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Modelling the Spatial Distribution of Heavy Metal Pollution in Groundwater System Near Selected Waste Dumpsites in Rivers State

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ABSTRACT:

This study was focused om development of model for the prediction of heavy-metal pollution in ground water sample near waste dumpsite in selected communities in Rivers State. Two waste dumpsites in Choba and Aluu communities in River state were randomly sampled. Boreholes were sampled at distances of 50m, 100m and 150m away from the dumpsites and a control sample was collected at 300m away from the dumpsite. Groundwater samples were collected from the boreholes and taken to laboratory for identification of presence and concentration of the heavy metals. The results of the analysis revealed eight different heavy metals in the water samples namely, Copper, Mercury, Barium, Cadmium, Chromium, Iron, Lead and Zinc.Model were developed using Excel to expressed the relationship between the concentration of the heavy metal and their distances away from the dumpsites. The models revealed that there is inverse relationship between concentration of the heavy metal and distance of sampled location from the dumpsites in both locations. In Aluu, the results revealed that the percentage deviation between model-calculated values and actual values for copper, mercury, barium, chromium and iron were 11.00, 8.30, 6.00, 8.75 and 15% respectively. However, the model-calculated values for cadmium, zinc and lead were negative which suggest that 300m is outside the active zone of the heavy metals originating from the dumpsite, meaning that the concentrations of cadmium, zinc and lead obtained at this distance did not originate from the dumpsites. In Choba, the results revealed that the percentage deviation between model-calculated values and actual values for copper, barium and lead were 6.00, 9,80 and 6.67% respectively, However, model-calculated values for chromium, cadmium, zinc, mercury and iron were negative which suggest that 300m is outside the active zone of these heavy metals originating from the dumpsite which also means that the concentrations of chromium, cadmium, zinc, mercury and iron obtained at this distance did not originate from the dumpsites. It was concluded that the models are significantly suitable for the prediction of heavy metal pollution with respect to their distance from dumpsite.

Keywords:

Modelling, Spatial distribution, Heavy Metal pollution, Groundwater, Dumpsite, Rivers State.

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1. Introduction

Groundwater is a major part of the natural water cycle and it has been established that about 30 percent of available freshwater in the world is groundwater. A unit of rock or an unconsolidated deposit is classified as an aquifer when it can yield a usable quantity of groundwater (Famiglietti.2014). A substantial fraction of precipitation that lands on the ground surface infiltrates into the subsurface to form groundwater system (Famiglietti.2014). The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from the surface; it may discharge from the surface naturally as springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipaland industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is known as hydrogeology, also called groundwater hydrology (Famiglietti.2014).

Contamination of groundwater by chemical species such as heavy metals, nitrates, fluorides, microorganisms etc. can affect the health status of humans who is the ultimate user of the water. These chemical species find their way into the water aquifer through leaching. Such human activities that introduces these unwanted species to the groundwater are processing of metals, exploration, production and eventual exploitation of oil, agricultural activities, mining and through indiscriminate disposal of the byproducts of these human activities have added to the already overburdened situation (Adeyemi and Awokunmi, 2016; Edori et al., 2019). The manner in which the inhabitants of a particular area dispose wastes can also contribute to the level of contamination of the groundwater. The groundwater can be easily polluted through wastes, sewage and effluents that originates from homes, industries and commercial centers through percolation into the water underground.

Groundwater has various advantages over surface water as it is not exposed to water pollutants associated with surface waters. It is in view of this that the WHO recommended that drinking water supplies should be well analyzed based on their contamination or pollution level (Mgbemena et al 20914). Very few people in small towns have access to safe water supply. Only about 5 percent get water from protected ground sources through boreholes (Bunce 2014). The WHO had stated that it is not sufficient merely to have access to water in adequate quantities, the water also needed to be of adequate quality to maintain good health (WHO 2017). Such water must be free from toxic biological, physiological and chemical contaminations. The widespread reports on pollutants in groundwater have increased in recent years and have resulted in increased public concern about the quality of groundwater. The importance of potable water, both for domestic and industrial uses, has created concern for water quality analysis (Bunce 2014). The compounds contained in groundwater, sometimes used as drinking water, are dangerous to human health because of the possibility of a mutagenic and carcinogenic reaction (Owabor et al., 2010).

Groundwater bodies are prone to contamination from both anthropogenic and natural activities (Umo& Okoye 2017). Boreholes, though more protected as a result of inherent chemical constituents of permeable rocks through which the water flows, can limit the quality of the water as they may have dissolved impurities which came from rock and sand strata through which the water flowed or passed (Okuo et al., 2016). The seepage of waste buried underground such as pit dump sites, pit toilets or leachate from fertilizer applications and debris from erosion can produce harmful effects on groundwater quality especially in groundwater reserve close to the pit dumpsites and pit toilets.

The widespread reports on contaminants in groundwater have increased in recent years and have resulted in increased public concern about the quality of groundwater (Bunce, 2004). The compounds contained in groundwater, sometimes used as drinking water, are dangerous to human health, particularly the heavy metals, because of their possible mutagenic and carcinogenic reaction (Okuo et al., 2007). Groundwater bodies are prone to contamination from both man-made and natural activities (Owabor et al 2010). The seepage of wastes dumped inside the underground dumps such as pit dump sites, pit toilets or leachate from fertilizer applications and debris from erosion can produce harmful effects on ground water quality especially in areas near the waste dumpsites. Hence, this current study was carried out to model the spatial distribution of heavy metals pollution in groundwater near waste dump sites in Port-Harcourt. This research is mainly targeted at ascertaining the how concentration of heavy metal near borehole water sourced close to dump sites could be predicted.

There are several empirical studies carried out to examine the heavy metal pollution in groundwater system near dumpsites in Nigeria. Festus et al (2016) carried out study on groundwater samples collected from boreholes close to a dumpsite in Rumuolumeni, Port Harcourt in the months of January, April, August and November. The water sampled were analyzed for physicochemical properties and heavy metals using APHA standard methods. The data obtained did not reveal any significant changes between the months and the seasons. The physicochemical parameter such as temperature. pH, conductivity, hardness and alkalinity were within the acceptable limits by WHO, NAFDAC and FMENV while Total dissolved solids (TDS) values were above the standard requirements by the agencies. The heavy metals such as Manganese (Mn), Lead and Cadmium (Cd) were higher than the recommended values while Iron and Cobalt values fell within the WHO requirements but were above the NAFDAC and FMENV values. The observed result is an indication of water contamination which suggest that presence of the dumpsite may have affected the quality of the groundwater. Therefore, the water is not suitable for drinking since it can constitute a source of health risk and hazard.

