83 mgL^{-1} still portend danger of hardness in water and slightly higher than the values of [17]. The implication is that forming lathe with soap will be a major challenge for domestic users [7].

The value of 0.9mg L^{-1} was an indication of oxygen depletion (DO) in the W_1 sample, closest to the landfill which also inferred the presence of pollutants that use up the oxygen in water. Heavy usage of the DO by the pollutants were noticed and showed that the wells were unsafe for consumption. The other two wells had DO to be 1.9 and 2.4 mg L^{-1}, though still low but indicated an indirect impact of the landfill on them. Similar results were reported as in [7, 17] underlining the presence of pollutants in appreciable quantities. DO is an important factor used for water control quality and similar values were reported by [13, 16].

The total dissolved solids (TDS) which ranged from 18 to 342 mg L^{-1}, though lower than the WHO and NSDWQ values still indicated pollution hence the suspension that were evident during analysis. Nitrate, the most highly oxidized 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^{-1}, showing appreciable presence of pollutants in all the water samples. Nitrite also ranged from 0.7 to 0.9 mg L^{-1} and all there agreed with observations made by [16, 17] in his study 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 metals which indicated presence of toxic wastes perhaps from disposed battery cells, used aerosol cans, and other materials with certain degree of toxicity. Iron and lead ranged from 0.9 to 1.2 mg L^{-1} and 1.11 to 1.2 mg L^{-1} which is a clear manifestation of presence of toxic wastes in the landfill. Zinc ranged from 3.3 to 5.4 mg L^{-1} which also indicated pollution. A similar result was reported by [14]. This agreed with the findings of [1], [2], [14], and [15]. The WHO [9] report indicated that a range of values 1 to 3 mg L^{-1} is permissible for iron metals in waters above which an objectionable and sour taste in mouth is given. It was also remarked that the formation of *blue baby syndrome* in babies and goitre in adults were results of consumption of water with quantity of iron above the specified values [12] [15]. Other metals tested for such as cyanide, mercury and silver were not detected however, the presence of chromium (0.25 mg L^{-1}) in the sample 100 meters from the landfill may suggest pollution from a nearby abattoir and not from the landfill site. Similar view as this was shared by [17].

Bacteriological Characteristics

The bacteriological characteristics of the samples tested were as reported in Table 4. The *Escherichia coli* and thermotolerant coliform bacteria were high and greater than one in all the samples analyzed an indication of fecal 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 perhaps from remains of dead animals or even a grave yard nearby. It was remarked that the probability of packing feces from public disposal systems due to lack of functional sewage systems in some parts of Akure was high [7].

These results showed that the three samples do not satisfy the WHO requirements for bacteriological characteristics human consumption. The WHO and NSDWQ standards were 1 in 100ml but all the samples analyzed had over 1/100ml. Major treatment of water from these wells would be required before its domestic consumption.

Soil Analyses

Tables 5 and 6 showed results of the physical and chemical properties of soil at the landfill site. From Table 5, the pronounced soil class is sandy/clay/loam using the USDA textural class triangle which was about 87% of the total samples of soil analyzed. The range of sand is between 58-60%, silt 12-14% and clay 28-30%. Sand reduces farther away from the dump site indicating the reduction in organic matter as the distance away from the site increases.

Table 5: Physical Properties of Soil Class (using USDA Textural Triangle).

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, and D are Locations (points) from the centre of dump site measured horizontally away from the dump. (0m, 10m, 20m, 30m) M/C = 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 (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Cu (mg/kg)	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

Other researchers [18] have made similar observations in his study which indicated a decrease in sand within refuse dump area as the soil depth increase. It was also reported that lower level of sand within 0-10m may be as result of binding effect of organic matter. The higher level of clay within 10-15m 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 increase in distance away from the refuse dump. This was similar to observations reported by [19, 20] 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 [21]. Water holding capacity (WHC) mean values ranged from 38 to 54%. It decreased with increase in distance from refuse dump. Water holding capacity is high as a result of high organic matter within the dump and clay content distribution. Porosity ranged between 31 and 56% in all the locations and depths.

