Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.22, 2015 www.iiste.org

# Trace Metals and Hydraulic Characterization of Soils and Groundwater Around Ajakanga Dumpsite in Ibadan Metropolis, Southwest Nigeria.

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**Abstract**

Trace metals concentrations and hydraulic characteristics of soil were studied with a view to assessing the impact of the Ajakanga dumpsite in Ibadan, Southwest Nigeria, on soil and groundwater. Forty one surface soil samples were taken at the depth of 0.2 cm, eleven samples each of disturbed and undisturbed soils along two (2) vertical profiles at up-slope and down-slope pits within the dumpsite premises. Eight groundwater samples were also collected. Digestion of 0.5 gm each of fraction (< 63 µm) of the soil samples was carried out. Both the digested soil and groundwater samples were analysed for Zn, Cu, Mn, Pb, Cd, Ni, As, Co and Cr using Buck Model 205 Atomic Absorption Spectrophotometer (AAS). The undisturbed soils were used for the determination of hydraulic properties. The data collected were interpreted using appropriate qualitative and quantitative statistical techniques. Trace elements results for soil showed average values for Zn (29.30 ± 16.1 mg/L), Pb (14.72 ± 0.84 mg/L), Cd (2.49 ± 0.48 mg/L), Ni (2.03 ± 1.12 mg/L), As (0.84 ± 0.22 mg/L), Co (0.16 ± 0.10 mg/L) and Cr (0.92 ± 1.40 mg/L) that were higher than those of control site values suggesting contamination. Grain size analysis showed that the clay size particles average abundance was higher in the B-level of the down-slope soil profile with mean value of 5.07±0.82 % compared with mean value of 4.85 ± 0.59 % at the up-slope pit. Evaluated results showed that the B-level is more polluted than the A and C levels probably due to adsorbion effect of clay-sized materials that are more abundant in the B-level. Groundwater trace elements average concentration values were Mn (0.31± 0.74), Pb (0.03 ± 0.04), Cd (0.02 ± 0.03 mg/L), As (0.06 ±0.03 mg/L) and Ni (0.13 ± 0.08mg/L) which were higher than the WHO (2007) permissible levels especially in samples taken close to the dumpsite. The study concluded that the soils and groundwater samples close to Ajakanga open dumpsites were more polluted than those taken far away. The soil contamination was well pronounced within 0 – 3.5 m of the vertical soil profile at the dumpsite vicinity.

**Keywords:** Trace Metals, Soil, Groundwater, Hydraulic Characteristics, Dumpsite, Environmental Impact.

## 1. Introduction

The dumpsite at Ajakanga is a major open waste disposal site in Ibadan metropolis (Figure 1) receiving domestic, commercial and industrial wastes. Continuous burning of waste at the dumpsite is an environmental hazard to the communities in the area (Plate 1). Also, leachate emanating from the dumpsite and run-off due to rainfall from the waste disposal site infiltrate the soil and water resources available for domestic, agricultural and industrial usage. Understanding the concentration levels of the toxic trace metals in soil at the vicinity of the dumpsite will give insight to the pollution buildup in the area because of possibility of potential transfer of the contaminants into food chain due to plant uptake from soil and water.

The downward movement of toxic metals into the groundwater will be better explained by the soil texture and hydraulic properties along the soil profiles because the dumpsite is not equipped with impermeable liner that can inhibit flow of leachate into the soil underlying the dumpsite. This study will provide information on effectiveness of natural subsurface processes of biodegradation, filtration, sorption and ion exchange to naturally attenuate/reduce the contaminants in the leachate and run-off recharge water before it gets to the groundwater (Gray *et al*., 1974). The geochemical results of the groundwater was compared with the WHO (2004) and SON (2007) standards for quality appraisal.

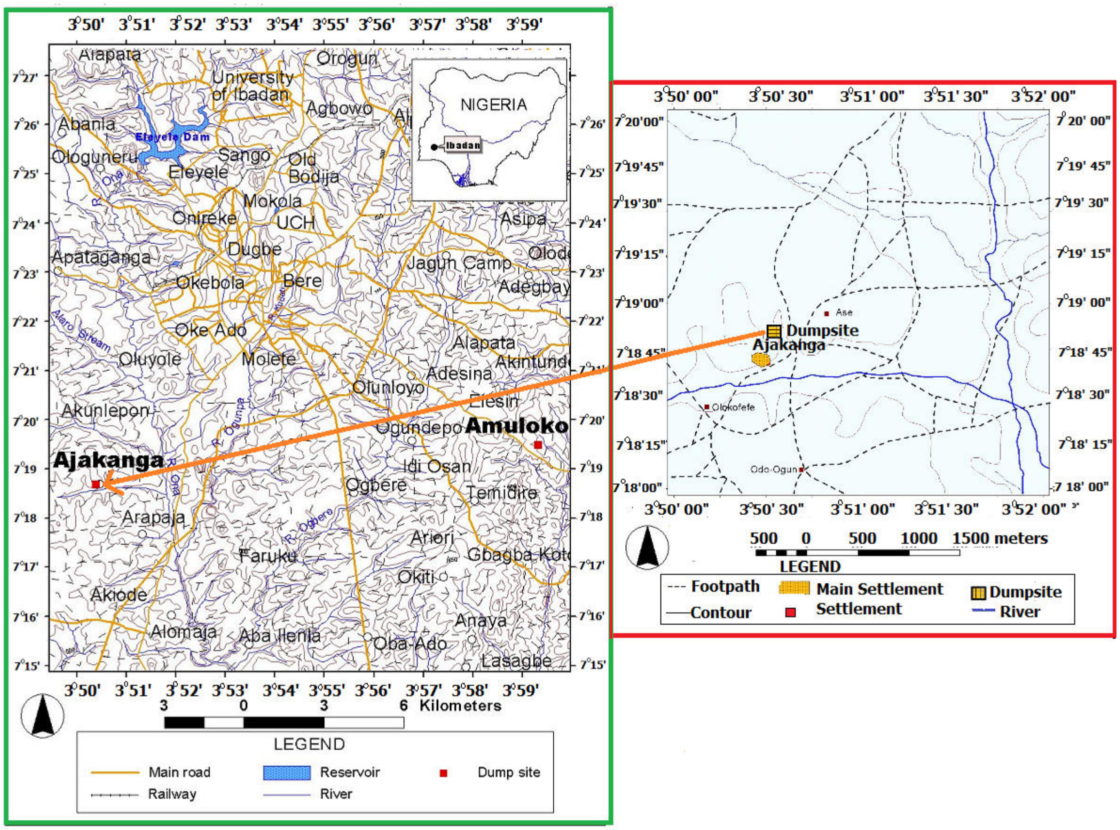


Figure 1: Topographical Map of Part of Ibadan Showing Ajakanga Area (Extracted from Nigerian Geological Survey Agency, Ibadan Sheet No.59, 1980)

Several authors such as Schumacher et al., 1997, Amuno (2008) and Odukoya *et al.*, 2011 assessed impact of dumpsite on soil. Gray, *et al.*, 1974; Assmuth and Strandberg, 1983; Baba *et al.*, 2004 and Singaraja *et al.*, 2015 examined impact of dumpsite on groundwater while Parth *et al.*, 2011, studied the impact of dumpsite on both soil and groundwater. This study therefore evaluates the impact of Ajakanga dumpsite on soil and groundwater in the immediate vicinity.

Plate 1: Ajakanga Dumpsite Showing Soild Wastes and Continous Burning of Wastes.

## 2. Description of Project Environment

### *2.1 Geographic Location*

The Ajakanga dumpsite is located between Latitudes $7^0$ 18.70'N and $7^0$ 18.90'N and Longitudes $3^0$ 50'E and $3^0$ 51' E along Odo Ona Elewe road near Arapaja at the Southwestern part of Ibadan Metropolis (Figure 1). It is accessible by network of good roads and foot paths. Due to rapid urbanization, the dumpsite is gradually being surrounded by built up areas.

### *2.2 Geomorphology Climate and Drainage*

The topography of the Ajakanga is gently undulating with isolated inselbergs of migmatite gneiss. The dumpsite is within the tropical climatic zone with average temperature of 27ºC during the rainy season (April to October) and a dry season, which usually begins in November and end in March with average temperature of 32ºC. The annual average rainfall in the area is 1300 mm (Ileoje, 1987). The vegetation is tropical rain forest with thick undergrowth. The Ajakanga area is drained by River Ona and its tributaries. The drainage pattern is dendritic.

### *2.3 The Local Geology*

Ajakanga waste dumpsite and its environs are underlain by biotite-hornblende gneiss, migmatite gniess and quartzite (Figure 2). The outcrops of the rocks are mainly low lying while isolated ridges and inselbergs of gneisses were encountered especially along the Arapaja – Odo Ona road. These outcrops are highly foliated. The strike of foliation is N-S while the dip is westward.

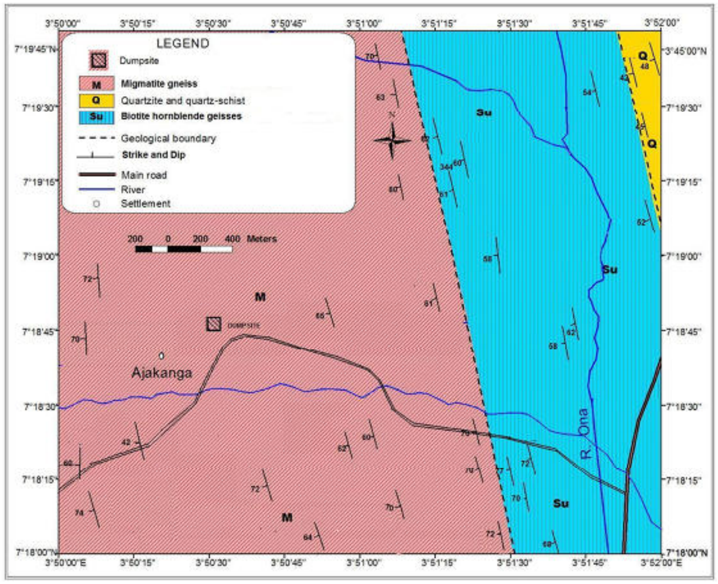


Figure 2: Geological Map of the Area around Ajakanga Dumpsite

## 3. Materials and Methods

Forty one (41) soil samples were collected within the study area (Figure 3). The soil samples were collected from depth 0 – 20 cm using a stainless steel hand auger. Control samples were taken in areas far away (beyond 1000 m) from the dumpsite and preferably located up-slope of the dumpsite. The first sampling area is within the radius of 0 - 500 m from the center of the dump. The second samples were collected within the radius of 500 m - 1000 m while the third samples were beyond 1000 m from the center of the dump. This approach was necessary in order to understand the spatial influence of the dumpsite on the surroundings. Soil samples collected were stored in sample bags and later air dried in the laboratory. The air-dried samples were disaggregated in a porcelain mortal and later sieved using polyethylene set of sieve to obtain minus 63 µm clay fraction which was used for Digestion using Aqua Regia (3:1, v/v, HCl to $HNO_3$) digestion procedure of Chen and Ma (2001).

