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# Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Nigeria

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*Abstract*— **Physical, chemical and bacteriological analyses of water samples from three boreholes located near a landfill at Akure, Nigeria was carried out to ascertain the magnitude of dumpsite pollution on groundwater quality. Borehole locations were at radial distances of 50m, 80m, and 100m respectively away from the landfill. The parameters determined included; turbidity, temperature, 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 using convectional equipment and standard laboratory procedures. Most of these parameters indicated traceable pollution but were below the World Health Organization (WHO) and the Nigerian Standard for Drinking water quality (NSDWQ) limits for consumption. The pH ranged from 5.7 to 6.8 indicating toxic pollution, turbidity values were between 1.6 and 6.6 NTU and temperature ranged from 26.5 to 27.50C. 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. For heavy metals, zinc ranged between 0.3 and 2.3 mg L-1 and lead ranged from 1.1 to 1.2 mg L-1. The landfill was not directly responsible for the presence of Chromium in one of the wells but could be traced to an abattoir near the well. Bacteriological examinations revealed severe pollution in all the wells. Statistical analyses indicated significant differences among all the parameters tested for in the samples at 95% level. The results showed that all but one of the boreholes was strongly polluted but require urgently certain levels of treatment before use. Public enlightenment on waste sorting, adoption of clean technology, using climate change mitigation strategies and the use of sanitary landfill to prevent further contamination of ground water flow are recommended.**

***Index Terms*— Groundwater; Landfill; Wastes; Quality; Pollution; Akure.**

## I. 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 [1]. 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 [2].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. 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]. 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 macro pores as suspended solids and sludge organic matter on the sorption degradation are often not understood by many [4]. 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, bad odour are some of the aesthetic problems associated with sanitary 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. 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 [5]. Increasing waste generation and disposal resulted in increase groundwater pollution. To what extent this pollution has affected the water wells in the area is unknown and hence needed to be determined. The objective of the study therefore was to assess the effect of landfill pollution on groundwater quality in Akure, Nigeria.

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## II. MATERIALS AND METHODS

### A. Study Area

The study area (figure 1) 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 [6]. 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 [5].

### B. *Water Analyses*

Three existing 6" diameter boreholes with average depth of 40 metres 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 litres 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: odour, taste, colour, 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 using titration methods in the water laboratories using standard methods for the examination of water (APHA) [7]. 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 (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) values.

## III. Results and Discussions

The results and comparison of the sample parameters with the World Health Organization (WHO)[8] and the Nigerian Standard for Drinking water quality (NSDWQ) [9] were presented in Tables 1, 2, and 4. The temperature, turbidity, colour and odour of the samples were shown in table 1. The presence of colour was an indication of pollution and confirmed leachate infiltration into the wells [4] and [10]. The [8] guideline values of 5 hazen unit is the desirable limit but for its presence violates the definition of potability of water. Potable water must be colourless, odourless, tasteless, and free from objectionable and pathogenic organisms and fit for consumption. 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. The high temperature signified presence of active micro organisms which resulted in the temperature increase. 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 colour 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 (table 1). Presence of suspended particles and other materials are usually responsible for high turbidity values. Similar high turbidity values were also reported as in [11] 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 [6] and the reasons adduced for the observation was as mentioned above. The [8] 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 5.72 which is acidic and indicated presence of metals in the samples particularly toxic metals. This falls outside the WHO permissible range of 6.5-8.5 and confirmed the acidic nature of the water from the wells. 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 [8]. 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 did not agree with values obtained by [1], [2], [6], [12], [13] - [14]. The pH values in [15]-[16] were slightly higher though acidic in nature but agreed with this findings. The results presented by [16] may be due to the fact that the analysis took place in the same country but variation was due to different geographical location which would normally affect all the parameters considered during analysis. Kano is located in north central part of Nigeria, close to Sahel savanna while Akure is located in the south western part of the country and within the tropical rain forest and nearer to the Atlantic Ocean, hence the disparity.

TABLE 1: PHYSICAL CHARACTERISTICS OF THE BOREHOLE WATER SAMPLES ANALYZED

| Sample | Colour | Odour | 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 |

## A. *Water Chemical Characteristics*

TABLE 2: CHEMICAL CONSTITUENTS IN THE BOREHOLES AND THEIR COMPARISONS WITH THE W.H.O STANDARDS

| Sample | Dist (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 |

The pH is dimensionless; EC is and except otherwise stated, all units are in mg/L NS- not specified

TABLE 3: HEAVY METAL CONTENTS IN THE BOREHOLES AND THEIR COMPARISONS WITH THE W.H.O STANDARD

| Sample | Dist (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 | 2.3 | ND | ND | ND |
| $W_2$ | 80 | 1.4 | 1.11 | 0.3 | ND | ND | ND |
| $W_3$ | 100 | 0.9 | ND | ND | ND | ND | 0.25 |

Except otherwise stated, all units are in mg/L

ND – not detected

TABLE 4: BACTERIOLOGICAL CONSTITUENTS IN THE BOREHOLES AND COMPARISON WITH W.H.O STANDARD

| Sample | Bact. Constituent | Water Sample Result | Variance from WHO |
|---|---|---|---|
| $W_1$ | T. coliform bacteria | >1.7 | +0.7 |
| | Escherichia coli | >1.6 | +0.6 |
| $W_2$ | T. coliform bacteria | >1.5 | +0.5 |
| | Escherichia coli | >1.5 | +0.5 |
| $W_3$ | T. coliform bacteria | >1.2 | +0.2 |
| | Escherichia coli | >1 | 0 |