The mean porosity showed that the values reduced with increase in distance from refuse dump. It ranged from 44 to 47% and is an indication of high percentage clay and low values with high sand percentage; this was also observed by [18]. The colors of the soil samples were observed to be dark.

It was noticed that the soil within the dump area was darker which was as a result of the decomposed organic matter. From Table 6, the Mean pH values ranged between 6.9 and 7.5. It decreased slightly with increase in distance from refuse dump. This could be as a result of high exchangeable bases around the refuse dump. The major effects of soil acidification on plants included reduction in supply of nutrients, increased concentrations of metal ions in solution, especially of aluminum, and including those of manganese, copper, zinc which may become toxic, nitrogen fixation by legumes may be reduced unless the Rhizobium strain is acid-tolerant [22].

Organic matter ranged between 2.44 and 4.27%. It decreased with increase in distance from refuse dump. High organic matter discovered around waste dump favors increased moisture content, water holding capacity and permeability [18]. 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 help to maintain a loose open, granular condition. Water is then better able to enter and percolate down ward through the soil with pollutants [18, 23]. Distances 0m, 0-10m, 10m-20m indicated higher values when compared with the FAO Standards. These high values are indication of pollution. Organic carbon values on the landfill ranged between 1.42 and 2.48%.

The values decreased from waste dump with increase in distance away from the dump. Increase in the values of organic carbon within waste dump may be as a result of burning of the waste on the landfill. The effects of burning are numerous and have adverse impacts on the environment. These included global warming (greenhouse effect) which is the primary causes are the increased amounts of carbon dioxide and other greenhouse gases. Burning could also cause acid rain which occurs when sulphur dioxide and nitrogen oxides are emitted into the atmosphere. Depletion of ozone layer occurs due to the production of chemicals such as carbon tetrachloride and trichloroethane [3].

Soil nutrients and essential elements were depleted during burning. Organic nitrogen ranged from 0.12 to 0.21%. There was a higher increase in the values of organic nitrogen within waste dump when compared with the [11] standards. Organic nitrogen decreased with increase in distance from waste dump site. Available phosphorus ranged between 11.36 - 33.52mg/km. It decreased with increase in distance. Phosphorus values were higher than 7-20mg/kg, the FAO standards with the exception of measurements taken between the distances 20 – 30 m apart which had a mean value of 11.36mg/kg. The high values of available phosphorus in addition to organic matter may be as a result of 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 cmol/kg, 0.65 - 1.02 cmol/kg, 10.27 - 11.77 cmol/kg and 4.97 - 6.23cmol/kg, respectively. From Table 6, it was shown that exchangeable bases were very high from 0 - 10m 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 – 54.2mg/kg was also indicated in the table which agreed with results obtained by [23]. The pronounced presence of heavy metals was noticed between 0 and 10m away from the refuse dump indicating toxic pollution.

The Dutch standard for Soil Contamination Assessment in total concentration of heavy metal and that of industrialized countries stated that target and intervention (TI) values for copper are 36 and 190 mg/kg, respectively. The highest value for copper concentration on the landfill was 116.4mg/kg, higher than the target value of (36mg/kg) but lower than the intervention value of (190mg/kg). The target and intervention values for Lead were 86 and 530 mg/kg, respectively indicating the presence of poison in the landfill. The highest value for lead concentration on the site was 58.7mg/kg, lower than target value of (85mg/kg) and intervention value of (530mg/kg). Therefore, lead concentration on the site, though moderate but dangerous if allowed to infiltrate towards the groundwater table.

Test of Significance of the Observed Correlation Coefficients

The significance of the observed correlation coefficients have been tested by using the 't'' test is as shown in Table 7. Out of the total 28 correlations found between two parameters, 15 were found to have significant at 5% level ($r > 0.8$).

Table 7: Correlation Coefficient of Different 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	-.095
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

The twelve negative correlations were found to be between pH and calcium (r = -0.92), pH and TH (r = -1.0), pH and TDS, pH and NO3 (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 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 with each other (r = 0.98).