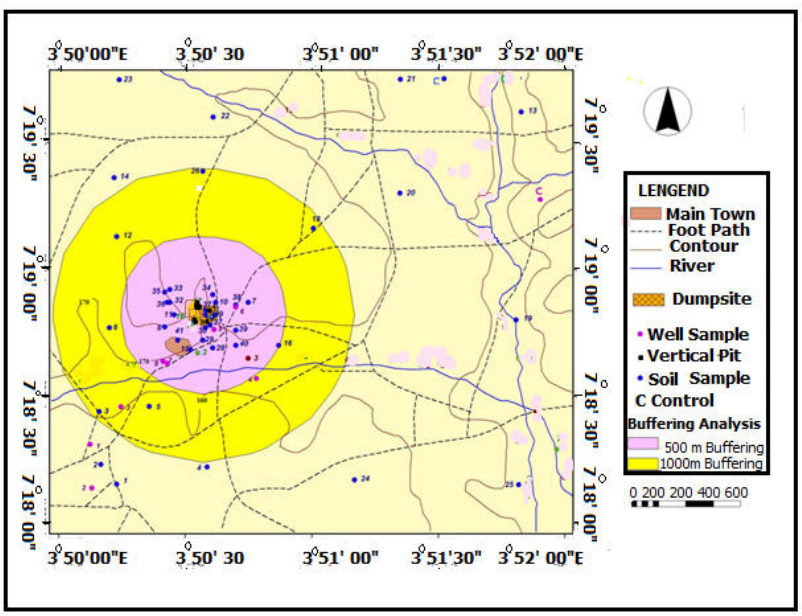


Figure 3: Location Map of Ajakanga Dumpsite Area Showing Sample Locations

The rock samples collected around the dumpsite were crushed and pulverized into powder and digested using the Multi-acid digestion procedure (United States Geological Survey Report, 2002). The Atomic Absorption Spectrophotometer (AAS) Buck Model 205, at the International Institute of Tropical Agriculture (IITA) Ibadan, was used for determination of the following trace elements in the digested samples of soil and rock:

Cd, Cu, Co, Mn, As, Ni, Pb, Cr and Zn. Another set of disturbed soil samples was collected at 0.5 m interval from two pits sunk within the dumpsite located at the up-slope and down-slope section respectively (Fig. 3). The pits were dug to a depth of 5 m. These sets of soil samples were used for grain size and trace metal analyses. The third set of samples were the undisturbed soil samples collected using cylindrical steel corer of 100 $mm^3$ for the determination of hydraulic properties such as Water Holding Capacity (WHC), Hydraulic Conductivity (K), Bulk Density (ρ) and Porosity ($\varphi$) using standard method.

Eight (8) shallow groundwater samples were collected within and around the vicinity of the dumpsite. Physico-Chemical parameters such as Total Dissolved Solids (TDS), Temperature, Electrical conductivity (EC) and pH were measured and recorded in the field using appropriate digital meters. The acidified water samples were analysed for the following elements: Cd, Cu, Co, Mn, As, Ni, Pb, Cr, Zn, Al, Na, K, Mg, Ca, Fe and Si, using the Atomic Absorption Spectrophotometer (AAS) model Accufys 211 at the Institute of Agricultural research and Training (IAR&T) laboratory Ibadan. Unacidified water samples were analysed using Titration method to determine and quantify $HCO_3^-$, $Cl^-$, $SO_4^{2-}$ and $NO_3^-$ at the Department of Agronomy, University of Ibadan, Nigeria. The Bacteriological analysis of water samples was carried out at the Department of Microbiology, Obafemi Awolowo University, Ile Ife, Nigeria, within twenty four hours of collection using WHO (2004) procedure.

Graphical presentations of data were carried out using Microsoft Origin version 6.1 and Rockworks model 2004. Contamination assessment of soil was carried out using Hakanson 1980 approach. Pollution map showing point distribution of degree of contamination around the dumpsite was prepared using Oasis montaj version 6.4.2. The 2D display of contamination degree along vertical soil profile was prepared using surfer 8.0.

## 4. Results and Discussion

### *4.1 Trace Element Geochemistry of Ajakanga Dumpsite*

The soil of Ajakanga dumpsite has Zinc concentrations ranging from 15.61 mg/L to 121.61 mg/L with mean value of 29.30 ± 16.1 mg/L, while Pb values vary from 3.41 mg/L to 39.1 mg/L with a mean value of 14.72 ± 0.84 mg/L (Table 1). Also, Cadmium values range from 1.36 mg/L to 3.67 mg/L with mean value of 2.49 ± 0.48 mg/L. The mean values of these elements are higher than the values obtained at the control site: 67.0 mg/L for Zn, 6.45 mg/L for Pb, 1.62 mg/L for Cd (Table 1) suggesting contamination. The values of Pb in samples 27, 29, 30 and 31 which are close to the dumpsite are 25.67 mg/L, 15.67 mg/L, 21.10 mg/L and 29.20 mg/L respectively (Table 2, Figure 3 ). These values are higher than the value of 6.45 mg/L for Pb at the control point which suggests possible contamination from the dumpsite. The Pb contamination could be due to disposed lead batteries, discarded paints and pesticides in the dumpsite (Amadi et al., 2012).

Table 1. Statistical Summary of Trace Elements Distributions in Soils of Ajakanga Dumpsites

| Parameters (mg/L) | Zn | Cu | Mn | Pb | Cd | Ni | As | Co | Cr |
|---|---|---|---|---|---|---|---|---|---|
| Minimum | 15.61 | 3.23 | 10 | 3.41 | 1.36 | 0.15 | 0.1 | 0.08 | 0.08 |
| Maximum | 121.61 | 15.06 | 188.36 | 39.1 | 3.67 | 3.84 | 1.13 | 0.56 | 4.22 |
| Mean | 29.3 | 6.66 | 44.34 | 14.72 | 2.49 | 2.03 | 0.84 | 0.16 | 0.92 |
| Std. Dev | 16.1 | 2.53 | 27.61 | 0.84 | 0.48 | 1.12 | 0.22 | 0.1 | 1.4 |
| Control | 20.9 | 4.01 | 49.2 | 6.45 | 1.62 | 0.2 | 0.71 | 0.12 | 0.11 |
| * BG Average n=4 | 56.16 | 1.56 | 168 | 18.9 | 0.33 | 44.2 | 1.23 | 1.12 | 3.14 |

*Average values of Ajakanga Migmatite Gneiss

Table 2. Chemical Analysis of Trace Elements in Soils Around Ajakanga Dumpsite.