Nwoke and Edori (2021) conducted empirical study on presence of six chemical species Pb, Cd, As, nitrates, fluorides and sulphates in the groundwater (borehole) samples from four boreholes sited close to a dumpsite in Rumuolumeni, Port Harcourt, Rivers State, Nigeria. Nitrates, fluorides and sulphates were analyzed using standard conventional methods while the heavy metals were determined and analyzed with Atomic Absorption Spectrophotometer. The mean values obtained for these heavy metals showed that the boreholes sited near the dumpsite were still at the level that will not pose any health risk to the user, for their concentrations were still within limits allowed by WHO and USEPA. Even though the government and its agencies should regulate the mode of dumping of refuse and also the siting of boreholes so that the groundwater will not be polluted

Sokpuwu (2017) carried out study to assess the groundwater quality of Ebubu community in Eleme between June 2015 and August 2015. Water samples were collected from ten functional boreholes using standard techniques. Heavy toxic metals (Cd, Pb, Ni and Co) and Polyaromatic Hydrocarbons (PAHs) levels were assessed using standard analytical protocols. The concentration of the heavy metals in the water sampled were above the WHO and NIS limits. The water quality parameters varied across the sampling periods (June and August). These results mean that the groundwater from the community is unsafe for drinking purpose due to elevated levels of toxic metals. In light of these findings, periodic analysis of samples from boreholes is inevitable. Such analysis will reveal pollution status of groundwater in this area and to determine the best method for water treatment, to intimate

consumers and other users of the groundwater, and also to safeguard their health against the subsequent impact that may arise from drinking polluted water.

These empirical studies confirm the widespread reports on contamination of groundwater, due to presence of waste dumpsites. They revealed that the compounds contained in groundwater, sometimes used as drinking water, are dangerous to human health, particularly the heavy metals, because of their possible mutagenic and carcinogenic reaction. Hence, this study is carried out to model the distribution of the heavy metal pollution in groundwater near waste dumpsite in selected communities in Rivers State in order to accurately predict the distribution of groundwater pollution due to heavy metal content and also predict the safe and unsafe distance from the waste dumpsite .therefore, the objectives of the study is to: Collect and analyse groundwater samples near waste dumpsites in Choba and Aluu Communities in River state for some selected heavy metals. Compare the concentrations of the selected heavy metals with drinking water standards and develop model to predict the distribution of the heavy metals' pollution in the groundwater samples.

2. Materials and Methods

2.1 Research Design

This study adopted Experimental design. The design is suitable for this study because it involves carrying out empirical study in which the researcher has room to control and manipulate the independent variable based on the limitations and scope of this study. In this study, the independent variables which are at the disposal of the researcher are distant of boreholes from dumpsite and time interval for the collection of water samples from boreholes while the dependent variable is the concentration of heavy metals in the water sample

2.2 Study Area

The study areas are Choba Community in Obioakpor LGA and Aluu Community in Ikwerre LGA all in River state. Two waste dumpsites located within these two communities were the focal point of the study along with some boreholes sited at various distances away from the waste dumpsites see Figure 1. These study areas as well as the entire Rivers State, lies within the Niger Delta Sedimentary Basin. Lithostratigraphically, the rocks are divided into the oldest Akata Formation (Paleocene), the Agbada Formation (Eocene) and the Youngest Benin Formation (Miocene to Recent) which hold the ground water aquifer in the area and the main subject of interest in this current study.

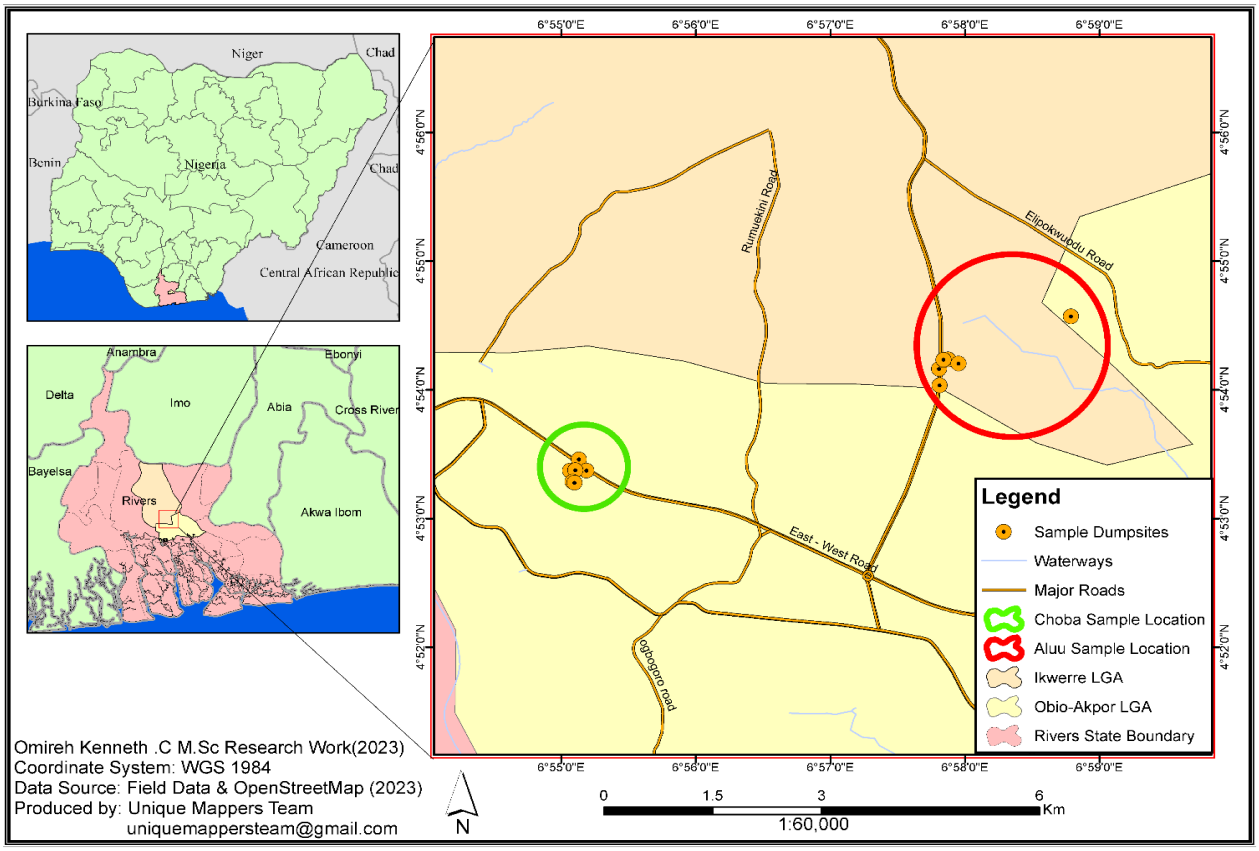

Figure 1: Map of the Study Area showing locations where main water samples were collected

2.3 Type of Data:

The data used in this study include both primary and secondary data. The primary data were sourced from the study area which included data on the concentration of the heavy metal in the water sample, data on the distance of the sampled boreholes from the dumpsites and the time interval for collection of the water samples. The secondary data was mainly data on the permissible limit for different concentration of heavy metal in water from (WHO, 2017).

