JOURNAL OF METEOROLOGY & CLIMATE SCIENCE
J. Met & Clim. Sci. 11(1):1-9 (2013)

N.Met.S
Nigerian Meteorological Society

THE EFFECTS OF LEACHATE ON GROUNDWATER IN OTA INDUSTRIAL AREA SOUTHWEST, NIGERIA

BELLO A.K.[1], ADEMOLA A.K.[2], ADEJUMOBI C.A.[2], AND UNUODE A.U.[1]

[1]Department of Physical Sciences, Bells University of Technology, Ota, Nigeria
[2]Department of Physics, The Polytechnic Ibadan, Nigeria
Corresponding author: A.K. Bello
e-mail: akbellokazeem@yahoo.com
Telephone: +234(0)8036803114

Abstract: Compositions of landfill leachate and groundwater pollution were studied at industrial sites landfill, which are located at Ota, Nigeria. The leachate was sampled at 5 different locations at the landfill, and at 15 and 20 m downstream of the landfill. Groundwater samples were collected from 10 different sources to study the possible impact of leachate percolation into the groundwater. The leachate and groundwater samples were collected during wet season, due to the excessive generation of leachate during this season. The objective of this work was to analyzed the groundwater pollution due to the landfill leachate. The leachate and groundwater were physically and chemically characterized. The parameters measured were pH, acidity, alkalinity, electrical conductivity *(EC)*, total hardness (TH), chloride (Cl^-),sulphate calcium hardness, heavy metals (Pb, Zn, Cd and Cu), major cations (Na, Mg, ph, and Fe). The leachate at this landfill were most likely in methanogenic phase, based on the pH value recorded (pH=6.08). The result show that the samples are contaminated, where the concentration of physicochemical parameters are below the standard acceptable levels which are required for drinking water adapted by The Nigerian Standard for Drinking water quality (NSDWQ). Therefore, detailed study of the leachate and its effect on the groundwater in the study area was recommended.

Keywords: Groundwater, leachates, conductivity, heavy metals, pollution.

INTRODUCTION

Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences. Its Quality is based on the physical and chemical soluble parameters due to weathering from source rocks and anthropogenic activities. 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 groundwater resource if not adequately managed. Protection of groundwater is a major environmental issue since the importance of water quality on human health has attracted a great deal of interest lately. Assessing groundwater quality and developing strategies to protect aquifers from contamination are necessary for proper planning and designing water resources.

Water pollution (surface and ground) may be considered as a naturally induced change in water quality or conditions induced directly by man's numerous activities which render it unsuitable for food, human health, industry, agriculture or leisure per suit (Dix 1981).

Groundwater provision is sometimes unsustainable because of poor water productivity of wells, drying of wells after prolonged drought and sometimes due to poor water quality. These problems are usually caused by the lack of understanding of the hydrological regime (Kortatsi 1994; Xu and Usher 2006).

Pollution occurs when product added to natural environment adversely affects nature ability to dispose it. Pollution includes water pollution, soil pollution, air pollution, oil pollution, etc. Generally, most pollutant are introduced in the environment as sewage, waste, accidental discharge and as compounds used to protect plants and animals. (Misra and Mani, 1991).

Landfill is an engineered waste disposal site facility with specific pollution control technologies designed to minimize potential impacts. Landfills are usually either placed above ground or contained within quarries and pits Landfills are sources of

groundwater and soil pollution due to the production of leachate and its migration through refuse (Chistensen and Stegmann 1992).

Water has always been an important and life-sustaining drink to humans and is essential to the survival of all organisms (Greenhalgh and Alison 2001).Excluding fat, water composes approximately 70% of the human body by mass. Municipal solid waste (MSW) disposal is a global concern, most especially in developing countries across the world, as poverty, population growth and high urbanization rates combine with ineffectual and under-funded governments to prevent efficient management of wastes. Land filling is the simplest, cheapest and most cost effective method of disposing of waste in both developed and developing nations of the world. Municipal landfill leachate are highly concentrated complex effluents which contain dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, copper, lead, zinc; and xenobiotic organic substances. Landfills are considered one of the major threats to groundwater (USEPA, 1984; Fatta et al*.,* 1999). Groundwater is the major source of potable water supply in the study area and Lagos in general and its contamination is a major environmental and health concern.