| SAMPLE NAME | Zn mg/L | Cu mg/L | Mn mg/L | Pb mg/L | Cd mg/L | Ni mg/L | As mg/L | Co mg/L | Cr mg/L |
|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA 1 | 20.24 | 9.7 | 37.07 | 9.8 | 2.42 | 3.52 | 1.1 | 0.15 | 0.12 |
| AJAKANGA 2 | 28.61 | 4.89 | 41.4 | 10.11 | 3.67 | 2.11 | 0.74 | 0.12 | 0.12 |
| AJAKANGA 3 | 27.08 | 3.77 | 27.45 | 9.57 | 2.81 | 2.32 | 0.75 | 0.12 | 0.14 |
| AJAKANGA 4 | 41.61 | 6.37 | 26.03 | 10.85 | 2.44 | 0.49 | 0.1 | 0.1 | 0.11 |
| AJAKANGA 5 | 24.49 | 9.3 | 34.65 | 12.03 | 2.65 | 3.34 | 1.13 | 0.15 | 0.12 |
| AJAKANGA 6 | 36.58 | 3.95 | 33.82 | 9.46 | 2.59 | 3.24 | 0.76 | 0.12 | 0.15 |
| AJAKANGA 7 | 25.72 | 4.7 | 44.24 | 11.46 | 3.5 | 2.28 | 0.83 | 0.15 | 2.48 |
| AJAKANGA 8 | 22.76 | 9.85 | 20.66 | 39.1 | 3.04 | 2.42 | 0.68 | 0.15 | 0.15 |
| AJAKANGA 9 | 40.56 | 5.2 | 32 | 28.5 | 3.21 | 3.84 | 0.85 | 0.45 | 1.88 |
| AJAKANGA 10 | 25.72 | 9.88 | 40.59 | 33.77 | 2.85 | 2.99 | 1.08 | 0.31 | 2.11 |
| AJAKANGA 11 | 26.79 | 3.4 | 24.65 | 22.86 | 2.57 | 3.38 | 0.87 | 0.12 | 0.16 |
| AJAKANGA 12 | 28.32 | 3.78 | 48.12 | 10.77 | 2.2 | 2.92 | 0.6 | 0.13 | 0.13 |
| AJAKANGA 13 | 27.69 | 6.7 | 58.67 | 7.1 | 2.35 | 0.3 | 1.09 | 0.11 | 0.09 |
| AJAKANGA 14 | 23.27 | 5.4 | 39.75 | 6.6 | 1.95 | 0.16 | 1.01 | 0.11 | 0.08 |
| AJAKANGA 15 | 22.55 | 9.7 | 24.43 | 16.22 | 2.67 | 2.7 | 0.93 | 0.14 | 0.15 |
| AJAKANGA 16 | 23.12 | 3.78 | 44.81 | 18.4 | 1.36 | 2.64 | 0.89 | 0.11 | 0.11 |
| AJAKANGA 17 | 121.61 | 15.06 | 188.36 | 7.5 | 1.86 | 0.21 | 0.88 | 0.09 | 0.1 |
| AJAKANGA 18 | 25.74 | 5.1 | 49.66 | 12.13 | 1.91 | 2.42 | 0.51 | 0.15 | 0.14 |
| AJAKANGA 19 | 20.52 | 3.41 | 40.55 | 17.38 | 2.01 | 2.07 | 0.67 | 0.12 | 0.12 |
| AJAKANGA 20 | 20.81 | 6.92 | 46.16 | 7.95 | 2.36 | 2.95 | 1.06 | 0.14 | 0.14 |
| AJAKANGA 21 | 22.55 | 9.88 | 46.89 | 7.66 | 2.43 | 2.74 | 0.3 | 0.1 | 0.11 |
| AJAKANGA 22 | 33.7 | 5.06 | 45 | 7.95 | 2.36 | 2.95 | 1.06 | 0.14 | 0.14 |
| AJAKANGA 23 | 21.97 | 5.3 | 49.87 | 6.5 | 1.86 | 0.21 | 0.75 | 0.12 | 0.11 |
| AJAKANGA 24 | 27.95 | 8.6 | 10 | 5.6 | 2.19 | 0.16 | 0.77 | 0.12 | 0.16 |
| AJAKANGA 25 | 28.32 | 5.44 | 14 | 3.41 | 2.74 | 2.75 | 0.98 | 0.16 | 0.14 |
| AJAKANGA 26 | 21.39 | 5.26 | 10 | 12.01 | 2.51 | 1.99 | 1.01 | 0.09 | 0.15 |
| AJAKANGA 27 | 46.93 | 8.56 | 39 | 25.67 | 2.65 | 2.53 | 1.05 | 0.14 | 4.22 |
| AJAKANGA 28 | 22.47 | 4.69 | 69 | 12.01 | 2.51 | 1.99 | 1.01 | 0.09 | 3.11 |
| AJAKANGA 29 | 23.33 | 7.82 | 72 | 15.67 | 2.65 | 2.53 | 1.05 | 0.14 | 3.65 |
| AJAKANGA 30 | 27.17 | 8.9 | 62 | 21.1 | 3.16 | 2.84 | 0.92 | 0.56 | 2.1 |
| AJAKANGA 31 | 30.55 | 8.9 | 42 | 29.2 | 1.79 | 2.11 | 0.69 | 0.42 | 4.22 |
| AJAKANGA 32 | 23.91 | 4.69 | 10 | 9.38 | 2.51 | 2.4 | 0.97 | 0.14 | 0.15 |
| AJAKANGA 33 | 25.48 | 8.1 | 49.31 | 24.9 | 2.62 | 0.21 | 0.86 | 0.12 | 0.13 |
| AJAKANGA 34 | 27.04 | 8 | 56.12 | 8.1 | 2.11 | 0.17 | 0.75 | 0.08 | 0.14 |
| AJAKANGA 35 | 30.63 | 5.07 | 54.58 | 20.3 | 2.11 | 2.41 | 0.73 | 0.24 | 3.81 |
| AJAKANGA 36 | 21.58 | 7.3 | 61.35 | 11.22 | 2.66 | 2.09 | 1.09 | 0.13 | 2.11 |
| AJAKANGA 37 | 39.26 | 6.5 | 49.17 | 29.2 | 3.08 | 2.12 | 0.69 | 0.1 | 4.11 |
| AJAKANGA 38 | 15.61 | 3.23 | 42.62 | 11.22 | 2.66 | 2.09 | 1.09 | 0.13 | 0.15 |
| AJAKANGA 39 | 24.49 | 4.87 | 30.56 | 15.93 | 2.75 | 2.3 | 0.75 | 0.13 | 0.14 |
| AJAKANGA 40 | 30.29 | 9.2 | 50.21 | 15.6 | 2.51 | 0.19 | 0.75 | 0.09 | 0.15 |
| AJAKANGA 41 | 22.75 | 6.7 | 51.11 | 9.2 | 1.79 | 0.15 | 0.82 | 0.09 | 0.11 |
| Duplicate Sample 39B | 24.46 | 4.85 | 30.55 | 15.95 | 2.75 | 2.31 | 0.76 | 0.13 | 0.15 |
| Control Sample | 20.9 | 4.01 | 49.2 | 6.45 | 1.62 | 0.2 | 0.71 | 0.12 | 0.11 |

The results (Table 2) also show relatively higher values of Zn (121.61 mg/L), Cu (15.06 mg/L) and Mn (188.36 mg/L) in sample 17 which was collected close to the dumpsite than the control site values for Zn,

Cu and Mn with values of 20.09 mg/L, 4.01 mg/L and 49.2 mg/L respectively (Table 2, Figure 3). This may also be due to the negative impact of the dumpsite on soils within its vicinity.

*4.2 Grain Size Analysis of the Soil Profiles of the Dumpsite*

The clay sized particles (<63µm) proportions (%) extracted from the grain size results are contained in Table 3. The results showed that the clay size particles (<63µm) abundance in Ajakanga up-slope pit A varies between 2.34 % and 3.06 % with an average value of 2.7 ± 0.36 % in the A-level, whilst the B-Level values vary between 3.88 % and 5.62 % with average of 4.85 ± 0.59 %. The C-Level clay proportion vary between 3.78% and 4.42 %

 

with average of 4.08 ± 0.32 % (Table 3). The clay size particles abundance in downslope pit B varies between 1.96 % and 2 28 % with an average value of 2.12 ± 0.16 % in the A-level, whilst the B-Level values vary between 4.12 % and 6.32 % with average of 5.07 ± 0.82 %. However, C-Level clay proportion vary between 3.96 % and 4.72 % with average of 4.25 ± 0.41 %. These results indicate that the B-Level has more clay size materials than the A and C levels (Table 3 and Figures 4 and 5). Also, the B-level of the downslope Pit B is richer in clay sized materials than the B-level of the up-slope Pit A.

Table 3: Abundance of Clay Size Materials (<63 µm) in Soil Profiles at the (Down-slope) and (Up-slope) of Ajakanga Dumpsite

| % Wt Retained (< 63µm) in AJAKANGA Dumpsite Soil Profiles | | | |
|---|---|---|---|
| LEVELS | DEPTH (m) | % Wt Retained (<63 µm) in PIT A (Up-Slope) | % Wt Retained (<63 µm) in Pit B (Down-Slope) |
| A | 0 | 2.34 | 1.96 |
| | 0.5 | 3.06 | 2.28 |
| B | 1 | 3.88 | 4.12 |
| | 1.5 | 4.54 | 4.24 |
| | 2 | 5.08 | 5.25 |
| | 2.5 | 5.62 | 6.32 |
| | 3 | 5.04 | 5.51 |
| | 3.5 | 4.96 | 4.97 |
| C | 4 | 4.42 | 4.72 |
| | 4.5 | 4.04 | 3.96 |
| | 5 | 3.78 | 4.06 |

Average Abundance of Clay Size Materials (<63µm) along Vertical Profiles at the Downslope and Upslope of Ajakanga Dumpsite

| LEVELS | DEPTH | Up-Slope (PIT A) | Down-Slope (PIT B) |
|---|---|---|---|
| A | 0-0.5 | 2.70±0.36 | 2.12±0.16 |
| B | 0.5-3.5 | 4.85±0.59 | 5.07±0.82 |
| C | 3.5-5 | 4.08±0.32 | 4.25±0.41 |

*PIT A = Pit sunk at Upslope Area at the Dumpsite
*PIT B = Pit sunk at Down-slope Area at the Dumpsite

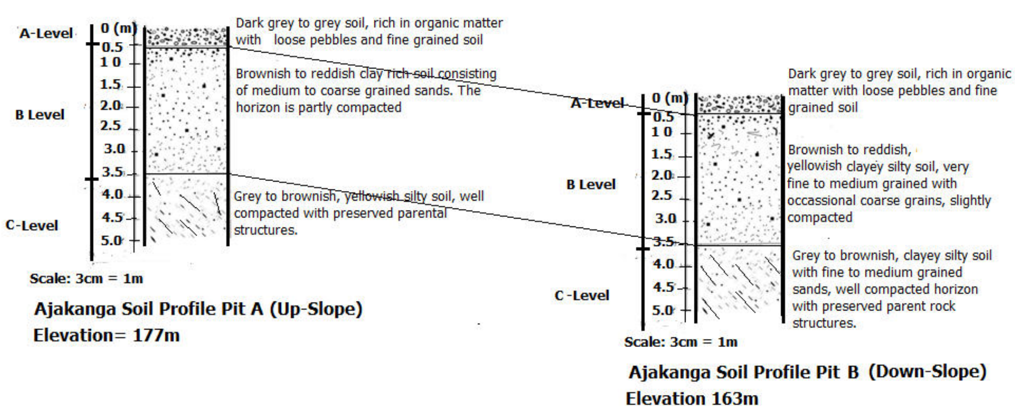


Figure 4: Sketch of Dug Pit A at Up-slope and Pit B at Down-slope within Ajakanga Dumpsite