2.4 Procedure for Data Collections.

1. Two dumpsites (Dumpsites in Choba Community in Obioakpor LGA and Aluu Community in Ikwerre LGA) were sampled within River state and they were labeled Site 1 (S1) and Site 2 (S2) respectively.
2. Different boreholes were sampled at different distances of 50m, 100m and 150m away from the dumpsite site 1 and site 2 these boreholes was labelled B1a, B1b, B1c, Cb1 for Site 1 and B2a, B2b, B2c and Cb2 for Site 2
3. Geo-mapping procedures was used to ascertain the coordinate of the dumpsites and the boreholes sampled.
4. Groundwater samples were collected from the boreholes in October, Hence, considering that there are four boreholes in each sampled area, which makes eight water samples was collected from the sites, four water samples for each area sampled for the study during the months.

5. The groundwater samples were taken to laboratory for identification of presence and concentration of the heavy metals

2.4.1 Procedure for identification of Presence and Concentration of the Heavy Metals in the water sample

The determination of presence and concentration of the heavy metal content in the sample was carried out according to the SNI 6989.8-2009 procedure; SNI 6989.6-2009 and SNI 062462-1991. this procedure involves

1. 50ml of sample was put into 100 ml Erlenmeyer, added 5ml of concentrated HNO3 then covered with a funnel.
2. It is heated slowly until the remaining volume is 15ml-20ml, if the digestion is not complete (not clear) then add another 5 ml of concentrated HNO3 then cover and heat again (not boiling) until all the metal dissolves.
3. The levels of the heavy metal were tested by testing the test samples one by one into the Atomic Absorption Spectrophotometer (AAS, Shimadzu AA-6300). AAS device with a wavelength of 283.3 nm. Furthermore, the metal absorption of each metal was carried out.
4. The AAS was calibrated with relevant Shimadzu AAS spectroscopic grade standards. Flame atomic absorption spectrophotometer (Shimadzu double beam Atomic Absorption Spectrophotometer) (Direct determination - Flame: Pb, 0.1ppm; Furnace: Pb, 0.3 ppb).
5. Some heavy metal that would be suspected based on results of other similar study in Rivers State are Cadmium, Lead, Iron, Copper, Mercury, Zinc, Barium and Chromium

2.5 Statistical Analysis

Descriptive statistic (means and graphs) was used for data analysis. Simple linear regression was used to develop the model. The data analysis was carried out using the Excel package

3.0 Results and Discussions

Eight different heavy metals were discovered in the water samples from the two sites as different distances from the dumpsites, and the metals includes, Copper (Cu), Mercury (Hg), Lead (Pb), Barium (Ba), Cadmium (Cd) Chromium (Cr), Iron (Fe) and Zinc (Zn). The discussion is based on WHO (2020) standard for drinking water.

3.1 Concentrations of the selected heavy metals with drinking water standards

Table 1 and Table 2 shows the concentration of heavy metal in the water samples collected at differences distance away from the dumpsites and the recommended WHO standard. From Table 1 it is observed that in Aluu area, the concentrations of cupper, mercury, barium, cadmium, Chromium, and iron were lower than the recommended standard limit within the distances of 50, 100 and 150m away from the waste dumpsite. However, the results revealed that the concentration of these aforementioned heavy metals increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite.It is also observed that the concentration of Lead was higher than the recommended standard within the distances of 50 and 100 away from the waste dumpsite, and that the concentration of the lead also increases

as distance toward the waste dumpsite decreases which is also an indication that the source of the metal is mostly likely to be the waste materials in the dumpsite.

Table 1 Concentration of heavy metal in water sampled from borehole at different distances from a waste dumpsite in Aluu area compare to WHO standard.

Distance	50m	100m	150m	WHO Standard
Copper	0.0038	0.0031	0.0024	0.020
Mercury	0.00027	0.00022	0.00013	0.001
Barium	0.027	0.022	0.0130	0.030
Cadmium	0.018	0.013	0.0080	0.050
Chromium	0.0028	0.0022	0.0020	0.003
Zinc	0.039	0.017	0.0120	3.000
Lead	0.0126	0.0105	0.0095	0.010
Iron	0.0155	0.0125	0.0065	0.300

From Table 2, it is observed that in Choba area, the concentrations of cupper were lower than the recommended standard within the distances of 50, 100 and 150m away from the waste dumpsite. The results also revealed that the concentration of the cupper increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite similar to what was observed in Aluu area.It is also observed that the concentrations of mercury were lower than the recommended standard limit within the same distances of 50, 100 and 150m away from the waste dumpsite, and that the concentration of the cupper increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite. These same results were observed for the other six heavy metals discovered in the water sampled within the area. However, it was observed that the concentration of all the heavy metals were higher in the water sample within the Aluu area than those sampled within Choba at same distance away from the dumpsites.

Table 2 Concentration of heavy metal in water sampled from borehole at different distance from a waste dumpsite in Choba area compare to WHO standard

Distance	50m	100m	150m	WHO Standard
Copper	0.0036	0.0030	0.00225	0.020
Mercury	0.00019	0.00017	0.00015	0.001
Barium	0.026	0.021	0.012	0.030
Cadmium	0.0016	0.0010	0.0006	0.050
Chromium	0.00185	0.0013	0.0009	0.003
Zinc	0.0095	0.0075	0.006	3.000
Lead	0.0086	0.0055	0.0025	0.010
Iron	0.005	0.0035	0.002	0.300

3.2 Development of models to predict the prevalence of heavy metals in groundwater with respect to distance from waste dumpsite

Figure 2 to 9 showed that graphical expression of the relationship between concentration of the heavy metals in the water sample from different distances of the boreholes away from a dumpsite using two dumpsites in Choba and Aluu. A simple linear model was also developed to further express the relationships mathematically.

3.2.1 Model for distribution of Copper

From Figure 2 it was observed that there is inverse and linear relationship between concentration of the Copper in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trend line of the relationship in Aluu is higher than that of the Choba which revealed that the concentration of copper is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the narrow gap between the two trendline in an indication of the fact that the difference between the concentration of copper in the water sampled from these two areas is not significant. The simple linear model for the relationship between concentration of the Copper in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$y = -0.0001x + 0.045 \quad (1)$$

$$y = -0.0001x + 0.0437 \quad (2)$$

where y is the concentration of copper (C) and x is distance (D) from dumpsite, replacing y with Cc and x with D

$$C_c = -0.0001D + 0.045 \quad (3)$$

$$C_c = -0.0001D + 0.0437 \quad (4)$$

Based on these models, the assumed concentration of copper at the center of the dumpsites is the values of C in the equation 3 and 4 at which D = 0, which are 0.045 and 0.0437 for Aluu and Choba. these values are higher that the WHO recommended concentration for copper in water sample which is 0.02,Also, the distance away from the dumpsite at which the there is no trace of copper in underground water sample is given as the value of distance D in the two models at which the C is equal to zero and it is calculated as 450 meters and 437 for Aluu and Choba area respectively.