Most landfills containing organic material will produce methane, some of which dissolves in the leachate. This could in theory be released in weakly ventilated areas in the treatment plant. The most important requirement is the prevention of discharge of dissolved methane from untreated leachate when it is discharged into public sewers and most sewage treatment authorities limit the permissible discharge concentration of dissolved methane to 0.14 mg/l, or 1/10 of the lower explosive limit. This entails methane stripping from the leachate. The greatest environmental risks occur in the discharges from older sites constructed before Modern engineering standards became mandatory and also from sites in the developing world where modern standards have not been applied. There are also substantial risks from illegal sites and ad-hoc sites used by criminal gangs to dispose of waste materials. Leachate streams running directly into the aquatic environment have both an acute and chronic impact on the environment which may be very severe and can severely diminish bio-diversity and greatly reduce populations of sensitive species. Where toxic metals and organics are present this can lead to chronic toxin accumulation in both local and far distant populations. Rivers impacted by leachate are often yellow in appearance and often support severe overgrowths of sewage fungus. These are clear correlations between access to safe water and Ground Domestic Product (GDP) per capital. In developing this standard, references were made to the Nigerian Industrial Standard for potable water. Water and Natural Minerals Water, the National Guidelines and Standard for Water Quality in Nigeria, the World Health Organization (WHO) guidelines for drinking water quantity (3rdEdition) and International Organization of Nigeria.

Hence, the aim of this study is the determination of health effects of leachate in ground water and in industrial dumpsites on people living in Ota, ogun state.

MATERIALS AND METHODS

The study area was Ota, located in South-Western part of Nigeria, located between latitude 6° 41' 24" N and Longitude 3° 14' 24" E. It has a tropical humid climate with two distinct seasons. Ota has a relatively dry season from November to March and a rainy season from April to October. Ota 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. The "elevation is 74.259m" above sea level. The per-capita generation of solid waste in Ota Ogun State ranged from 150 grams to 600 grams per day depending upon the economic status of the community involved and it mainly includes waste from household, industries and medical establishments. Ota has grown into an industrial city due to the economic development planning by the Manufacturers Association of Nigeria.

In an effort to study the extent of the groundwater contamination 10 sampling sites were selected within 200m of the landfill sites. The samples were collected from different kinds of well in the neighborhood of the dumpsites, the water samples were collected in plastic bottles. Since the landfill sites were not equipped with a leachate collector, the leachate collected at the base of the landfill was sampled randomly from different locations and were mixed prior to its analysis. For soil samples, five dumpsite were considered. The

dumpsites are located at the close proximity of the Industries. The waste dumped at this site includes domestic and industrial wastes

Analysis of water sample

All the samples were analyzed for selected relevant physicochemical parameters and heavy metals according to internationally accepted procedures and standard methods (APHA, 1994) Various physicochemical parameters examined in groundwater samples includes, pH, electrical conductivity (EC),total alkalinity (TA), total hardness (TH), calcium (Ca_2^+), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), chloride (Cl^-), sulphate (SO_4^{-2}), phosphorous (P), sulphur (S), dissolved free CO_2 and Acidity. EC and PH were recorded using a Systronics conductivity meter, mode 306 and i pH system 361(Systronics). TH, Ca2+, Mg2+ and Cl- were estimated by titrimetry, Na+ and by flame photometry (Systronic-128). While for the heavy metals, The concentrations of calcium (Ca), copper (Cu), iron (Fe), lead (Pb) and zinc (Zn), magnesium (mg), cardium(cd) were determined using a SpectrAA-20 (Varian) atomic absorption spectrometer. All the experiments were carried out in triplicate and the results were found reproducible within ± 3% error. The data were statistically analyzed by setting up and calculating a correlation matrix for the various parameters using Statistical Package for Social Sciences (SPSS) software package.

Physicochemical analysis

Two - three ml of each sample were measured into the tube, 5ml of perchloric acid and 5ml of nitric acid were added and mixed then placed on the digester, arrange and digested for 30mins-one hour until a clear solution is obtained, the solution was allowed to cool and dissolved with a little de-ionized water the solution was filter through a filter paper into 100ml volumetric flask, after filtering, 100ml of the solution was made in the volumetric flask. Thereafter, the metal was determine using (AAS) Atomic Absorption Spectrophotometer.

$$Concentrai\,on\ of\ samples = \frac{reading \times 100}{weight\ of\ sample} \quad (1)$$

pH Procedure: 10g of the sample was suspended in 100ml of distilled H_2O and then mix thoroughly with stirrer, pH was measured with pH meter, liquid samples are determine direct