The positive correlations observed existed between TH and Ca (0.92), Ca and NO_3 (0.97) and NO_3 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). 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 presence of pollutants at irregular concentrations in all the water samples.

CONCLUSIONS

The effect of such pollution as determined from the study declined away from the polluting source which also implied that the contamination of the groundwater was more dependent on proximity to dump sites. The less dependency has been attributed to the influence of topography, type, state of waste disposal systems and to some extent, the hydrogeology of the area. However, the results indicated very poor sanitation and damaging effects to health of both man and animals if surrounding well waters were used for domestic and agricultural purposes that require certain degree of hygiene.

As a result of the high levels of chemical and bacteriological contamination of water from the boreholes, health problems as typhoid fever, worm infestation are imminent when such water is consumed. Also from the study, the effect of waste disposal on soils is damaging. This has led to the destruction of several hectares of productive land and has also altered the soil fertility.

Dumping of industrial wastes and accumulation of heavy metals are considered the greatest hazard on landfill site from the study. When these chemical elements are absorbed by soils the toxic could be passed 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 included; increase day-time temperature, global warming, increase incidences of crop abortion and subsequent reduction in yield and productivity. Governmental policies on waste disposal and management should be enacted and strictly enforced, citing of dumpsites far away from residential areas to minimize pollution of nearby well-waters, waste sorting and treatment before disposal are encouraged. Re-designing of sanitary landfill with clay or plastic liners to prevent leachates from getting to water table, adoption of clean technology for recycling greenhouse gases emanating from the landfill and a sustainable land management program for reclamation are recommended.

ACKNOWLEDGMENTS

The author is grateful to Messers T.O. Ajayi and O.O. Ayowole for their assistance in data collection and to Third World Academy of Science (TWAS) for the provision of one year Post Doctoral fellowship (FR Number: 3240223476) and the Universiti Sains Malaysia (USM) that enabled him utilize the fellowship for research study.

REFERENCES

1. Longe, E.O. and M.R. Balogun, 2010. “Groundwater Quality Assessment near a Municipal Landfill, Lagos, Nigeria”. *Res. Jour. of Applied Sci., Eng. and Technol*. 2(1):39-44.

2. Ikem, A., Osibanjo, O., Sridhar, M.K.C., and A. Sobande. 2002. “Evaluation of Groundwater Quality Characteristics near Two waste Sites in Ibadan and Lagos, Nigeria”. *Water, Air, and Soil Poll*. 140**:**307–333. Kluwer Academic Publishers, the Netherlands.

3. Al-Sabahi, E. Abdul Rahim, S. Wan Zuhairi, W.Y. Al-Nozaily, F., and F. Al-Shaebi. 2009. “The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen”. American Jour. of Environ. Sci. 5(3): 256-266.

4. USEPA. 2007. *Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 2006*. EPA-530-F-07-030. http://www.epa.gov/osw//nonhaz/municipal/pubs/msw06.pdf

5. Mohamed, A.F., Yaacob, W.Z.W., Taha, M.R., and A.R. Samsudin. 2009. "Groundwater and Soil Vulnerability in the Langat Basin Malaysia". *European Jour. of Scientific Res*. 27(4):628-635.

6. Olanrewaju, O.O. and O.A. Ilemobade. 2009. "Waste to Wealth; A Case Study of the Ondo State Integrated Waste Recycling and Treatment Project, Nigeria". *European Jour. of Social Sci*. 8(1):7 – 14.

7. Akinbile, C.O. 2006. "Hawked Water Quality and its Health Implications in Akure, Nigeria". *Botswana Jour. of Technol*. 15(2): 70-75.

8. APHA. 2005. *Standard Methods for the Examination of Water and Waste Water, twenty first ed. American Public Health Association*. APHA: Washington, DC.

9. World Health Organization (WHO). 2004. *Guidelines for Drinking Water Quality*. 3rd Edn.Vol. 1 Recommendation. WHO: Geneva. 515.