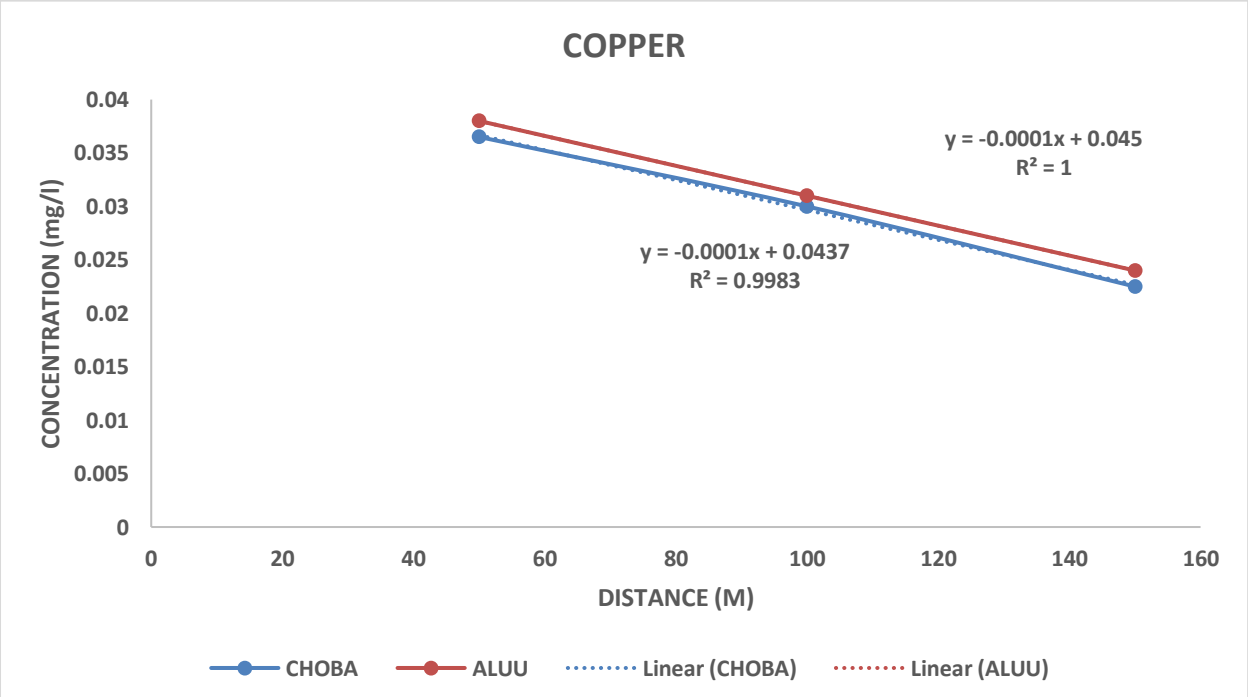

Figure 2The relationship between concentration of copper and distance from waste dumpsite for Choba and Aluu area

3.2.2 Model for distribution of Mercury

From Figure 3 it was observed that there is inverse and linear relationship between concentration of the mercury in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which revealed that the concentration of mercury is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the wider gap between the two trendline in an indication of the fact that the difference between the concentration of mercury in the water sampled from these two areas is significant. The simple linear model for the relationship between concentration of the mercury in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$y = -0.00001x + 0.0035 \quad (5)$$

$$y = -0.000005x + 0.0012 \quad (6)$$

where y is the concentration of mercury C_{Hg} and x is distance (D) from dumpsite, replacing y with C_{Hg} and x with D

$$C_{Hg} = -0.00001D + 0.0035 \quad (7)$$

$$C_{Hg} = -0.000005D + 0.0012 \quad (8)$$

Based on these models, the assumed concentration of mercury at the center of the dumpsites is the values of C_{Hg} in the equation 7 and 8 at which D =0, which are 0.0035 and 0.0012 for Aluu and Choba. these values are higher that the WHO recommended concentration for mercury in water sample which is 0.001, Also, the distance away from the dumpsite at which the there is no trace of mercury in underground water sample is given as the value of distance D in the two models at which the C_{Hg} is equal to zero and it is calculated as 350 meters and 240 meters for Aluu and Choba area respectively.

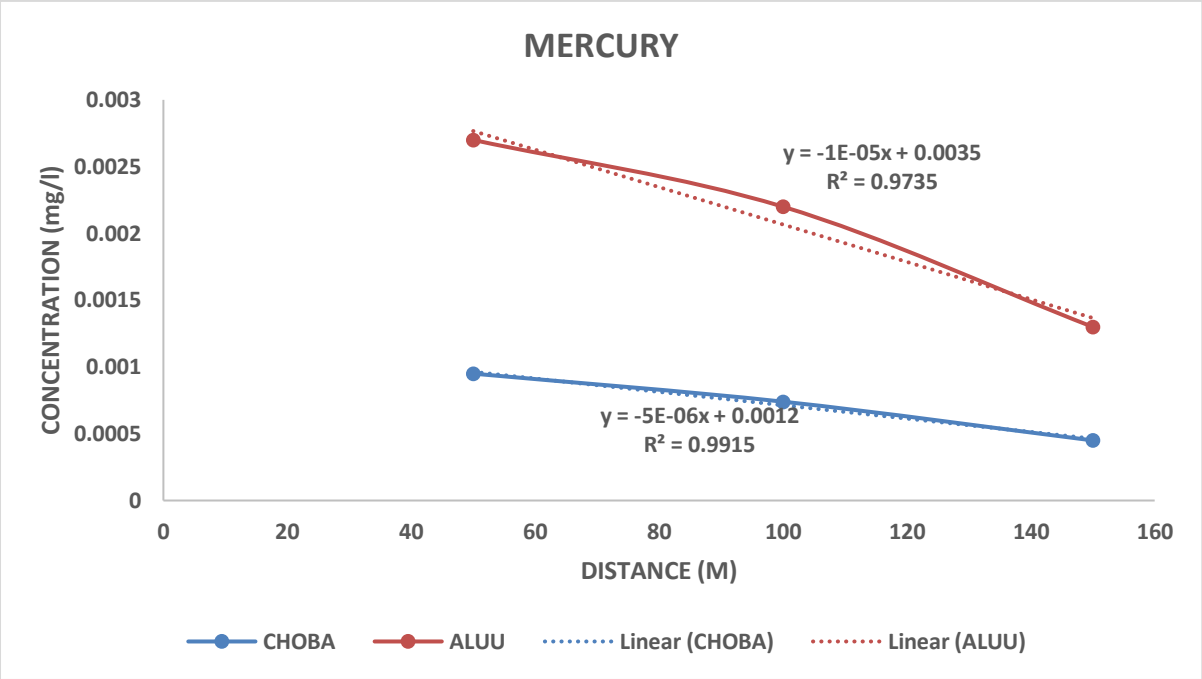

Figure 3 The relationship between concentration of mercury and distance from waste dumpsite for Choba and Aluu area