All units are in 1/100 mg/l

All the ions were below the WHO and NSDWQ 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 $L^{-1}$ 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. This agreed with the findings of [14]-[15]. 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. Nitrates and nitrites had their values ranging from 30 to 61 $mgL^{-1}$ and from 0.7 to 0.9 $mgL^{-1}$ respectively (Table 2) showing appreciable presence of pollutants in all the water samples. Nitrites are relatively short-lived because they are quickly converted into nitrates by bacteria which exist in the air. Nitrites react directly with hemoglobin in human blood to produce methemoglobin, which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 $mgL^{-1}$should not be consumed by humans let alone given to babies. Nitrite concentrations in drinking water seldom exceed 0.1$mgL^{-1}$. With the values higher than the 'safe value', it therefore constitutes a menace if consumed without treatment. Nitrate is a major ingredient in farm fertilizer and necessary for crop production. After rainfall, varying quantities of nitrate are washed from farmland into nearby waterways and also to groundwater table through infiltration, percolation and seepage. Nitrates also get into waterways from, leaking septic tanks, leachate from landfills and manure from farm livestock, animal wastes and discharges from car exhausts. It has been established that 10 $mgL^{-1}$ of nitrate-nitrogen as the maximum contamination level allowed in drinking water and maximum tolerable limit of 50 $mgL^{-1}$. $W_1$ samples had nitrate concentration level higher than these limits, hence unfit for consumption. Perhaps this may be due to the nearness of the well to the landfill and road in which discharges from car exhausts also contributed to the high concentration values. This agreed with the findings of [15] in their study. 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. All these agreed with observations made by [14] in his study despite being below the WHO and NSDWQ values for potable 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 [6] 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] and [14]. 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. The implication is that forming lathe with soap will be a major challenge for domestic users [6]. 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. Closely related to calcium is total hardness (TH) which ranged from 136 to 140 mg $L^{-1}$ respectively (Table 2) but is below the maximum permissible limit of 200 mg $L^{-1}$. Hardness refers to reaction with soap and scale formation which increases boiling point of water but does not have any adverse effects on human health. The hardness of water samples may be due to leaching of Ca and Mg ions into the groundwater [15]. Boiling of water at boiling temperature will naturally remove temporary hardness while addition of carbonates and sulphates will eliminate permanent hardness.

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 off of battery cells, used aerosol cans and other materials with certain degree of toxicity. 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 [10], [16]. 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. The maximum permissible of iron content in drinking water is 1.0 $mgL^{-1}$ above which the water is unsafe for consumption. Lead must not be more than 0.1 $mgL^{-1}$ as the water becomes poisonous if present in higher concentration. These values were higher than the desired concentrations for domestic water consumption hence unfit for use as potable water. This agreed with the findings of [17]-[20] which is a clear indication of the danger pose to consumers if the water is used. The WHO (2004) 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 goiter in adults was the result of consumption of water with quantity of iron above the specified values [10] [12]. Zinc ranged from 0.3 to 2.3 mg $L^{-1}$ though, not up to the maximum permissible level, it still indicated pollution. The zinc contamination may be as a result of wastes containing zinc metals which were dumped on the landfill, decomposed and found its way into the water table. A similar result was reported by [14], [17]. This agreed with the findings of [1], [2], [11] and [12]. 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 water samples 100 metres from the landfill may suggest pollution from a nearby abattoir and not from the landfill site. Similar view as this was shared by [14]. Higher concentrations of $Cr^{3+}$ was found and reported by [16] which agreed with these findings that the metal could be found in contaminated water given similar circumstances.

### *B. 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 faecal pollution of human wastes from the landfill. The high values of *E. Coli* and total coliform bacteria count did not comply with the water quality standards of the WHO [20], FAO and NSDWQ. 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 [6]. These results showed that the three samples do not satisfy the WHO requirements for bacteriological characteristics human consumption. The WHO and NSDWQ standards were 0 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. Disinfection of wells [19] and other forms of treatment such as chlorination, sedimentation and filtration would be required to make the water potable and fit for domestic use [18].

### *C. Test of significance of the observed correlation coefficients*

The significance of the observed correlation coefficients have been tested by using't' test is as shown in table 5. Out of the total 28 correlations found between two parameters, 15 were found to have significant at 5% level ($r > 0.8$). 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 NO3 (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.

TABLE 5: 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 |

## IV. Conclusions

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 water from the boreholes, health problems as typhoid fever, worm infestation are imminent when such water is consumed in its present state. Presence of *E-Coli* and total coliform bacteria indicated microbial pollution of the groundwater by anthropogenic activities. 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. Presence of Fe, Pb and Cr 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. Although, the presence of Cr in the groundwater sample 100 metres away from the polluting source was independent of leachate from the landfill, it nonetheless indicated the existence of another pollution source contaminating the groundwater from another part of the region. When these chemical elements are absorbed by soils, they could be passed into the food chain through grazing animals. When such animals are consumed, the effect of passing these chemicals into the humans could better be imagined than experienced. 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 leachate from getting to water table, adoption of clean technology for recycling greenhouse gases emanating from the landfill and a sustainable land management programmed for reclamation are recommended.

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[20] World Health Organization. 2006. WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater: Volume II wastewater use in Agriculture. Geneva, Switzerland: WHO.

Figure 1: Picture of some portions of the dumpsite along Igbatoro road Akure, Nigeria