Acidity Procedure: Half gram of Na_2Co_3 was added to 100ml of H_2O, then 10ml of the sample was measured into a conical flask with drops of phenolphthalein indicator and thoroughly mixed and then titrate against 0.5% Na_2Co_3 The titre was recorded when a clear pink colour was seen

$$Acidity = volume\ of\ 0.5\%\ Na_2CO\ used \quad (2)$$

Alkalinity Procedure: 100ml of the sample was added to water in a 250ml conical flask, then 2-3 drops of phenolphthalein indicator was added to form a coloured solution which was titrated against H_2SO_4 until the colour dissappears

$$Calculation\ of\ alkalinity = \frac{molarity\ of\ H_2SO_4 \times 1000}{50ml\ of\ weigh\ sample\ (used)} \quad (3)$$

Chloride procedures: 100ml of water was measured into 250ml conical flask then, drops of phenolphthalein indicator was added (red colour was produced) we add 0.1 ml nitric acid until the solution becomes colourless, then, 2-3 drops of $K_2Cr_2O_4$ was added and titrate with 0.01ml of silver nitrate until colour changes from yellow to reddish brown. The titre value recorded was (ppm =3.55)

$$Calculation\ of\ Chloride = titre\ value \times 3.55 \quad (4)$$

Total Hardness procedure: 100ml of H_2O sample was measured into 250ml conical flask, then 1m of buffer solution was added and mixed by shaking, a drop of solo chrome was also added to give wine red colour and then titrate with standard EDTA to give a pure blue end point with reddish colour remaining

$$Total\ Hardness = \frac{volume\ of\ EDTA\ used \times 1000g\ of\ CaCO_3}{volume\ of\ water\ sample} \quad (5)$$

Calcium hardness procedure: 100ml of water sample was measured, 2ml of NaoH, was added with 1-2 drops of solo chrome dark blue indicator and then titrate with 0.01m EDTA to give a pure blue end point and titre value was recorded

Table I: Concentration of the physicochemical analysis carried out on water samples

SAMPLES	PH (mg/l)	Conduct-ivity (mg/l)	Acidity (mg/l)	Alkali-nity (mg/l)	Chloride (mg/l)	Co2 (mg/l)	Total hardness (mg/l)	Calcium hardness (mg/l)	Sulphate (mg/l)
S1	6.41	026	0.3	2.2	12.04	11.44	28	24	0.10
S2	6.57	043	0.4	1.0	10.30	15.00	20	28	0.20
S3	2.81	187	11	0.0	0.00	97.52	60	192	0.40
S4	6.70	062	0.4	1.2	11.36	22.00	24	180	0.20
S5	6.91	081	1.0	2.6	11.01	11.44	20	32	0.80
S6	6.42	041	1.0	1.0	10.30	8.80	28	32	0.40
S7	6.13	054	0.9	1.2	16.33	10.56	28	28	0.05
S8	6.98	050	1.0	0.8	13.50	7.92	16	72	0.10
S9	5.94	049	1.0	1.0	11.72	6.16	36	76	0.25
S10	5.90	049	1.0	1.0	11.01	12.32	12	88	0.20

Table II: Concentration of the physicochemical analysis carried out on soil samples

SAMPLES	Conduct-ivity (mg/l)	pH (mg/l)	Acidity (mg/l)	Cu (mg/l)	Mg (mg/l)	P (mg/l)	Fe (mg/l)	Pb (mg/l)	Zn (mg/l)	Cd (mg/l)
S1	116	9.36	0.1	31.5	3.0	3.0	48.0	0	43.6	3.35
S2	149	10.2	0.1	47.0	7.5	2.5	68.0	0	30.4	2.85
S3	226	11.5	3.5	63.0	9.5	4.0	0.0	0.6	69.1	0.60
S4	79	9.15	0.1	28.0	5.0	3.0	67.0	0	25.2	2.40
S5	392	9.71	2.0	41.5	2.5	2.5	69.5	0	43.2	2.65

$$Calcium\ Hardness = \frac{volume\ of\ 0.01m\ EDTA \times 1000}{volume\ of\ sample} \quad (6)$$

Sulphate procedures: 10ml water was measured into 100ml conical flask, 1ml gelatin was added and then make it up to 100ml with distilled water .then, the single beam spectrophotometer was made to be warm and reading was recorded

Calcium and Magnesium. These two metals are present in water of almost any origin in rather large concentrations. The best modern method for their determination is the atomic absorption method, which is brought about with the use of a special spectrophotometer utilizing so called lamps with a hollow cathode. The cathode in the lamp contains the element that should be determined in the analyzed material, Thus, electromagnetic radiation is generated in the lamp, the energy of which is compared with the excitation energy of the atoms or ions of the element to be determined. This radiation is directed on an aerosol of the element under investigation. The radiation utilized has wave length $\lambda = 239.86$ nm for calcium and $\lambda = 202.58$ nm for magnesium.