3.2.3 Model for distribution of Barium

From Figure 4, it was observed that there is inverse and linear relationship between concentration of the barium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of barium is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the narrow gap between the two trendline in an indication of the fact that the difference between the concentration of barium in the water sampled from these two areas is not significant. The simple linear model for the relationship between concentration of the barium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$y = -0.0001x + 0.0347 \quad (9)$$

$$y = -0.0001x + 0.0337 \quad (10)$$

where y is the concentration of barium C_{Ba} and x is distance (D) from dumpsite, replacing y with C_{Ba} and x with D

$$C_{Ba} = -0.0001D + 0.0347 \quad (11)$$

$$C_{Bs} = -0.0001D + 0.0337 \quad (12)$$

Based on these models, the assumed concentration of Barium at the center of the dumpsites is the values of C_{Ba} in the equation 11 and 12 at which D =0, which are 0.0347 and 0.0337 for Aluu and Choba. these values are higher that the WHO recommended concentration for barium in water sample which is 0.03, Also, the distance away from the dumpsite at which the there is no trace of barium in underground water sample is given as the value of distance

D in the two models at which the C_{Hg} is equal to zero and it is calculated as 347 meters and 337 meters for Aluu and Choba area respectively.

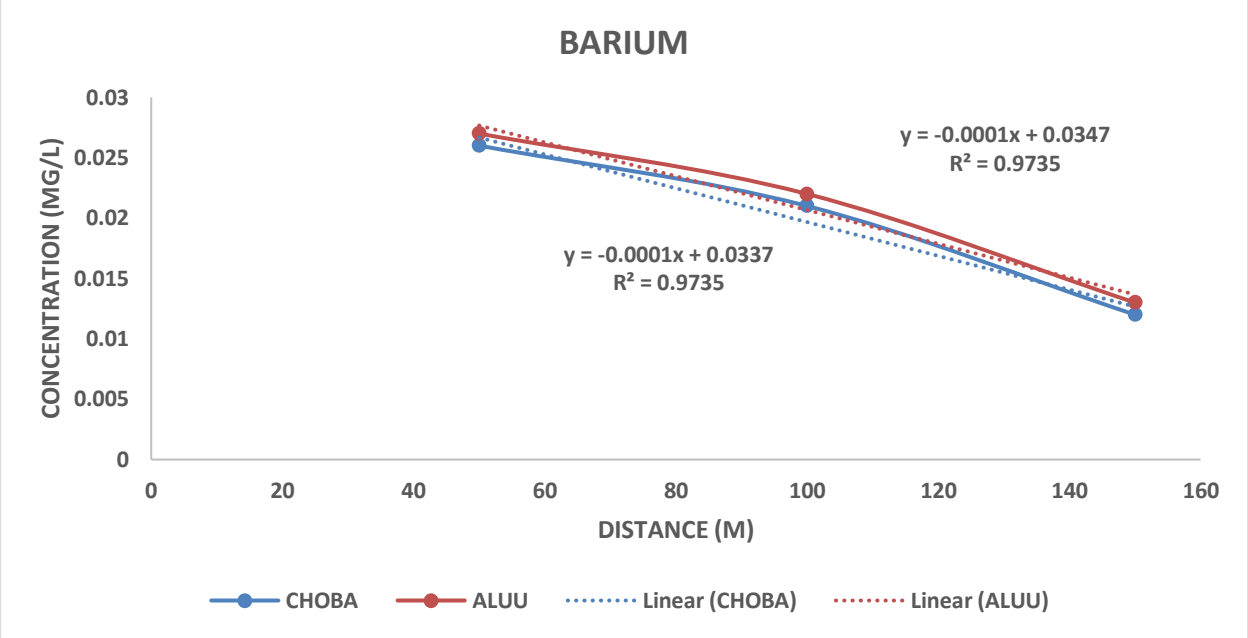

Figure 4 The relationship between concentration of Barium and distance from waste dumpsite for Choba and Aluu area

3.2.4 Model for distribution of Cadmium

From Figure 5 it was observed that there is inverse and linear relationship between concentration of the cadmium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of cadmium is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the narrow gap between the two trendline in an indication of the fact that the difference between the concentration of cadmium in the water sampled from these two areas is not significant. The simple linear model for the relationship between concentration of the cadmium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$\mathbf{y = -0.00001x + 0.0023} \qquad \mathbf{13}$$

$$\mathbf{y = -0.00001x + 0.0021} \qquad \mathbf{14}$$

where y is the concentration of Cadmium C_{cd} and x is distance (D) from dumpsite, replacing y with C_{Cd} and x with D

$$\mathbf{C_{Cs} = -0.00001D + 0.0023} \qquad \mathbf{15}$$

$$\mathbf{C_{Cd} = -0.00001D + 0.0021} \qquad \mathbf{16}$$

Based on these models, the assumed concentration of cadmium at the center of the dumpsites is the values of C_{Ba} in the equation 15 and 16 at which D =0, which are 0.0023 and 0.0021 for Aluu and Choba. these values are lower than the WHO recommended concentration for

cadmium in water sample which is 0.05, Also, the distance away from the dumpsite at which the there is no trace of cadmium in underground water sample is given as the value of distance D in the two models at which the C_{Cd} is equal to zero and it is calculated as 230 meters and 210 meters for Aluu and Choba area respectively.

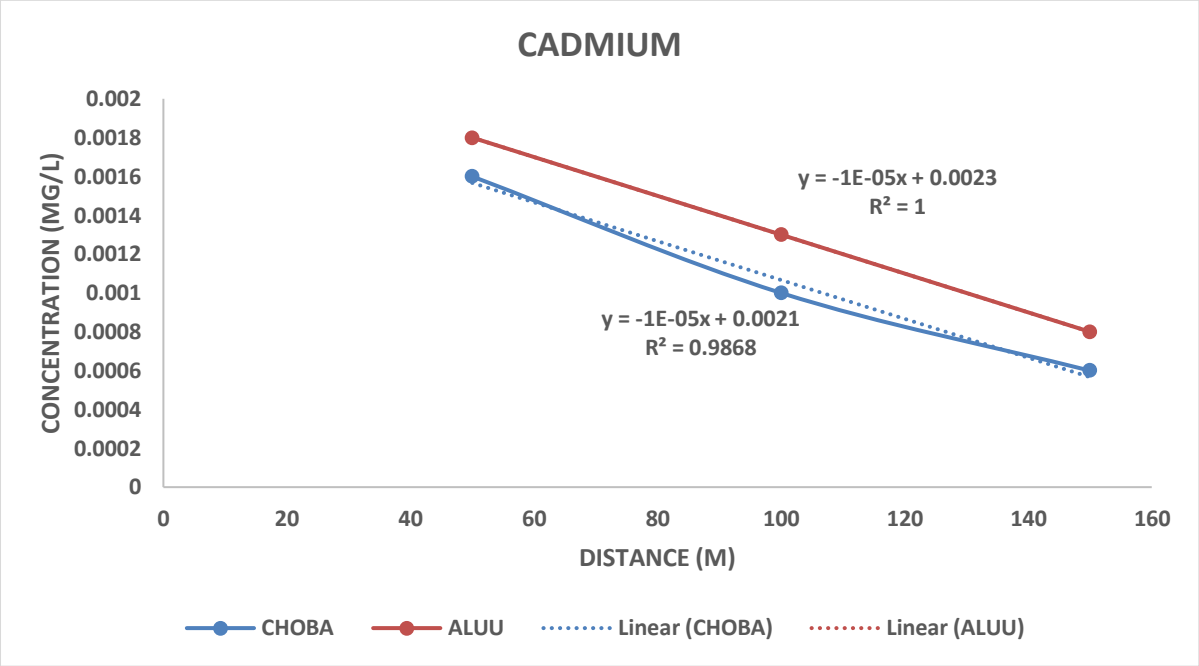

Figure 5The relationship between concentration of Cadmium and distance from waste dumpsite for Choba and Aluu area