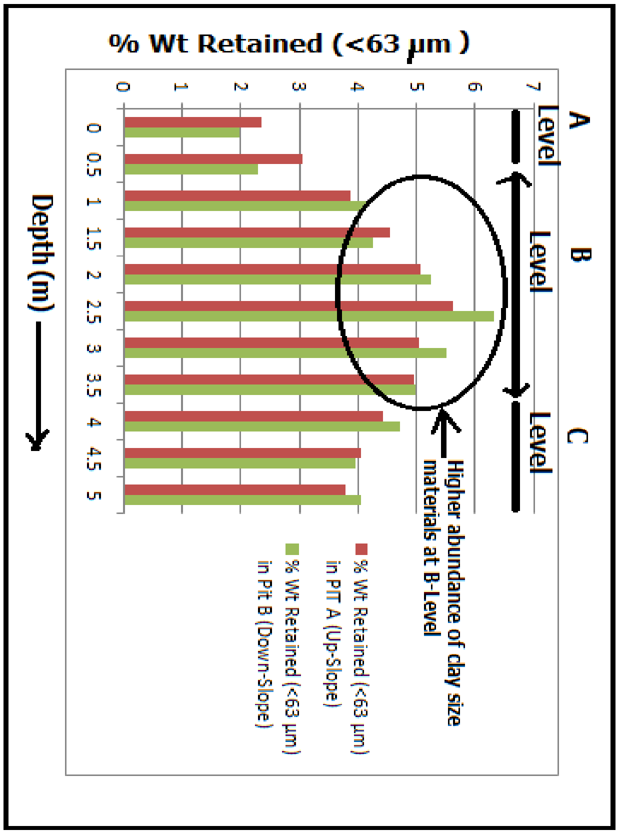


Figure 5: Plot of Abundance of Clay Size Materials (<63 µm) in Down-slope and Up-slope of Ajakanga Dumpsite Soil

4.3 Hydraulic Properties Of The Soil Profiles At Study Dumpsite

The raw data of the hydraulic properties consisting of hydraulic conductivity, water holding capacity, bulk density and porosity of undisturbed samples of the soil profiles at Ajakanga dumpsite are presented in Tables 4 and 5 while the graphical illustrations are contained in Figures 6 and 7 respectively. The raw data (Tables 4 and 5) show a general decrease in the trend of hydraulic conductivity and porosity from the top soil (A –Level) to the bottom of the soil profiles (Figures 4, 6 and 7) probably due to increse in soil compaction from the top to bottom (USAID, 2008). The bulk density increases from the top to bottom of the vertical soil profiles. This is attributable to increase in soil compaction as a result of increase in overburden

Table 4: Hydraulic Properties of Undisturbed Soil Samples of Ajakanga Dumpsite Pit A (Up-slope)

| LEVEL | DEPTH (m) | Hydraulic conductivity cm/hr | W.H.C. (%) | Bulk Density gm/cc | Porosity % |
|---|---|---|---|---|---|
| A | 0 | 19.2 | 17 | 1.56 | 41.13 |
| | 0.5 | 15 | 19 | 1.45 | 45.28 |
| B | 1 | 12 | 22.7 | 1.58 | 40.38 |
| | 1.5 | 7.8 | 24.7 | 1.56 | 41.13 |
| | 2 | 5.12 | 28.3 | 1.72 | 35.09 |
| | 2.5 | 2.88 | 30.1 | 1.74 | 34.34 |
| | 3 | 2.52 | 30.8 | 1.83 | 30.94 |
| | 3.5 | 2.28 | 32.5 | 1.83 | 30.94 |
| C | 4 | 2.46 | 29.3 | 1.86 | 29.81 |
| | 4.5 | 2.58 | 27.6 | 1.82 | 31.32 |
| | 5 | 1.89 | 25.5 | 1.88 | 29.06 |

 

Table 5: Hydraulic Properties of Undisturbed Soil Samples of Ajakanga Dumpsite Pit B (Down-slope)

| LEVEL | DEPTH (m) | Hydraulic conductivity cm/hr | W.H.C. (%) | Bulk Density gm/cc | Porosity % |
|---|---|---|---|---|---|
| | 0 | 20.88 | 12 | 1.28 | 51.70 |
| A | 0.5 | 10.62 | 14 | 1.34 | 49.43 |
| | 1 | 8.52 | 30.2 | 1.45 | 45.28 |
| | 1.5 | 7.02 | 33.2 | 1.46 | 44.91 |
| B | 2 | 6.90 | 31.9 | 1.68 | 36.60 |
| | 2.5 | 6.94 | 30.1 | 1.66 | 37.36 |
| | 3 | 3.48 | 26.1 | 1.68 | 36.60 |
| | 3.5 | 2.52 | 18.5 | 1.7 | 35.85 |
| | 4 | 2.04 | 18.4 | 1.69 | 36.23 |
| C | 4.5 | 2.29 | 18.2 | 1.74 | 34.34 |
| | 5 | 1.74 | 15.3 | 1.78 | 32.83 |

from the top to the bottom (Tables 4, 5 and Figures 4, 6 and 7). The water holding capacity however shows higher values in the B-level than in A and C levels across the two pits (Tables 4, 5 and Figures 4, 6 and 7) possibly due to relatively higher abundance of clay size materials in B-levels compared to the A and C-levels (Table 3 and Figure 5) .

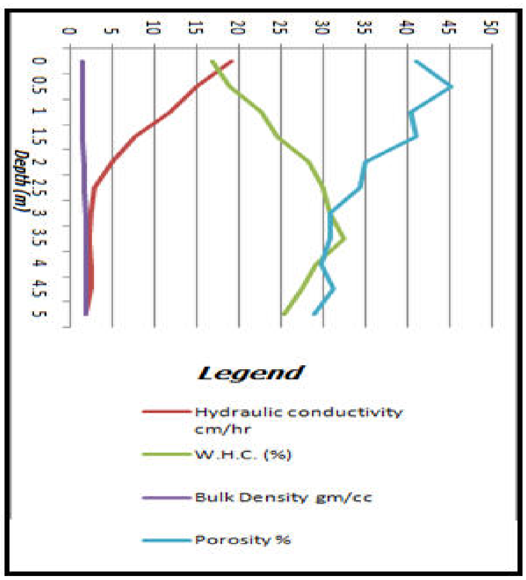


Figure 6 : Plot of Hydraulic Properties at Pit A (Up-slope) Based on Core Samples of Ajakanga Dumpsite

 

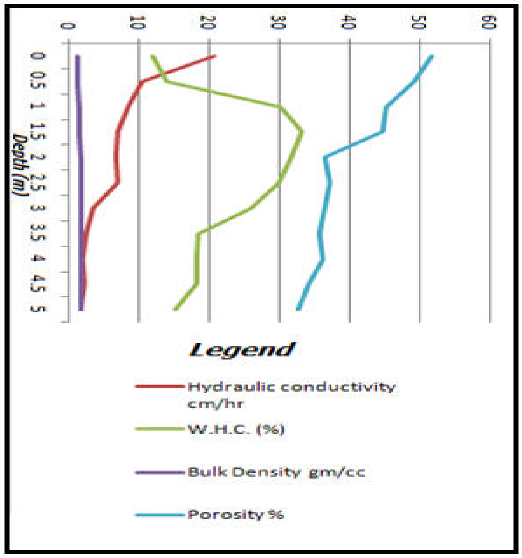


Figure 7**:** Plot of Hydraulic Properties at Pit B (Down-slope) Based on Core Samples of Ajakanga Dumpsite

*4.3 Contamination Assessment along Vertical Soil Profiles.*

The raw geochemical data of the soil profiles of Ajakanga upslope and downslope areas are presented in Tables 6 and 7, while the contamination factor and degree of contamination using Hakanson 1980 approach (Table 8) are presented in Tables 9 and 10.

The relationship between the contamination factor (CF) and degree of contamination (Cdeg) for vertical soil profiles was described using the equation below:

CF = Cm / CB ------Equation (1)

Where Cm = concentration of respective elements in sample;

CB = background concentration (Concentration of elements in the rock sample underlying the dumpsite) and

CF = Contamination Factor (This is a single element index)

Cdeg = Degree of contamination

The Degree of Contamination (Cdeg) = $\sum$ {Cm/CB} --------Equation (2)

Four classes/categories of contamination degrees and factors are recognized as shown in Table 8.

 

Table 6: Chemical Analysis of Ajakanga Upslope Vertical Soil Samples

| NAME | Zn ppm | Cu ppm | Mn ppm | Pb ppm | Cd ppm | Ni ppm | As ppm | Co ppm | Cr ppm |
|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA SOIL A1 | 34.84 | 6.16 | 23.83 | 8.93 | 3.457 | 2.05 | 0.65 | 0.12 | 2.33 |
| AJAKANGA SOIL A2 | 22.76 | 5.98 | 25.74 | 7.54 | 2.655 | 2.11 | 0.58 | 0.13 | 2.85 |
| AJAKANGA SOIL A3 | 37.70 | 6.90 | 34.51 | 13.59 | 3.410 | 2.01 | 0.72 | 0.13 | 4.12 |
| AJAKANGA SOIL A4 | 40.43 | 7.09 | 25.71 | 11.01 | 3.520 | 2.17 | 0.81 | 0.15 | 4.28 |
| AJAKANGA SOIL A5 | 89.70 | 7.82 | 29.68 | 16.42 | 3.880 | 2.66 | 0.84 | 0.12 | 4.54 |
| AJAKANGA SOIL A6 | 122.64 | 4.20 | 40.00 | 18.20 | 3.600 | 2.87 | 0.60 | 0.13 | 3.32 |
| AJAKANGA SOIL A7 | 54.73 | 4.10 | 28.00 | 12.20 | 2.140 | 2.72 | 0.42 | 0.12 | 3.12 |
| AJAKANGA SOIL A8 | 52.65 | 3.30 | 32.00 | 4.10 | 2.300 | 1.21 | 0.21 | 0.10 | 2.88 |
| AJAKANGA SOIL A9 | 40.43 | 2.30 | 26.00 | 2.10 | 1.400 | 1.22 | 0.21 | 0.06 | 1.84 |
| AJAKANGA SOIL A10 | 21.71 | 2.10 | 21.00 | 0.30 | 1.200 | 0.32 | 0.15 | 0.02 | 0.86 |
| AJAKANGA SOIL A11 | 19.63 | 1.80 | 18.00 | 0.20 | 1.200 | 0.52 | 0.11 | 0.02 | 0.85 |
| *Parent Rock (N=4) | 45.24 | 15.6 | 59.81 | 7.2 | 0.25 | 10.12 | 1.1 | 1.13 | 3.24 |