Free CO_2: This was carried out through titration method

$$Free\ CO_2 = \frac{titre\ value \times 440}{volume\ of\ water\ used} \quad (7)$$

Atomic Absorption Spectrophotometer: This was used to carry out analysis on the following metals copper(cu), iron(fe), lead(pb), cardium(cd), zinc(zn) by using each hallow cathode lamp to take every reading after the solution gotten from the wet digestion have been made up with de ionized H_2O.

Single Beam Spectrometer: This was used to carry out analysis on sulphur and phosphorous, pipettes 10ml of sample in a 100ml conical flask then add 10ml distilled H_2O. Add 1ml of gelatin and then make it up to 100ml with distilled H_2O after that put on the spectrophotometer on for 30 minutes and then took my reading.

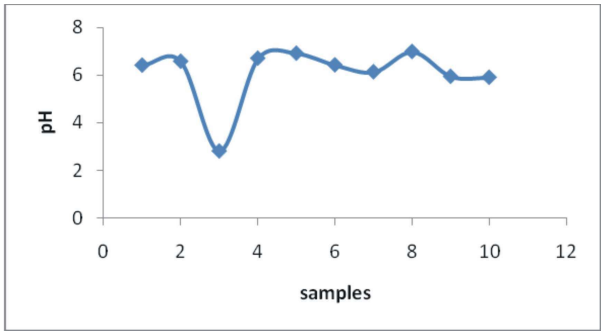

Figure 1: Graph of pH in samples

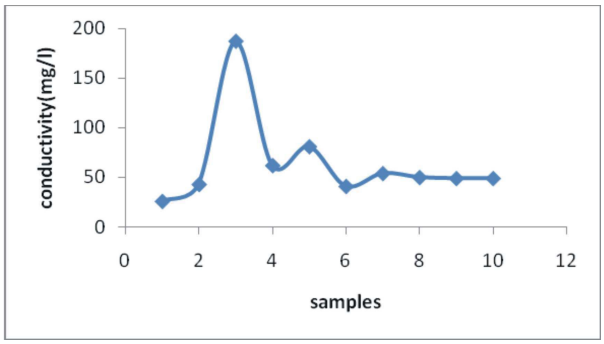

Figure 2: Graph of conductivity in samples

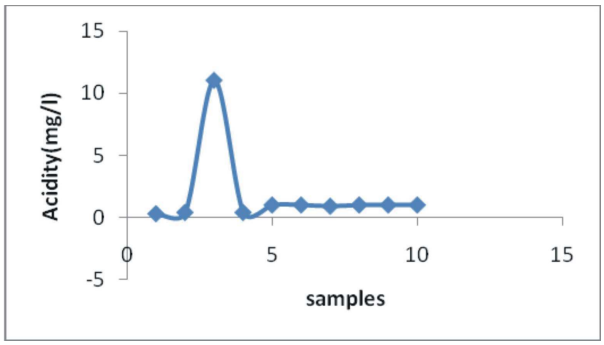