3.2.5 Model for distribution of Chromium

From Figure 6 it was observed that there is inverse and linear relationship between concentration of the chromium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of chromium is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the wide gap between the two trendline in an indication of the fact that the difference between the concentration of chromium in the water sampled from these two areas is significant. The simple linear model for the relationship between concentration of the chromium in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$y = -0.00008x + 0.0313 \quad (17)$$

$$y = -0.00009x + 0.0230 \quad (18)$$

where y is the concentration of Chromium C_{Cr} and x is distance (D) from dumpsite, replacing y with C_{Cr} and x with D

$$C_{Cr} = -0.00008D + 0.0313 \quad (19)$$

$$C_{Cr} = -0.00009D + 0.0230 \quad (20)$$

Based on these models, the assumed concentration of chromium at the center of the dumpsites is the values of C_{Ba} in the equation 19 and 20 at which D =0, which are 0.0313 and 0.023 for Aluu and Choba. these values are higher than the WHO recommended concentration for chromium in water sample which is 0.003, Also, the distance away from the dumpsite at which the there is no trace of chromium in underground water sample is given as the value of distance D in the two models at which the C_{Cr} is equal to zero and it is calculated as 391.25 meters and 255.56 meters for Aluu and Choba area respectively.

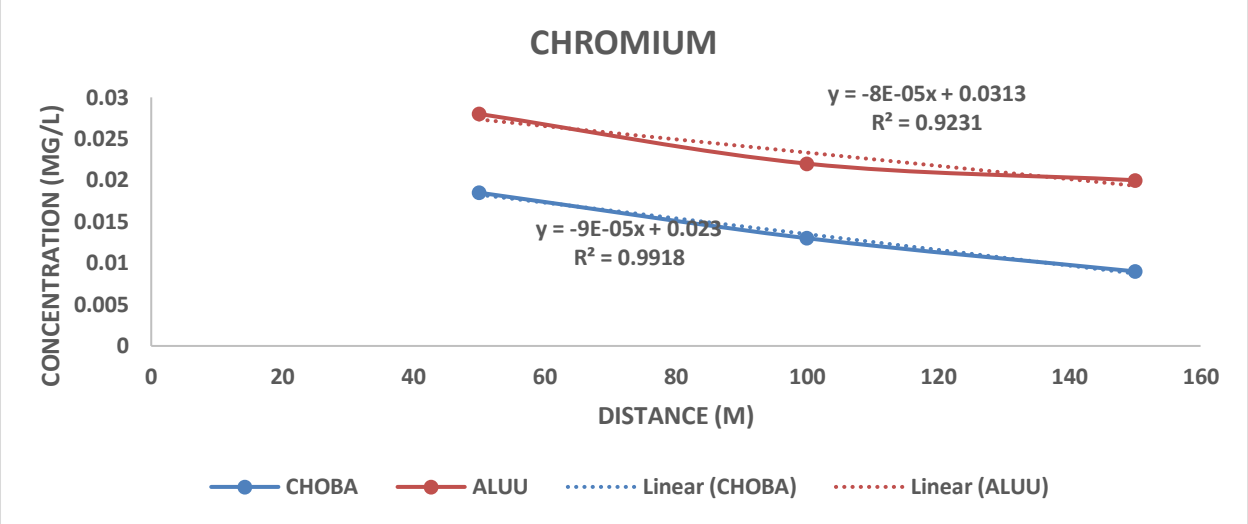

Figure 6The relationship between concentration of Chromium and distance from waste dumpsite for Choba and Aluu area

3.2.6 Model for distribution of Zinc

From Figure 7 it was observed that there is inverse and linear relationship between concentration of the zinc in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of zinc is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the wide gap between the two trendline in an indication of the fact that the difference between the concentration of zinc in the water sampled from these two areas is significant. The simple linear model for the relationship between concentration of the zinc in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$\mathbf{y = -0.0003x + 0.0497} \qquad \mathbf{21}$$

$$\mathbf{y = -0.00004x + 0.0112} \qquad \mathbf{22}$$

where y is the concentration of Zinc C_{Zn} and x is distance (D) from dumpsite, replacing y with C_{Zn} and x with D

$$\mathbf{C_{Zn} = -0.0038D + 0.0497} \qquad \mathbf{23}$$

$$\mathbf{C_{Zn} = -0.00004D + 0.0112} \qquad \mathbf{24}$$

Based on these models, the assumed concentration of Zinc at the center of the dumpsites is the values of C_{Zn} in the equation 23 and 24 at which D =0, which are 0.0497 and 0.023 for Aluu and Choba. these values are lower than the WHO recommended concentration for zinc in water sample which is 3.00, Also, the distance away from the dumpsite at which the there is no trace of zinc in underground water sample is given as the value of distance D in the two models at which the C_{Zn} is equal to zero and it is calculated as 165.25 meters and 255.56 meters for Aluu and Choba area respectively

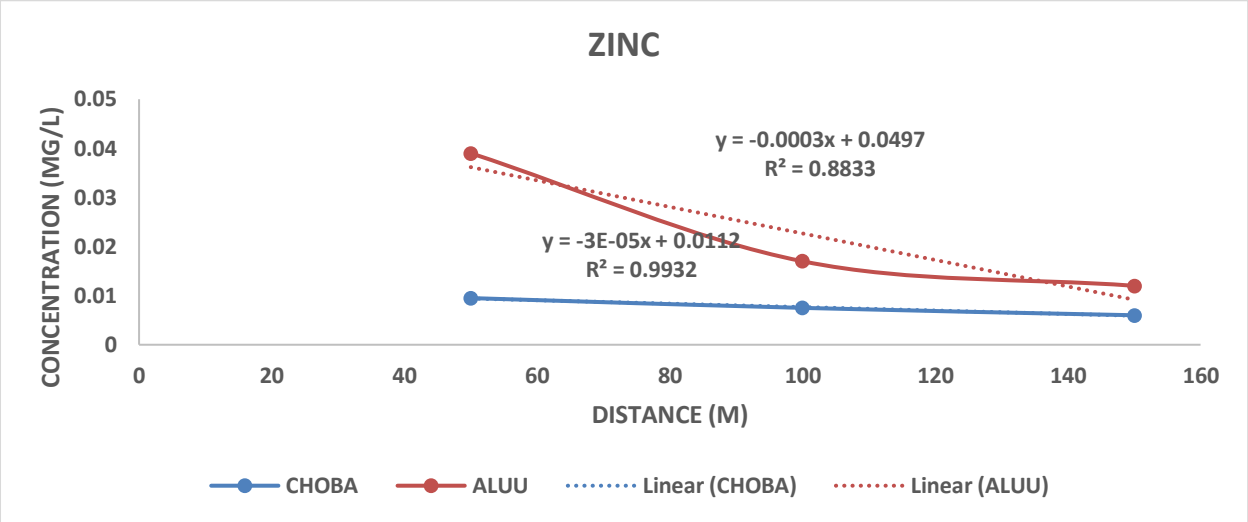

Figure 7The relationship between concentration of Zinc and distance from waste dumpsite for Choba and Aluu area