*Average values of Ajakanga Migmatite Gneiss

Table 7: Chemical Analysis of Ajakanga Downslope Vertical Soil Profile

| NAME | Zn ppm | Cu ppm | Mn ppm | Pb ppm | Cd ppm | Ni ppm | As ppm | Co ppm | Cr ppm |
|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA SOIL B1 | 50.05 | 6.90 | 33.78 | 10.42 | 3.53 | 2.17 | 0.72 | 0.34 | 4.48 |
| AJAKANGA SOIL B2 | 53.43 | 8.77 | 22.11 | 15.56 | 3.62 | 2.54 | 0.74 | 0.40 | 6.40 |
| AJAKANGA SOIL B3 | 88.66 | 8.56 | 38.00 | 18.31 | 3.67 | 2.62 | 0.77 | 0.42 | 6.80 |
| AJAKANGA SOIL B4 | 108.03 | 8.93 | 49.39 | 10.66 | 3.71 | 2.77 | 0.82 | 0.45 | 7.10 |
| AJAKANGA SOIL B5 | 109.72 | 8.93 | 56.00 | 21.00 | 3.80 | 2.92 | 0.84 | 0.48 | 7.22 |
| AJAKANGA SOIL B6 | 121.16 | 19.30 | 53.58 | 15.20 | 3.82 | 2.96 | 0.86 | 0.28 | 7.46 |
| AJAKANGA SOIL B7 | 93.73 | 10.00 | 72.00 | 14.20 | 3.21 | 2.21 | 0.72 | 0.28 | 6.20 |
| AJAKANGA SOIL B8 | 83.46 | 7.20 | 44.00 | 11.20 | 2.25 | 1.88 | 0.62 | 0.13 | 5.82 |
| AJAKANGA SOIL B9 | 54.73 | 5.30 | 54.00 | 5.50 | 2.41 | 1.57 | 0.30 | 0.12 | 4.82 |
| AJAKANGA SOIL B10 | 43.42 | 2.40 | 34.00 | 0.40 | 1.96 | 1.52 | 0.01 | 0.12 | 1.81 |
| AJAKANGA SOIL B11 | 40.56 | 2.20 | 32.00 | 0.20 | 1.90 | 1.50 | 0.01 | 0.12 | 1.72 |
| *Parent Rock (N=4) | 45.24 | 15.6 | 59.81 | 7.2 | 0.25 | 10.12 | 1.1 | 1.13 | 3.24 |

*Average values of Ajakanga Migmatite Gneiss

Table: 8 Classification of Contamination Degree and Contamination Factor (After Hakanson, 1980)

| Classes/Categories of Contamination Degree (After Hakanson, 1980) | |
|---|---|
| Classes/Categories | Contamination Degree (Cdeg) |
| Cdeg <8 | Low Degree of Contamination |
| 8 <Cdeg < 16 | Moderate Degree of Contamination |
| 16 < Cdeg < 32 | Considerable Degree of Contamination |
| 32 < Cdeg | Very High Degree of Contamination |
| Classification of Contamination Factor (After Hakanson, 1980) | |
| Classes/Categories | Contamination Degree (Cdeg) |
| CF < 1 | Low contamination |
| 1 < CF < 3 | Moderate contamination |
| 3 < CF < 6 | Considerable contamination |
| 6 < CF | Very high contamination |

Table 9: Impact of Trace Elements on Soil Quality: Contamination Factor and Degree of Contamination in Ajakanga Upslope Vertical Soil Profile

| SAMPLE NAME | Level | DEPTH | CF Zn | CF Cu | CF Mn | CF Pb | CF Cd | CF Ni | CF As | CF Co | CF Cr | Cdeg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA SOIL A1 | A | 0 | 0.77 | 0.4 | 0.4 | 1.24 | 13.83 | 0.2 | 0.59 | 0.11 | 0.72 | 18.25 |
| AJAKANGA SOIL A2 | | 0.5 | 0.5 | 0.38 | 0.43 | 1.05 | 10.62 | 0.21 | 0.53 | 0.11 | 0.88 | 14.71 |
| AJAKANGA SOIL A3 | B | 1 | 0.83 | 0.44 | 0.58 | 1.89 | 13.64 | 0.2 | 0.65 | 0.11 | 1.27 | 19.62 |
| AJAKANGA SOIL A4 | | 1.5 | 0.89 | 0.45 | 0.43 | 1.53 | 14.08 | 0.21 | 0.74 | 0.14 | 1.32 | 19.8 |
| AJAKANGA SOIL A5 | | 2 | 1.98 | 0.5 | 0.5 | 2.28 | 15.52 | 0.26 | 0.76 | 0.11 | 1.4 | 23.32 |
| AJAKANGA SOIL A6 | | 2.5 | 2.71 | 0.27 | 0.67 | 2.53 | 14.4 | 0.28 | 0.54 | 0.12 | 1.02 | 22.54 |
| AJAKANGA SOIL A7 | | 3 | 1.21 | 0.26 | 0.47 | 1.69 | 8.56 | 0.27 | 0.38 | 0.11 | 0.96 | 13.91 |
| AJAKANGA SOIL A8 | | 3.5 | 1.16 | 0.21 | 0.54 | 0.57 | 9.2 | 0.12 | 0.19 | 0.09 | 0.89 | 12.97 |
| AJAKANGA SOIL A9 | C | 4 | 0.89 | 0.15 | 0.43 | 0.29 | 5.6 | 0.12 | 0.19 | 0.05 | 0.57 | 8.3 |
| AJAKANGA SOIL A10 | | 4.5 | 0.48 | 0.13 | 0.35 | 0.04 | 4.8 | 0.03 | 0.14 | 0.02 | 0.27 | 6.26 |
| AJAKANGA SOIL A11 | | 5 | 0.43 | 0.12 | 0.3 | 0.03 | 4.8 | 0.05 | 0.1 | 0.02 | 0.26 | 6.11 |

Table 10: Impact of Trace Elements on Soil Quality: Contamination Factor and Degree of Contamination in Ajakanga Downslope Vertical Soil Profile

| SAMPLE NAME | Levels | DEPTH(m) | CF Zn | CF Cu | CF Mn | CF Pb | CF Cd | CF Ni | CF As | CF Co | CF Cr | Cdeg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA SOIL B1 | A | 0 | 1.11 | 0.44 | 0.56 | 1.45 | 14.1 | 0.21 | 0.65 | 0.3 | 1.38 | 20.22 |
| AJAKANGA SOIL B2 | | 0.5 | 1.18 | 0.56 | 0.37 | 2.16 | 14.48 | 0.25 | 0.67 | 0.35 | 0.08 | 20.11 |
| AJAKANGA SOIL B3 | B | 1 | 1.96 | 0.55 | 0.64 | 2.54 | 14.68 | 0.26 | 0.7 | 0.37 | 0.08 | 21.78 |
| AJAKANGA SOIL B4 | | 1.5 | 2.39 | 0.57 | 0.83 | 1.48 | 14.84 | 0.27 | 0.75 | 0.4 | 0.09 | 21.61 |
| AJAKANGA SOIL B5 | | 2 | 2.43 | 0.57 | 0.94 | 2.92 | 15.2 | 0.29 | 0.76 | 0.42 | 0.09 | 23.61 |
| AJAKANGA SOIL B6 | | 2.5 | 2.68 | 1.24 | 0.9 | 2.11 | 15.28 | 0.29 | 0.78 | 0.25 | 0.09 | 23.61 |
| AJAKANGA SOIL B7 | | 3 | 2.07 | 0.64 | 1.2 | 1.97 | 12.84 | 0.22 | 0.65 | 0.25 | 0.07 | 19.92 |
| AJAKANGA SOIL B8 | | 3.5 | 1.84 | 0.46 | 0.74 | 1.56 | 9 | 0.19 | 0.56 | 0.12 | 0.07 | 14.53 |
| AJAKANGA SOIL B9 | C | 4 | 1.21 | 0.34 | 0.9 | 0.76 | 9.64 | 0.16 | 0.27 | 0.11 | 0.06 | 13.45 |
| AJAKANGA SOIL B10 | | 4.5 | 0.96 | 0.15 | 0.57 | 0.06 | 7.84 | 0.15 | 0.01 | 0.11 | 0.02 | 9.86 |
| AJAKANGA SOIL B11 | | 5 | 0.9 | 0.14 | 0.54 | 0.03 | 7.6 | 0.15 | 0.01 | 0.11 | 0.02 | 9.48 |

 

The degree of contamination (Cdeg) for Ajakanga vertical soil profile for downslope varies between 9.48 and 23.61, indicating moderate to considerable degree of contamination, while the upslope contamination is within the range of 6.11 to 23.32, which indicates low to considerable degrees of contamination (Tables 8, 9 and 10). Based on the above results, the down-slope Pit B is more polluted than the upslope pit A. This might be due to washing/leaching of metals from upslope to down-slop area by leachate and run-off water emanating from the dumpsite. The evaluated results (Tables 9, 10 and Figures 4 and 8) show that the degree of contamination at the B-level is higher compare with A-level and C-levels (Degree of contamination of B > A > C ). The higher contamination in B-level might be due to adsorption of metals by the clay sized materials (<63 µm) found in higher proportion in the B level than A and C levels (Tables 3, 9, 10 and Figures 5 and 8).

The results of the water holding capacity from the undisturbed samples (Tables 4, 5 and Figures 6 and 7) show that B-level has higher water holding capacity than the A and C levels in the area possibly due to its higher contents of clay sized materials (Table 3 and Figures 4 and 5). The bulk density increases with depth due to increase in compaction while hydraulic conductivity and porosity decrease downwards (Tables 4, 5 and Figures 6 and 7) mainly because of increase in compaction with depth (Mitchell *et al*., 2005).