Figure 3: Graph of acidity in samples

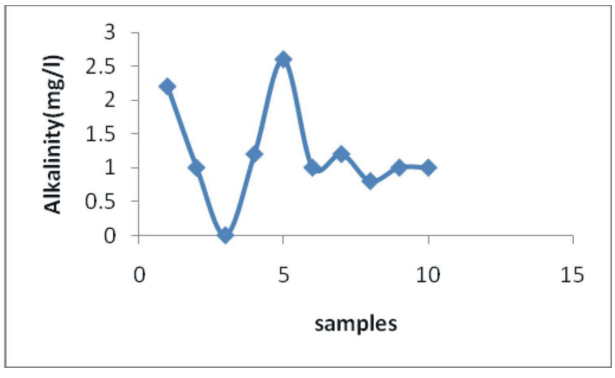

Figure 4: Graph of alkalinity in samples

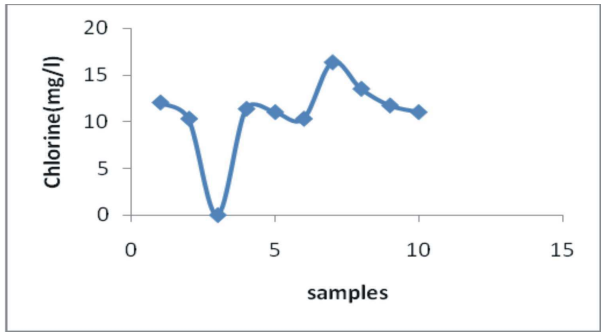

Figure 5: Graph of chlorine in samples

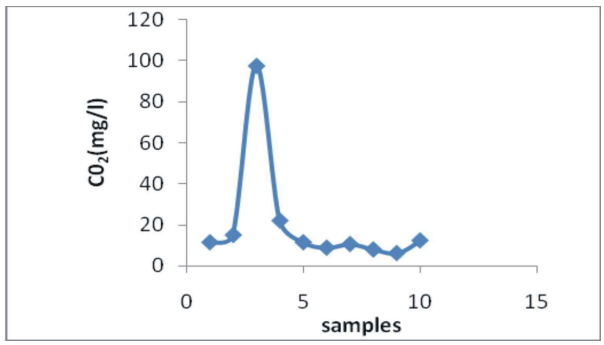

Figure 6: Graph of dissolved free co_2 in samples

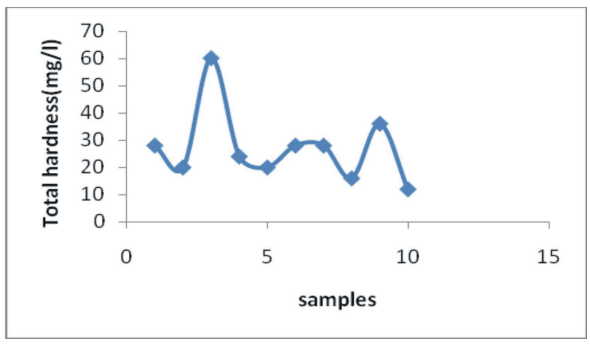

Figure 7: Graph of total hardness in samples

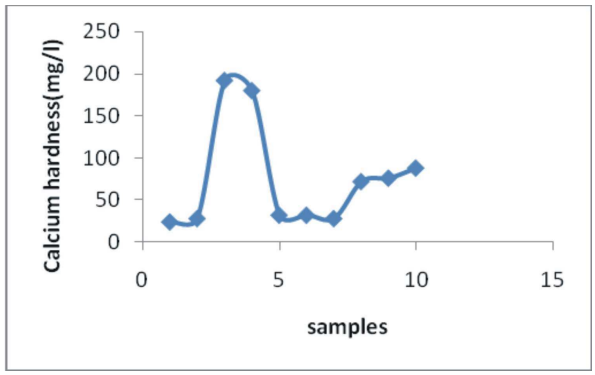

Figure 8: Graph of calcium hardness in samples

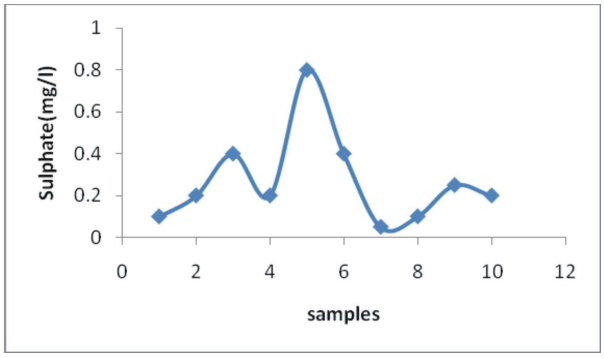

Figure 9: Graph of sulphate in samples

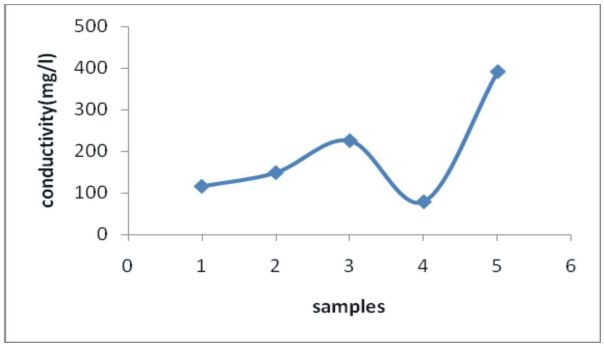

Figure 10: Graph of conductivity in dump site samples

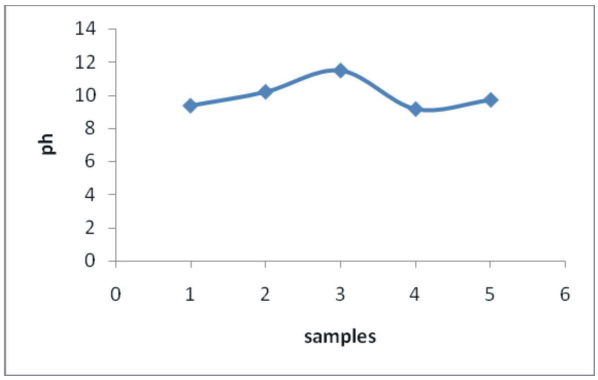

Figure 11: Graph of pH in dump site samples

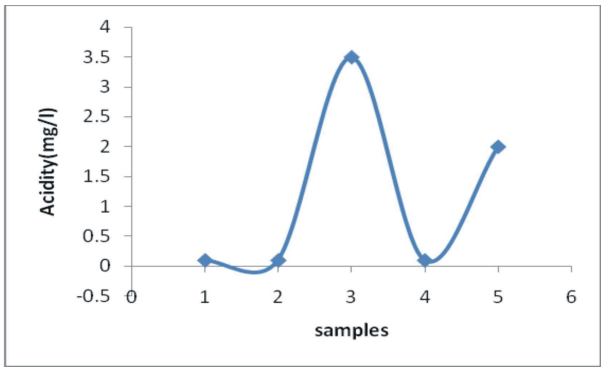

Figure12: Graph of acidity in dump site samples

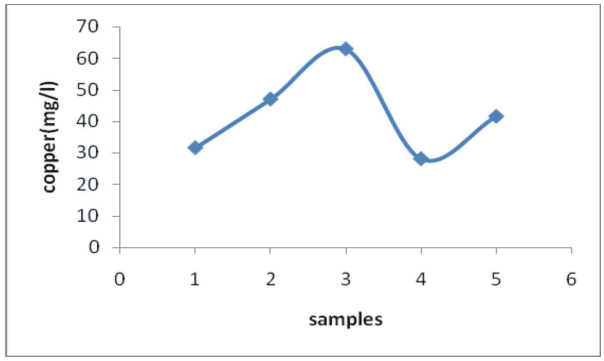

Figure 13: Graph of (cu) in dump site samples