3.2.7 Model for distribution of Lead

From Figure 8 it was observed that there is inverse and linear relationship between concentration of the Lead in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of lead is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the wide gap between the two trendline in an indication of the fact that the difference between the concentration of lead in the water sampled from these two areas is significant. The simple linear model for the relationship between concentration of the lead in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$y = -0.0003x + 0.1397 \quad (25)$$

$$y = -0.00006x + 0.0116 \quad (26)$$

where y is the concentration of lead C_{Pb} and x is distance (D) from dumpsite, replacing y with C_{Zn} and x with D

$$C_{Pb} = -0.0003D + 0.1397 \quad (27)$$

$$C_{Pb} = -0.00006D + 0.0116 \quad (28)$$

Based on these models, the assumed concentration of lead at the center of the dumpsites is the values of C_{Pb} in the equation 27 and 28 at which D =0, which are 0.1397 and 0.0116 for Aluu and Choba. these values are higher than the WHO recommended concentration for lead in water sample which is 0.01, Also, the distance away from the dumpsite at which the there is no trace of lead in underground water sample is given as the value of distance D in the two models at which the C_{Zn} is equal to zero and it is calculated as 193.33meters and 465.67meters for Aluu and Choba area respectively

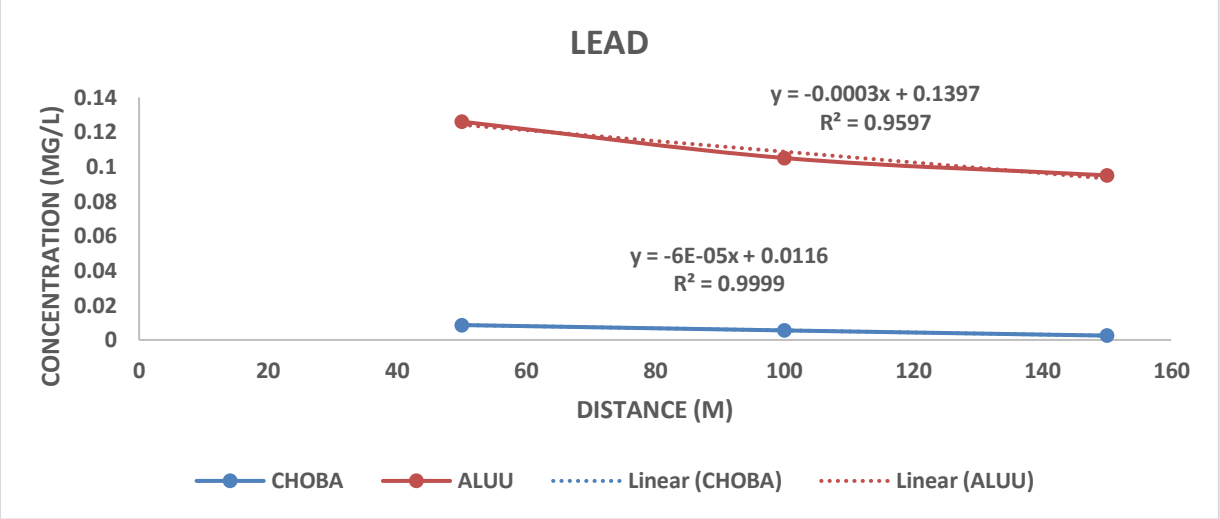

Figure 8The relationship between concentration of Lead and distance from waste dumpsite for Choba and Aluu area

3.2.8 Model for distribution of Iron

From Figure 9 it was observed that there is inverse and linear relationship between concentration of the iron in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu. It is observed that the trendline of the relationship in Aluu is also higher than that of the Choba which also revealed that the concentration of iron is higher in water sample obtained from boreholes in Aluu are than those obtained from boreholes in Choba area. However, the wide gap between the two trendline in an indication of the fact that the difference between the concentration of iron in the water sampled from these two areas is significant.The simple linear model for the relationship between concentration of the iron in the water sample and the distance of the water sources (borehole) from the dumpsite in the two sampled area in Choba and Aluu respectively is expressed as

$$\mathbf{y = -0.00009x + 0.0205} \qquad \mathbf{29}$$

$$\mathbf{y = -0.00003x + 0.0065} \qquad \mathbf{30}$$

where y is the concentration of lead C_{Fe} and x is distance (D) from dumpsite, replacing y with C_{Zn} and x with D

$$\mathbf{C_{Fe} = -0.00003D + 0.0205} \qquad \mathbf{31}$$

$$\mathbf{C_{Fe} = -0.00003D + 0.0065} \qquad \mathbf{32}$$

Based on these models, the assumed concentration of iron at the center of the dumpsites is the values of C_{Fe} in the equation 31 and 32 at which D =0, which are 0.0205 and 0.0065 for Aluu

and Choba. these values are lower than the WHO recommended concentration for lead in water sample which is 0.3, Also, the distance away from the dumpsite at which the there is no trace of irony in underground water sample is given as the value of distance D in the two models at which the C_{Fe} is equal to zero and it is calculated as 683.33meters and 216.67meters for Aluu and Choba area respectively