The B-level is a clay rich horizon (Figure 4) and clay is known to have lots of micro pore spaces that are not interconnected (USAID, 2008). The lack of connectivity of the pore spaces will impede or reduce the flow of leachate emanating from the dumpsite through the soil colum thereby increasing the resident time of the pollutants in the subsurface and aid their adsorption by the fine grained clay size particles which are abundant within this level (USAID, 2008). The result is that the trace elements were concentrated more in the B-level as shown by the graphical 2D displays of contamination degree in Figure 9. The 2D graphical display shows that adsorption of metals at the B-level reduced contamination at the C-level and will subsequently decrease movement of contaminants into the underground water. The public health implication of this is that the clay/silt rich overburden as shown in Figure 4 serve as natural filtering/purifying materials which will help in substantial attenuation of pollutants (Assmuth, 1983). This will improve the percolating water quality as the leachate from the waste infiltrates from above within and around the dumpsite vicinities through the overburden before it gets to the shallow groundwater which is the major water resources available for human consumption, agricultural and industrial usage in the area. These natural attenuation controls are similar to the dilute and disperse principle of leachate management proposed by Gray *et al*. (1974) which is based on the natural subsurface processes of biodegradation, filtration, sorption and ion exchange to attenuate the contaminants in the leachate.

Soil contamination is well pronounced within (0 – 3.5) m of the vertical profile at the dumpsite vicinity (Figure 8 and Tables 9 and 10).

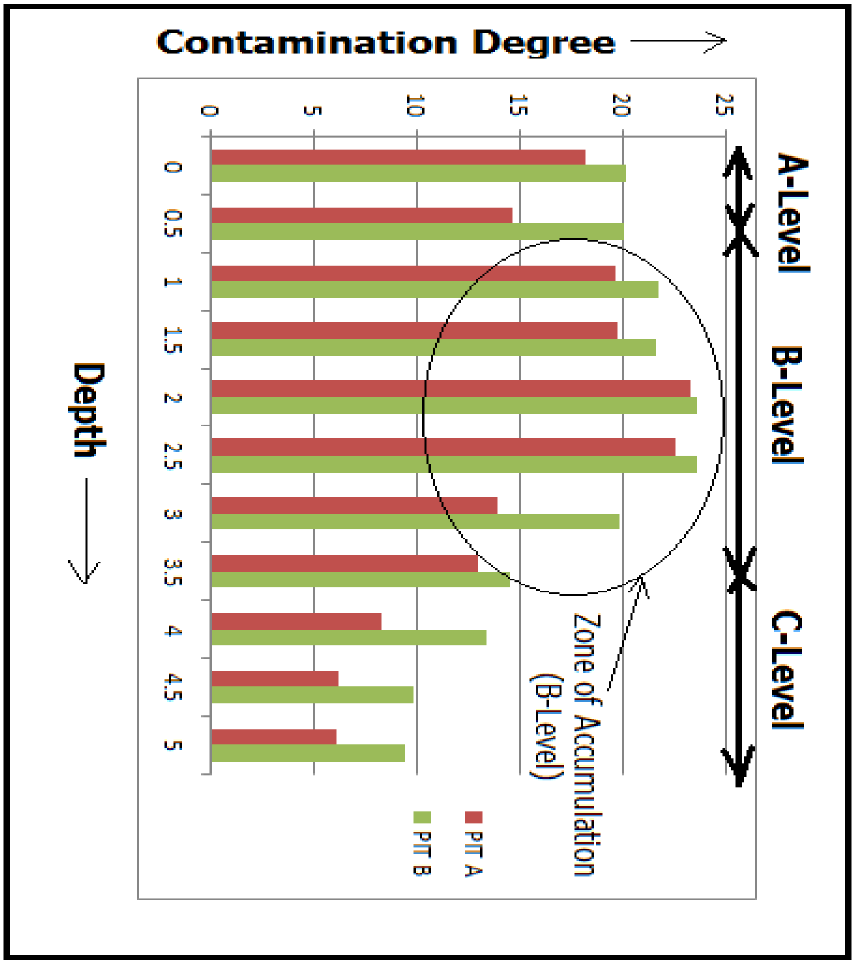


Figure 8: Plot of Contamination Degree Along Vertical Soil Profiles of Up-slope (Pit A) and Down-slope (Pit B) at Ajakanga Dumpsite

 

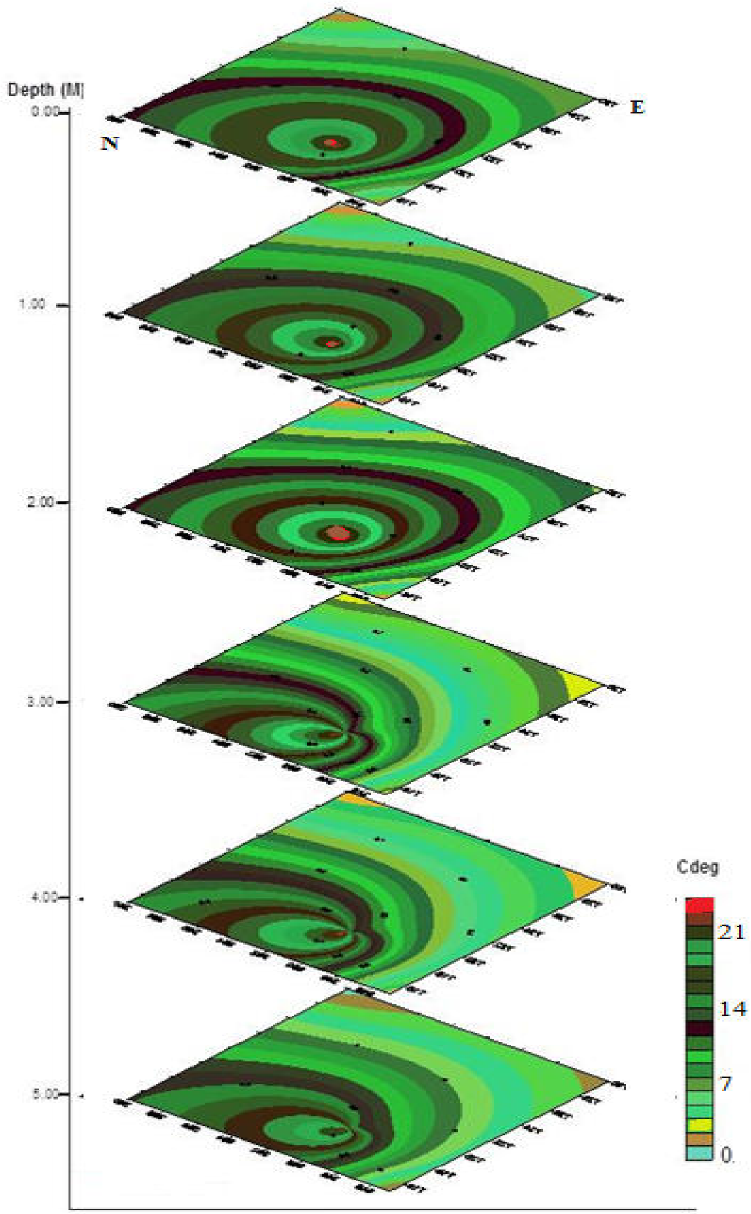


Figure 9: A 2D Display of Contamination Degree Along Vertical Soil Profile of Ajakanga Dumpsite Showing Contamination Plume

*4.4 Contamination Assessment in Soils around Ajakanga Dumpsite*

The degree of contamination (Cdeg) in soils around Ajakanga dumpsite ranges between 4.88 and 28.12 indicating low to considerable contamination (Tables 8 and 11). Pollution map of soil around the dumpsite (Figure 10) shows that pollution is more prominent within 0-500 m radius from the dumpsite.

Table 11: Impact of Trace Elements on Soil Quality: Contamination Factor and Degree of Contamination in Soils around Ajakanga Dumpsite