10. NSDQW. 2007. *Nigerian Standard for Drinking Water Quality*. Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria: Lagos, Nigeria. 30.

11. United Nations Food and Agriculture Organization (FAO). 2004. Statistical database. FAO, New York, NY.

12. Ogedengbe, K. and C.O. Akinbile. 2004. "Impact of Industrial Pollutants on Quality of Ground and Surface waters at Oluyole Industrial Estate, Ibadan, Nigeria". *Nigerian Jour. of Technological Dev*., 4(2):139-144.

13. Jaji, M.O., Bamgbose, O., Odukoya, O.O., and T. A. Arowolo. 2007. "Water Quality Assessment of Ogun River, South West Nigeria". *Environ. Monitor. and Assess*.133:473-482 .

14. Sangodoyin, A.Y. 1991. "Ground Water and Surface Water Pollution by Open Refuse dump in Ibadan, Nigeria". *Dis. and Innov.* 3(1):24 - 31.

15. Shyamala, R., Shanti, M., and P. Lalitha. 2008. "Physicochemical Analysis of Borewell Water Samples of Telungupalayam Area in Coimbatore District, Tamilnadu, India". *E-Jour. of Chem.* 5(4): 924-929.

16. Igbinosa, E.O. and A.I. Okoh. 2009. "Impact of Discharge Wastewater Effluents on the Physic-Chemical Qualities of a Receiving Watershed in a Typical Rural Community". *Inter. Jour. of Environ. Sci. and Technol*. 6(2):1735 – 1742.

17. Chauhan, J. and J.P.N. Rai.2010. "Monitoring of Impact of Ferti-Irrigation by Post-Methanated Distillery Effluent on Groundwater Quality". *Clean – Soil, Air, Water.* 38(7):630–638. Wiley-VCH, Weinheim, Germany.

18. Ibitoye, A.A. 20001. "Effects of Municipal Refuse Dump on Soil and Water Quality in Akure Metropolis". *Jour. of Appl. Soil Sci.* 2(2):16-44.

19. Moura, E.G., Moura, N.G., Marques, E.S., Pinheiro, K.M., Costa-Sobrinho, J.R.S., and A.C.F. Aguiar. 2009. "Evaluating Chemical and Physical Quality Indicators for a Structurally Fragile Tropical Soil. *Soil Use and Mgt*. 25:368–375.

20. Silva, A.P. and B.D. Kay.1997. "Estimating the Least Limiting Water Range of Soils from Properties and Mgt. *Soil Sci. Soc. of America J*. 61:877–883.

21. Zhang, S., Lovdahl, L., Grip, H., Jansson, P., and Y. Tong. 2007. Modelling the Effects of Mulching and Fallow Cropping on Water Balance in the Chinese Loess Plateau. *Soil & Til. Res.* 93:283–298.

22. Dorraji, S.S., Golchin, A. and S. Ahmadi.2010. "The Effects of Hydrophilic Polymer and Soil Salinity on Corn Growth in Sandy and Loamy Soils". *Clean – Soil, Air, Water.* 38(7):584–591. Wiley-VCH, Weinheim, Germany.

23. Shepherd, M.A., Harrison, R., and J. Webb. 2002. "Managing Soil Organic Matter: Implications for Soil Structure on Organic Farms". *Soil Use and Mgt*. 18:284–292.

ABOUT THE AUTHOR

Dr. Christopher Akinbile is a Senior Lecturer at the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. He is a registered Engineer and a member of many professional organizations one of which is the American Society of Agricultural and Biological Engineers (ASABE). He holds a Ph.D. degree from the University of Ibadan, Nigeria. His research interests are in areas of agricultural engineering, soil and water conservation, irrigation and drainage, water quality, waste management and control, and environmental control and climate change.

SUGGESTED CITATION

Akinbile C.O. 2011. “Environmental Impact of Landfill on Groundwater Quality and Agricultural Soils in Akure, Nigeria”. *Pacific Journal of Science and Technology*. 12(2):488-497.