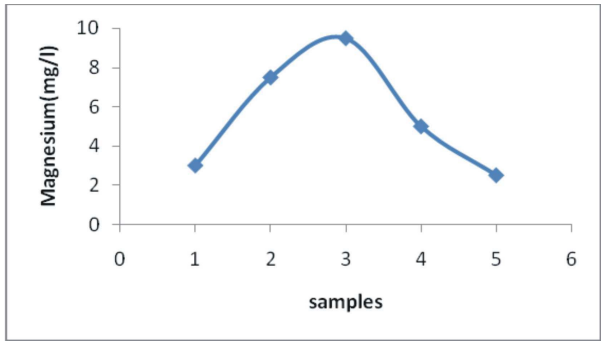

Figure 14: Graph of (mg) in dump site samples

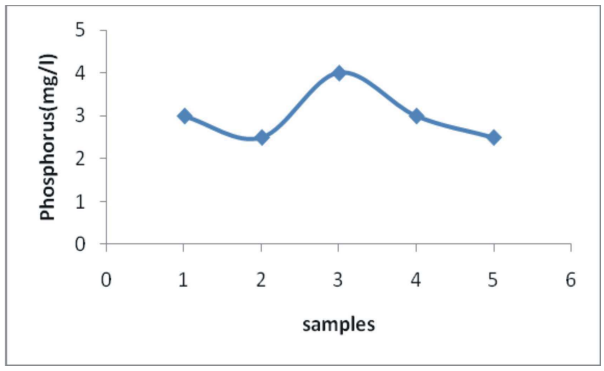

Figure 15: Graph of (ph) in dump site samples

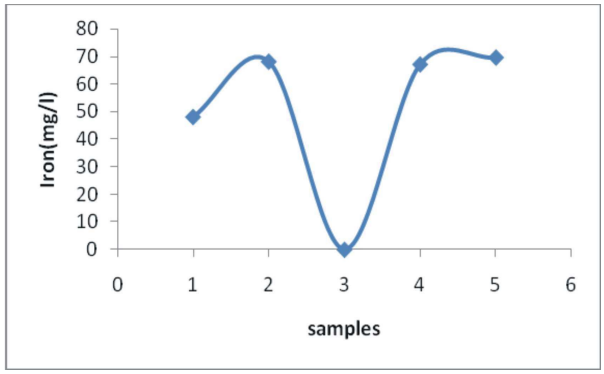

Figure 16: Graph of (fe) in dump site samples

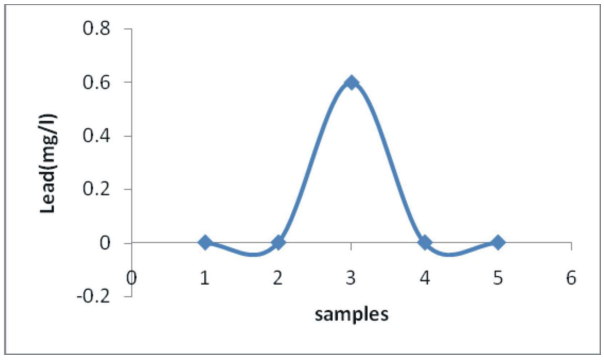

Figure 17: Graph of (pb) in dump site samples

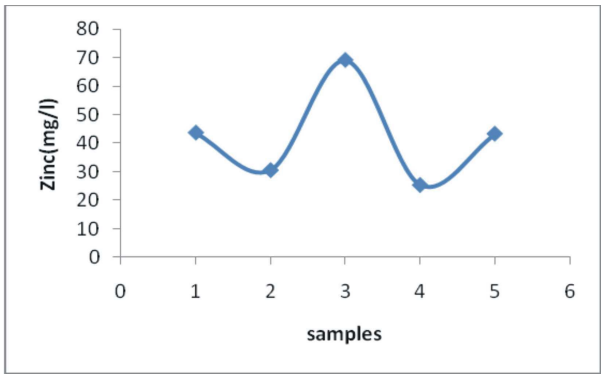

Figure 18: Graph of (Zn) in dump site samples

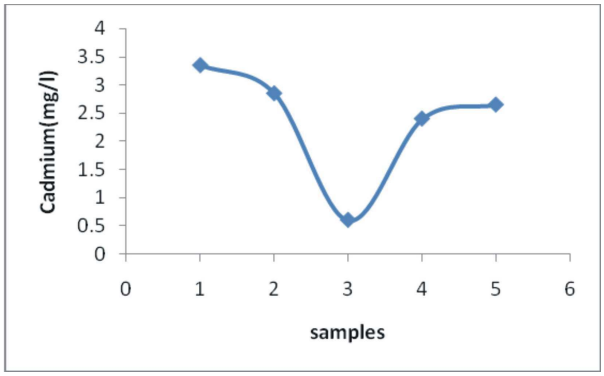

Figure 19: Graph of (cd) in dump site samples

RESULTS AND DISCUSSIONS

The concentration of Physicochemical characteristics and heavy metal characteristics of the leachate samples collected from the industries and dump site has been presented in Table I and II. The results and comparison of the sample parameters with the World Health Organization (WHO), The Nigerian Standard for Drinking water quality (NSDWQ) and Federal Environmental Protection Agency (FEPA) shows that there was a reason for the research. Most of these parameters indicated traceable pollution but were within the World Health Organization (WHO) and the Nigerian Standard for Drinking water quality (NSDWQ) limits for consumption of the regulatory standards of 7.00 respectively. The pH ranged from 2.81 to 6.91for ground water and for dump site 9.15 to 11.5 indicating toxic pollution, The significance of this pH imbalance is that it can inhibit or completely wipe out all biological processes that may be necessary for the natural treatment of the abandoned site thereby resulting in incomplete natural treatment and consequent pollution of the surrounding environment. Also, the pH values could be inferred that complex varieties of inorganic soluble substances are major components of the dumpsite and since they are still active, these components are easily leached resulting in the acidic and alkaline conditions of the leachates.