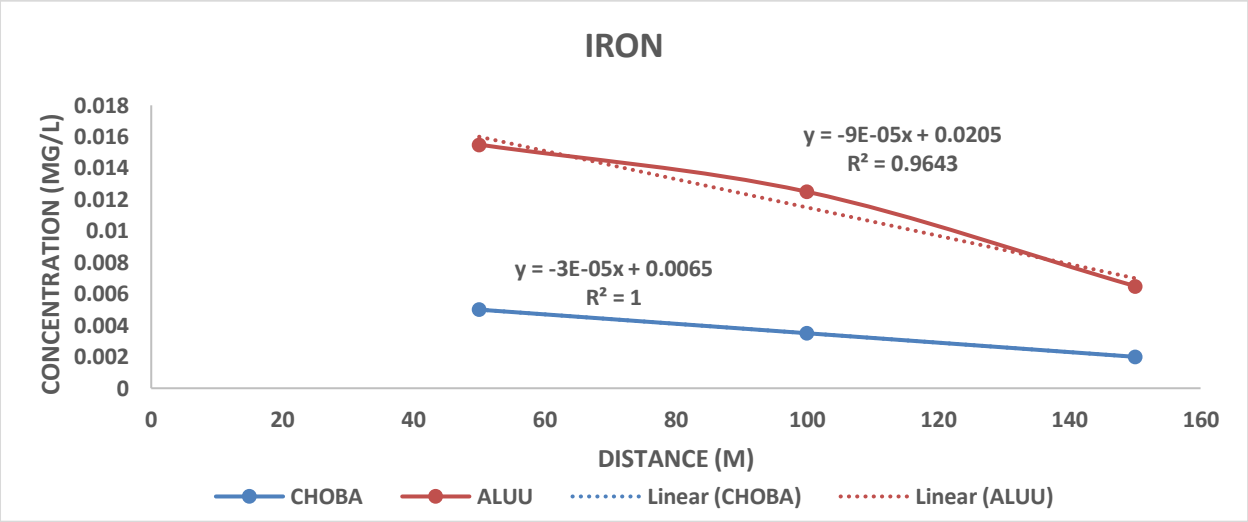

Figure 9The relationship between concentration of Iron and distance from waste dumpsite for Choba and Aluu area

3.3 Validation of the Models

In order to validate the models formulated in section 4.1.3 above for the prediction of the concentration of the heavy metals near the dumpsites in the researched areas, a control water samples were obtained from three boreholes at distances of 300m from the two dumpsites and the concentration of the heavy metal were also ascertained. The average of the concentration of the heavy metals from the three water samples were obtained and compared with the value calculated from the models.

Table 3 and 4 shows the values of the model validation process which comprised of the calculated value from the models, the control value and the percentage deviation of the calculated value from the control value for the Aluu and Choba areas. From Table 3, it was observed that the percentage deviation of the model-calculated values from the actual or control values for copper, mercury, barium, chromium and iron were 11.00, 8.30, 6.00, 8.75 and 15% respectively for Aluu area. These values imply that the models developed in this study for the prediction of the copper, mercury, barium, chromium and iron in water samples close to dumpsites in Aluu area predicted the concentrations of these aforementioned heavy metals with accuracy levels of 89%, 91.70%, 94%, 91.25% and 85%. This accuracy levels are significantly high which means that the models are substantially valid. However, the model-calculated values for cadmium, zinc and lead were negative which suggest that 300m is outside the active zone of the heavy metals originating from the dumpsite. This means that the concentrations of cadmium, zinc and lead obtained at this distance are not from the dumpsites but could be as a result of other activities within this area.

From Table 4, it was also observed that the percentage deviation of the model-calculated values from the actual or control values for copper, barium and lead were 6.00, 9,80 and 6.67% respectively for Choba area.These values imply that the models developed in this

study for the prediction of the copper, barium and lead in water samples close to dumpsites in Choba area predicted the concentrations of these aforementioned heavy metals with accuracy levels of 94%, 90.20% and 93,33%. This accuracy levels are also significantly high which means that the models are substantially valid. However, the model-calculated values for other heavy metal such as chromium, cadmium, zinc, mercury and iron were negative which suggest that 300m is outside the active zone of these heavy metals originating from the dumpsite. This also means that the concentrations of chromium, cadmium, zinc, mercury and iron obtained at this distance are not from the dumpsites but could be as a result of other activities within this area.

Table 3 Validation of Models for Aluu area

Heavy metal	Calculated Value at 300m	Actual Value at 300m	Percentage deviation
Copper	0.0150	0.0170	11.0
Mercury	0.0005	0.00055	8.30
Barium	0.0047	0.0050	6.00
Cadmium	-0.0007	0.0014	-
Chromium	0.0073	0.0080	8.75
Zinc	-1.0900	0.0151	-
Lead	-0.7603	0.050	-
Iron	0.0115	0.010	15.00

Table 4 Validation of Models for Choba area

Heavy metal	Calculated Value at 300m	Actual Value at 300m	Percentage deviation
Copper	0.014	0.015	6.00%
Mercury	-0.0005	0.0008	-
Barium	0.0037	0.0041	9.80
Cadmium	-0.0090	0.0015	-
Chromium	-0.0040	0.0075	-
Zinc	-0.0008	0.010	-
Lead	0.0064	0.0060	6.67
Iron	-0.0025	0.015	-

3.4 Discussion of the finding

The study was centered om development of models suitable for prediction of concentration of heavy metal in groundwater with respect to distance from waste dumpsite. The mathematical models revealed that there is inverse and linear relationship between concentration of the heavy metals and distance from the dumpsites. This means that the concentration of the heavy mental increases as distance to the dumpsite decreases (as one gets crosser to the dumpsite). These results indicate that the waste dumpsite could be the source of the heavy metal. Thus, there could be a gradual vertical seepage of the heavy metals from the dumpsite through the vertical permeable and porous underground formations down to the water aquifer and another horizontal seepage of the contaminated groundwater through the porous horizontal underground formations down to distances away from the dumpsites therefore, the vertical and horizontal porosity of the underground formation below the dumpsite could play

a crucial role in controlling the rate of movement of the heavy metal. This is the major reason behind the introduction of polyethene materials under waste dumpsites to prevent seepage of contaminant into the underground water through the underground formations.

The position of the models trend line revealed that the concentrations of the heavy metals in the water samples were higher in water samples obtained from Aluu compare to the ones obtained from Choba, this trend of results could be attributed to several reasons, one, this result could be due to the fact that Aluu dumpsite is older than Choba dumpsite thus the heavy metal concentration in Aluu has taken time to increase, and drain down into the water aquifer and also drain down to distances faster than younger Choba dumpsite which is still building and draining gradually, two, the result could also be attributed to activity level of the two dumpsites, thus Aluu dumpsite could be more active in terms of amount and nature of waste dumped in the sites compare to Choba dumpsite, hence the higher that amount of wastes that contain heavy metal being dumped in the site, the higher the chances of having heavy metal contaminated ground water. three, the results could also be attributed to the design of the dumpsites, thus, Choba dumpsites might have been design using polyethene material to cover the base in order to avoid seepage of pollutant into the ground water while the Aluu site was not, therefore resulting to higher rate of seepage around Aluu waste site compare to Choba. Lastly, the results also be attributed to porosity level of the underground formation, Aluu area may have higher porosity than Choba area leading to higher rate of seepage of heavy metal pollutant in Aluu compare to Choba.

4 Conclusions

Based on these findings, it was concluded that; first, substantial number of heavy metals are usually available in groundwater within and around waste dumpsites and the most likely ones are Copper (Cu), Mercury (Hg), Lead (Pb), Barium (Ba), Cadmium (Cd) Chromium (Cr), Iron (Fe) and Zinc (Zn)., secondly, the model developed for all the heavy metal sampled in the two location revealed that there is inverse relationship between concentration of the heavy metal and distance of the water sampled location from the waste dumpsite which means that the concentration of the heavy metals in the groundwater sample increases as distance away from the dumpsite decreases.

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