| SAMPLE NAME | Cf Zn | Cf Cu | Cf Mn | Cf Pb | Cf Cd | Cf Ni | Cf As | Cf Co | Cf Cr | Cdeg |
|---|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA 1 | 0.45 | 0.62 | 0.62 | 1.36 | 9.68 | 0.35 | 1 | 0.14 | 0.04 | 14.25 |
| AJAKANGA 2 | 0.63 | 0.31 | 0.69 | 1.4 | 14.7 | 0.21 | 0.67 | 0.11 | 0.04 | 18.76 |
| AJAKANGA 3 | 0.6 | 0.24 | 0.46 | 1.33 | 11.25 | 0.23 | 0.68 | 0.11 | 0.04 | 14.94 |
| AJAKANGA 4 | 0.92 | 0.41 | 0.44 | 1.51 | 9.76 | 0.05 | 0.09 | 0.09 | 0.03 | 13.3 |
| AJAKANGA 5 | 0.54 | 0.6 | 0.58 | 1.67 | 10.6 | 0.33 | 1.03 | 0.13 | 0.04 | 15.51 |
| AJAKANGA 6 | 0.81 | 0.25 | 0.57 | 1.31 | 10.34 | 0.32 | 0.69 | 0.1 | 0.05 | 14.44 |
| AJAKANGA 7 | 0.57 | 0.3 | 0.74 | 1.59 | 13.99 | 1.21 | 2.57 | 0.13 | 0.77 | 21.88 |
| AJAKANGA 8 | 0.5 | 0.63 | 0.35 | 5.43 | 12.17 | 1.23 | 3.35 | 0.13 | 0.35 | 24.14 |
| AJAKANGA 9 | 0.9 | 0.33 | 0.54 | 3.96 | 12.84 | 1.37 | 2.59 | 0.75 | 0.58 | 23.85 |
| AJAKANGA 10 | 0.57 | 0.63 | 0.68 | 4.69 | 15.42 | 1.28 | 2.8 | 0.27 | 0.65 | 27 |
| AJAKANGA 11 | 0.59 | 0.22 | 0.41 | 3.18 | 10.29 | 1.32 | 2.61 | 0.11 | 0.36 | 19.09 |
| AJAKANGA 12 | 0.63 | 0.24 | 0.8 | 1.5 | 8.81 | 0.29 | 0.54 | 0.11 | 0.04 | 12.96 |
| AJAKANGA 13 | 0.61 | 0.43 | 0.98 | 0.99 | 9.4 | 0.03 | 0.08 | 0.1 | 0.03 | 12.65 |
| AJAKANGA 14 | 0.51 | 0.35 | 0.66 | 0.92 | 7.8 | 0.02 | 0.92 | 0.1 | 0.02 | 11.3 |
| AJAKANGA 15 | 0.5 | 0.62 | 0.41 | 2.25 | 10.7 | 0.27 | 0.84 | 0.12 | 0.05 | 15.75 |
| AJAKANGA 16 | 0.51 | 0.24 | 0.75 | 2.56 | 5.43 | 0.26 | 0.81 | 0.1 | 0.04 | 10.69 |
| AJAKANGA 17 | 2.69 | 0.97 | 3.15 | 1.04 | 7.44 | 0.02 | 0.8 | 0.08 | 0.03 | 16.22 |
| AJAKANGA 18 | 0.57 | 0.33 | 0.83 | 1.68 | 7.64 | 0.24 | 0.46 | 0.13 | 0.04 | 11.92 |
| AJAKANGA 19 | 0.45 | 0.22 | 0.68 | 2.41 | 8.05 | 0.2 | 0.61 | 0.11 | 0.04 | 12.76 |
| AJAKANGA 20 | 0.46 | 0.44 | 0.77 | 1.1 | 1.45 | 0.29 | 0.96 | 0.12 | 0.04 | 5.65 |
| AJAKANGA 21 | 0.5 | 0.63 | 0.78 | 1.06 | 1.72 | 0.27 | 0.27 | 0.09 | 0.04 | 5.37 |
| AJAKANGA 22 | 0.74 | 0.32 | 0.75 | 1.1 | 1.45 | 0.29 | 0.05 | 0.12 | 0.04 | 4.88 |
| AJAKANGA 23 | 0.49 | 0.34 | 0.83 | 0.9 | 3.44 | 0.02 | 0.68 | 0.11 | 0.03 | 6.84 |
| AJAKANGA 24 | 0.62 | 0.55 | 0.17 | 0.78 | 8.76 | 0.02 | 0.7 | 0.11 | 0.05 | 11.75 |
| AJAKANGA 25 | 0.63 | 0.35 | 0.23 | 0.47 | 10.98 | 0.27 | 0.89 | 0.14 | 0.04 | 14.01 |
| AJAKANGA 26 | 0.47 | 0.34 | 0.17 | 1.67 | 10.05 | 0.2 | 0.92 | 0.08 | 0.05 | 13.94 |
| AJAKANGA 27 | 1.04 | 0.55 | 0.65 | 3.56 | 10.61 | 1.24 | 1.87 | 0.12 | 1.3 | 20.94 |
| AJAKANGA 28 | 0.5 | 0.3 | 1.15 | 1.67 | 10.05 | 0.2 | 0.92 | 0.08 | 0.96 | 15.82 |
| AJAKANGA 29 | 0.52 | 0.5 | 1.2 | 2.18 | 10.61 | 0.25 | 0.96 | 0.12 | 1.13 | 17.46 |
| AJAKANGA 30 | 0.6 | 0.57 | 1.04 | 2.93 | 12.64 | 2.26 | 2.65 | 0.5 | 0.65 | 23.83 |
| AJAKANGA 31 | 0.68 | 0.57 | 0.7 | 4.06 | 7.16 | 2.18 | 3.35 | 0.37 | 1.3 | 20.38 |
| AJAKANGA 32 | 0.53 | 0.3 | 0.17 | 1.3 | 10.04 | 1.23 | 1.79 | 0.13 | 0.36 | 15.83 |
| AJAKANGA 33 | 0.56 | 0.52 | 0.82 | 3.46 | 10.48 | 2.29 | 3.51 | 0.11 | 0.35 | 22.1 |
| AJAKANGA 34 | 0.6 | 0.51 | 0.94 | 1.13 | 8.44 | 0.02 | 0.68 | 0.07 | 0.04 | 12.43 |
| AJAKANGA 35 | 0.68 | 0.33 | 0.91 | 2.82 | 8.44 | 1.23 | 2.48 | 0.21 | 1.18 | 18.27 |
| AJAKANGA 36 | 0.48 | 0.47 | 1.03 | 1.56 | 10.63 | 1.19 | 2.81 | 0.12 | 0.65 | 18.93 |
| AJAKANGA 37 | 0.87 | 0.42 | 0.82 | 4.06 | 12.32 | 1.4 | 5.17 | 1.86 | 1.27 | 28.18 |
| AJAKANGA 38 | 0.35 | 0.21 | 0.71 | 1.56 | 10.63 | 1.19 | 1.9 | 0.12 | 0.66 | 17.32 |
| AJAKANGA 39 | 0.54 | 0.31 | 0.51 | 2.21 | 11 | 0.23 | 0.68 | 0.12 | 0.04 | 15.65 |
| AJAKANGA 40 | 0.67 | 0.59 | 0.84 | 2.17 | 10.04 | 1.11 | 2.5 | 0.08 | 0.35 | 18.35 |
| AJAKANGA 41 | 0.5 | 0.43 | 0.85 | 1.28 | 7.16 | 0.01 | 0.75 | 0.08 | 0.03 | 11.1 |

Soil samples with considerable degree of contamination cluster within this area (0-500 m radius from dumpsite centre) while samples with low to moderate degree of contamination dominate areas beyond 500 m (Table 8 and Figure 10). This suggests the dumpsite as point source of contamination in the area.

 

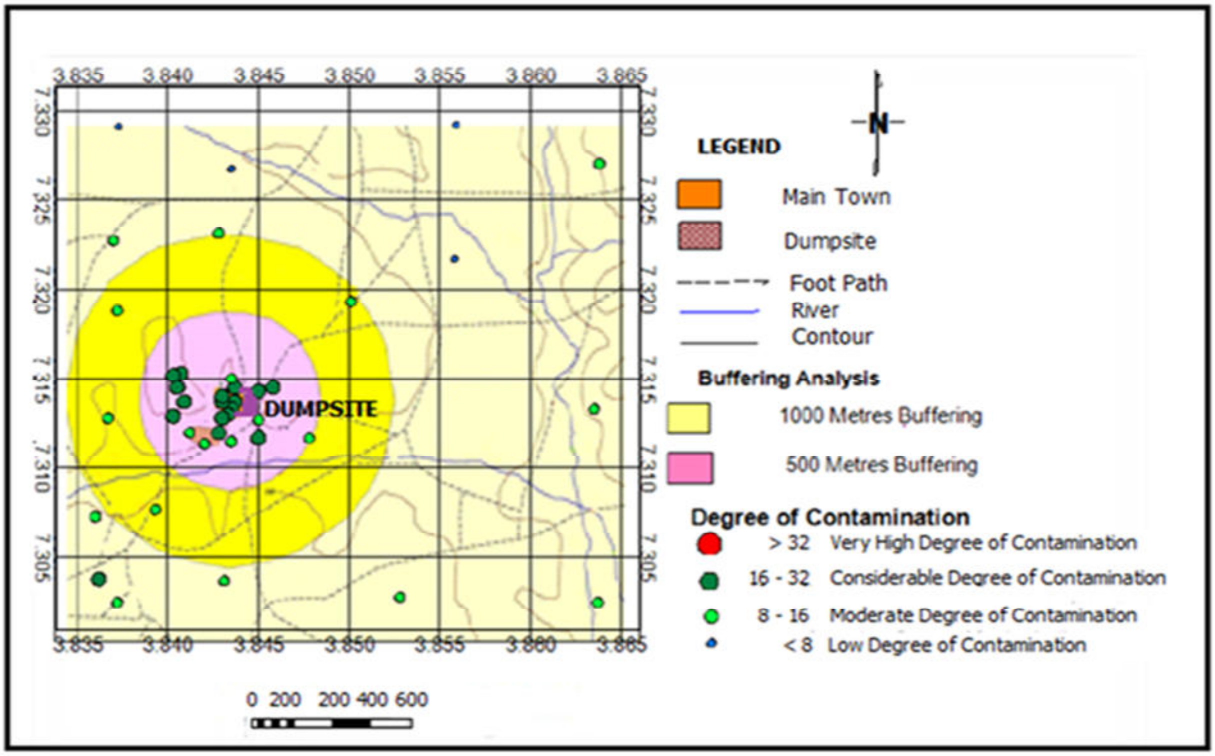


**Figure 10: Pollution Distribution Map of Soils around Ajakanga Dumpsite**

*4.5 Groundwater Geochemistry*

*4.51 Physico-Chemical Parameters of Ajakanga Shallow Well Water*

The results of the physico-chemical parameters of Ajakanga well water are contained in Tables 12a and 12b. The results show that the pH values range between 7.16 and 7.9 with average of 7.48 ± 0.29. The EC values vary between 110 µS/cm and 975 µS/cm with average value of 523.13 µS/cm ± 356.62 µS/cm while TDS values range between 82.5 mg/L and 731.25 mg/L with average value of 392.34 ± 267.47 mg/L. These indicate that pH, EC and TDS are within the permissible limit prescribed by WHO (2004) and SON (2007) (Tables 12a and 12b).