The leachates conductivity values are 26-187 mg/l for ground water and 79-320mg/l for dump sites. These values were higher than the control values and exceeded FEPA and WHO guidelines. These observations revealed that the leachates contain high proportion of pollutants. The significance is that considerable amount of dissolved inorganic materials are present in the dumpsite; such materials can provide adsorptive sites for certain chemicals and biological agents. This process may eventually foster pollution of surrounding soils and underground water within the area of the dumpsite. The alkalinity of the leachates is considerably higher than the control value and also exceeded FEPA and WHO standards. The high alkalinity value is attributed to the agedness of the dumpsite and is correlated with its pH value. Chloride ranged from 0-16.33mg L-1 which is below the maximum permissible level of 250 mg L^{-1} though below the WHO and NSDWQ levels, its presence connotes pollution hence require treatment before use. The high value of chlorides connotes the presence of weathered silicate rich rocks beneath the overburden and leaching from soil due to infiltration from the landfill and other anthropogenic activities. The levels of chloride determined for the leachate is significantly lower than the control value and far below FEPA and WHO standards. Though chloride does not react chemically with species in water and harmless at relatively low concentration, the lower level observed for the dumpsite leachates is an indication of excess salinity and mineral pollution

being active in the dumpsite and ground water. Increase in Cl- level is injurious to people suffering from diseases of heart or kidney (WHO, 1997). The 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. The values of some heavy metal in dumpsite leachate are shown in Table 2. The range of concentration (mg/L) were : 0 - 69.5 (Fe), 2.5 - 9.5 (Mg), 28 - 63 (Cu), 25.2 - 69.1 (Zn), 0.60 - 3.35 (Cd), 0 - 0.6 (Pb) and 2.4 – 4.0 (P) exceeding the control values. However, the concentrations of (Cd) and (P) were slightly above the permissible limit of 1.0 mg/L for waste disposal at surface water and the level of Mg in the leachate is 28-63 mg/L which is much higher than the allowable limit of 5.0 mg/L set by FEPA and WHO. This observation suggests high possibility of heavy metal accumulation in the dumpsite. In this regard the dumpsite represents a significant source of heavy metal in the dump site. Also it could be inferred that the higher levels of Fe, Mn and Zn recorded for the dumpsite leachates may be responsible for the unacceptable colour of the leachates

Presence of Fe, Pband Cd in detectable quantities was an indication of toxicity level in the groundwater and therefore poses serious environmental risk to humans, animals and even the soil. 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.

CONCLUSION

The data recorded in this study support the assertion that most shut down dumpsites in heavily industrial society may have been contaminated significantly due to ongoing industrial activities. 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 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 purposes. As a result of the high levels of chemical and bacteriological contamination of ground water, health problems as typhoid fever, worm infestation are imminent when such water is consumed in its present state. Water hardness was higher due to the leaching of both Ca and Mg into the groundwater table. Dumping of industrial wastes and accumulation of heavy metals are considered the greatest hazard on landfill site from the study.

ACKNOWLEDGEMENT

The Authors acknowledge the contributions of Mrs. Ayano, Miss Seun and Mr. Adekoyeni of Central Research Laboratory Bells University Ota for providing the facilities used and also the contributions of all the Supervisors of various Industries in Ota for allowing us to gain access to the samples used, we thank you all.

REFERENCE

Christensen, T.H. & Stegmann, R. 1992. Landfill Leachate: An Introduction. In *Land Filling of Waste Leachate*, Christensen

Clasen, et, al 2007. “Interventions to improve water quality for preventing diarrhea: a systematic review and mata-analysis”. British Medical Journal 334 (7597): 782.

Dix, H.M. *Environmental pollution*, John Wiley and sons. Toronto, Pp.54-56. Drever, J. (1982) *The Geochemistry of Natural Waters*, Prentice Hall, Englewood Cliffs NJ.

Fatta D., A Papadopoulos and M., Loizidou, 1999.A study on the landfill leachate and its impact on the groundwater quality of the greater area. Environ. Geochem. Health 21 (2): 175-190.

Greenhalgh, Alison (2001). “Healthy living-Water” BBC *Health*. Retrieved 2007 page 02-19

Kortatsi B. K. (1994) Future Groundwater Resources at Risk. *In Proceedings of the Helsinki Conference*, IAHS Publ, June 1994, no. 222.

Misra, S.G. & Mani, D. 1991. soil pollution. New Delhi: pp 6-42. Efficient Offset Printers

NSDWQ. Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria, 2007,pp3

Xu, Y.; Usher, B. H. 2006 *Ground water pollution in Africa*. Taylor and Francis/Balkema, Leiden, the Netherlands, p 355.

United States Environmental Protection Agency (USEPA), 1984. Office of Drinking Water, A Ground Water Protection Strategy for the Environmental Protection Agency, pp.11.

World Health Organization – Guideline for Drinking Water Quality, 3rd Edition, 2004