Table 12a: Physico-Chemical and Bacteriological Parameters of Shallow Well Water, Ajakanga Dumpsite

| SAMPLE NAME | pH | EC(µS) | TDS (mg/L) | TEMP (°C) | COLIFORM cells/100ml | $HCO_3^-$ mg/L | $Cl^-$ mg/L | $SO_4^{2-}$ mg/L | $NO_3^-$ mg/L | $Ca^{2+}$ mg/L | $Mg^{2+}$ mg/L | $Na^+$ mg/L | $K^+$ mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA 1 | 7.48 | 130.00 | 97.50 | 29.30 | 43.00 | 95.20 | 162.00 | 0.49 | 0.84 | 10.07 | 2.26 | 83.00 | 80.00 |
| AJAKANGA 2 | 7.90 | 670.00 | 502.50 | 29.70 | 460.00 | 24.40 | 201.60 | 4.57 | 1.21 | 20.08 | 34.90 | 35.00 | 47.00 |
| AJAKANGA 3 | 7.52 | 160.00 | 120.00 | 29.80 | 15.00 | 18.30 | 76.80 | 2.47 | 1.80 | 0.16 | 2.79 | 32.00 | 40.00 |
| AJAKANGA 4 | 7.88 | 580.00 | 435.00 | 28.60 | 1100.00 | 18.30 | 167.20 | 2.84 | 1.80 | 32.27 | 2.93 | 48.00 | 55.00 |
| AJAKANGA 5 | 7.50 | 590.00 | 442.50 | 28.80 | 1100.00 | 12.20 | 118.80 | 8.40 | 1.51 | 10.25 | 4.84 | 34.00 | 54.00 |
| AJAKANGA 6 | 7.21 | 110.00 | 82.50 | 28.30 | 1100.00 | 58.10 | 86.40 | 4.08 | 1.24 | 0.01 | 2.31 | 43.00 | 62.00 |
| AJAKANGA 7 | 7.16 | 970.00 | 727.50 | 26.90 | 43.00 | 146.10 | 2143.00 | 40.15 | 1.78 | 0.78 | 2.87 | 45.00 | 49.00 |
| AJAKANGA 8 | 7.18 | 975.00 | 731.25 | 26.90 | 43.00 | 148.00 | 1525.00 | 32.11 | 1.71 | 0.68 | 2.99 | 44.00 | 46.00 |
| AJAKANGA 8B | 7.16 | 975.00 | 731.00 | 26.90 | 42.00 | 147.00 | 1527.00 | 31.96 | 1.70 | 0.67 | 2.96 | 43.00 | 45.00 |
| Control | 7.24 | 110.00 | 82.50 | 28.10 | 12.00 | 94.00 | 160.00 | 0.42 | 0.86 | 10.07 | 2.25 | 81.00 | 82.00 |

Ajakanga 8B is duplicate of sample 8

 

Table 12b: Statistical Summary of Physico-Chemical and Microbial Parameters of Well Water Around Ajakanga Dumpsite

| Parameters Ajakanga (N=08) | PH | EC (uS/cm) | TDS (mg/L) | TEMP(˚C) | Coliform. Cell/100 ml |
|---|---|---|---|---|---|
| Minimum | 7.16 | 110 | 82.5 | 26.9 | 15 |
| Maximum | 7.9 | 975 | 731.25 | 29.8 | 1100 |
| Average | 7.48 | 523.13 | 392.34 | 28.54 | 488 |
| Std. dev. | 0.29 | 356.62 | 267.47 | 1.14 | 526.74 |
| Control | 7.24 | 110 | 82.5 | 28.1 | 12 |
| WHO 2004 | 6.5-8.5 | 1400 | 1000 | 27 | 0 |
| SON 2007 | 6.5-8.5 | 1000 | 500 | 27 | 0 |

The temperature vary between 26.9$^0$C and 29.8$^0$C with an average of 28.54$^0$C ± 1.14$^0$C which is beyond the permissible limit prescribed by WHO (2004) and SON (2007). Microbial loads of the groundwater samples vary between 15 cell/100 ml and 1101 cell/100 ml with average of 488 cell/100ml. These values are beyond permissible limits of WHO (2004) and SON (2007), indicating that the wells are contaminated (Tables 12a and 12b).

***4.5.2 Major Ions Concentrations of Ajakanga Shallow Well water***

The basic statistical summary of Ajakanga well water major ions (Table 13) showed that $Mg^{2+}$ concentrations vary between 2.26 and 34.9 mg/L with average value of 6.99 mg/L ± 11.31 mg/L, $HCO_3^-$ concentrations range between 12.2 mg/L and 148 mg/L, with an average of 65.08 mg/L ± 57.60 mg/L, $Cl^-$

Table 13: Statistical Summary of Major Ions in Shallow Wells Around Ajakanga Dumpsite

| Parameters (mg/L) n=08 | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ |
|---|---|---|---|---|---|---|---|---|
| Minimum | 0.01 | 2.26 | 32 | 40 | 12.2 | 76.8 | 0.49 | 0.84 |
| Maximum | 32.27 | 34.9 | 83 | 80 | 148 | 2143 | 40.15 | 1.8 |
| Average | 9.29 | 6.99 | 45.5 | 54.13 | 65.08 | 560.1 | 11.89 | 1.49 |
| Std. dev. | 11.72 | 11.31 | 16.24 | 12.39 | 57.6 | 804.51 | 15.28 | 0.36 |
| Control | 10,07 | 2.25 | 81 | 82 | 94 | 160 | 0.42 | 0.85 |
| WHO 2004 | 200 | 200 | 200 | | 100 | 250 | 400 | 10 |
| SON 2007 | 75 | 20 | 200 | | 100 | 100 | 250 | 10 |

ranges between 76.80 mg/L and 2143 mg/L with average value of 560.10 mg/L ± 804.51 mg/L. Some of the concentrations of these ions are higher than the recommended values by SON (2007), especially in samples 7 and 8 that are close to the dumpsite (Tables 12a, 13 and Figure 3) suggesting the dumpsite as point source of contamination. However, $Ca^{2+}$ values range between 0.01 mg/L and 32.27 mg/L, $Na^+$ concentration values vary between 32 mg/L and 83 mg/L, $K^+$ concentration ranges between 40 mg/L and 80 mg/L, $SO_4^{2+}$ values range between 0.49 mg/L and 40.15 mg/L and $NO_3^-$ concentration varies between 0.84 mg/L and 1.8 mg/L which are all below the permissible limits by WHO (2004) and SON (2007) (Tables 12a and 13).

*4.5.3 Trace Element Concentration of Ajakanga Shallow Well Water*

Table 14 contains the concentrations of trace elements in Ajakanga shallow well water while Table 15 contains the statistical summary which showed that the average values for Mn (0.31± 0.74 mg/L), Pb (0.03 ± 0.04 mg/L), Cd (0.02 ± 0.03 mg/L), As (0.06 ±0.03 mg/L) and Ni (0.13 ± 0.08 mg/L) are higher than the WHO (2007) permissible levels especially in samples 3, 4, 5, 7 and 8 that are close to the dumpsite (Tables 14, 15 and Figure 3) suggesting negative impact of the dumpsite on the wells in the immediate vicinity.

Table 14: Trace Element Concentrations of Shallow Well Water Samples, Ajakanga Dumpsite

| SAMPLE NAME (mg/L) | Fe | Si | Al | Mn | Pb | Cd | Cr | Co | Zn | Cu | As | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AJAKANGA 1 | 0.02 | 0.01 | 0.04 | 0.06 | 0.01 | 0.01 | 0.01 | 0.06 | 0.02 | 0.01 | 0.05 | 0.07 |
| AJAKANGA 2 | ND | 0.02 | 0.01 | 2.13 | ND | ND | 0.1 | ND | ND | 0.02 | 0.12 | 0.32 |
| AJAKANGA 3 | 0.01 | 0.01 | ND | 0.02 | ND | 0.01 | 0.01 | ND | ND | ND | 0.06 | 0.12 |
| AJAKANGA 4 | 0.02 | 0.38 | ND | 0.07 | 0.07 | 0.09 | 0.01 | 0.05 | 0.01 | 0.01 | 0.03 | 0.09 |
| AJAKANGA 5 | 0.02 | 0.1 | 0.05 | ND | 0.08 | 0.01 | 0.01 | ND | ND | ND | 0.07 | 0.13 |
| AJAKANGA 6 | ND | 0.28 | 0.11 | 0.1 | ND | 0.01 | 0.01 | ND | 0.01 | ND | 0.06 | 0.14 |
| AJAKANGA 7 | 0.01 | 0.03 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.07 |
| AJAKANGA 8 | 0.02 | 0.08 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.03 | 0.09 |
| AJAKANGA 8B | 0.01 | 0.07 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.08 |
| Control Sample | 0.02 | 0.02 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | ND | 0.01 | 0.02 | 0.01 | 0.02 |

ND= Not Detected

Ajakanga 8B is a duplicate of sample 8

Table 15: Statistical Summary of Trace Elements in Well Water Around Ajakanga Dumpsite

| Ajakanga (N=13) Parameters (mg/L) | Fe | Si | Al | Mn | Pb | Cd | Cr | Co | Zn | Cu | As | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | ND | 0.01 | ND | ND | ND | ND | 0.01 | ND | ND | ND | 0.02 | 0.07 |
| Maximum | 0.02 | 0.38 | 0.11 | 2.13 | 0.08 | 0.09 | 0.1 | 0.06 | 0.02 | 0.02 | 0.12 | 0.32 |
| Mean | 0.01 | 0.11 | 0.03 | 0.31 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.06 | 0.13 |
| Std. Dev | 0.01 | 0.14 | 0.04 | 0.74 | 0.04 | 0.03 | 0.03 | 0.03 | 0.01 | ND | 0.03 | 0.08 |
| Control | 0.01 | 0.02 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | ND | 0.01 | 0.02 | 0.01 | 0.02 |
| WHO 2004 | 0.3 | | 0.2 | 0.05 | 0.01 | 0.003 | 0.05 | | 3 | 2 | 0.01 | 0.02 |
| SON 2007 | 3 | | 0.5 | 0.2 | 0.01 | 0.01 | 0.003 | | 5 | 1 | 0.01 | |

ND = Not detected

## 5. Conclusion

The soil and groundwater in the immediate vicinity of the dumpsite had been negatively impacted and the pollution is more pronounced in the B-level of the soil probably due to the abundance of clay sized materials in this zone compared with A and C levels. The results of the water holding capacity from the undisturbed soil samples showed that B-level has higher water holding capacity than the A and C levels in the area possibly due to its higher contents of clay sized materials. The bulk density increases with depth due to increase in compaction while hydraulic conductivity and porosity decrease downwards. The natural subsurface processes of biodegradation, filtration, sorption and ion exchange known for attenuation of contaminants (Gray *et al*., 1974) were not effective in mitigating pollution of groundwater in the environment. Pollution is well pronunced in soil and groundwater samples taken within 500 m radius of the dumpsite.

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