

IMPACT OF REFUSE WASTE ON IRRIGATION WATER QUALITY OF THE ALLUVIAL PLAIN OF RIVER BENUE YOLA, NIGERIA

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ABSTRACT

Subsurface water quality can be poor in Nigeria due to indiscriminate refuse dumping. Exposed dumpsites serve as appoint source pollution that discharges potentially toxic heavy metals into the environment. It is speculated that due to the control refuse waste dumps the irrigation water used for the production of vegetables around the active dumpsites, the vegetables might be polluted. The irrigation water quality of the alluvial plain of River Benue in Jimeta-Yola is thus investigated. The research is aimed to assess the impact of the refuse waste dump, visa vi physiochemical parameters, and heavy metals concentrations in irrigation water sources (shallow boreholes and hand-dug wells). Water samples from shallow boreholes and hand-dug wells for irrigation purposes were collected around two dumpsites. Five (5) samples were collected each from boreholes and hand-dug wells for cations, anions, and heavy metals analysis. Collected samples were analyzed using standard laboratory methods and procedures. Waste samples totalling ten, five each from dumpsite were collected for laboratory analysis. Various components of the waste were sorted out and analyzed by a fresh weight percentage. PH values range from 6.9 -7.3 indicating that the water is alkaline and within FAO standard limit for irrigation water. Mean values of EC, SAR and TDS, 0.25dsm^{-1} , 0.47me/l and 159mg/l indicates no salinity /alkalinity hazards. Heavy metals concentrations of Zn, Fe, Mn and Cr, 2.29mg/l , 0.01mg/l , 0.056mg/l and 0.021mg/l respectively are within WHO standard limits. Heavy metals concentration in refuse waste ranges from $0.05\text{-}0.06\text{mg/l}$ for Fe, $8.0\text{-}19\text{mg/l}$ for Zn, $0.3\text{-}0.8\text{mg/l}$ for Cu and $0.04\text{-}0.06\text{mg/l}$ for Mn respectively in the two dumpsites. Iron and Manganese are slightly high in concentration, indicating point pollution. Lead, Chromium, and mercury were not detected in all the samples. The result showed that dumpsite I was less polluted than II which may cause point pollution and requires good waste management and disposal strategies/ remediation.

Keywords: Groundwater, Refuse dump, alluvial, water quality, metals, Deposits.

1 INTRODUCTION

Ground water is the most reliable water supply source for domestic, agricultural, and industrial use in most parts of Nigeria and other developing countries. However, despite its reliability, this precious vital resource is under increasing threat due to anthropogenic activities related to incessant waste disposal and poor management, [1, 2]. Besides, the usefulness of water to human depend on its chemical status; thus, assessment of subsurface water quality is important for agriculture and socio-economic development of most developing countries, [3, 4]. Groundwater is also a primary source of potable water supply and irrigation in most parts of Jimeta-Yola metropolis, [5, 6, 7]. It consists of low-cost domestic (private) boreholes or shallow hand-dug wells, [8, 9]. In Jimeta-Yola metropolis, uncontrolled urbanization has resulted in increased anthropogenic activities. Heavy metals through incessant waste disposal, the proliferation of pit latrines, effluent from sewage, and routine agricultural activities are matters of concern. Long pressure from these, pollution sources can considerably influence negatively on the underlying aquifers. These pollutants may infiltrate into the aquifer due to the unconfined nature

of the alluvial deposit formation. As reported by [2], medical experts have associated some diseases with groundwater contamination; diarrhoea, pneumonia, typhoid fever, asthma, respiratory and chest diseases.

1.1 Refuse Waste Dumps and Shallow Aquifers

The refuse waste dumps consist of solids and microbial organisms and in special situations, chemicals. [10]. Shallow wells like hand-dug wells and shallow boreholes are more polluted. This solid waste includes food garbage, polythene and paper/glass, leaves, and some, faces while the liquid waste usually is composed of dissolved solids, effluent from the kitchen, bath, and even latrines. As population and urbanization increase more water is required the more the stress is on ground and surface water. Also, more of organic and inorganic wastes are spread back into water sources making it unsuitable for drinking. [2]. The activities of agricultural production and waste disposal along Jimeta Bye-pass remain unregulated due to poor management practice and inefficient waste disposal practice that pose significant threats to the alluvial deposit of the shallow aquifer and the surface water of the Upper Benue River within its flood plain. This study, therefore, aims at assessing the level of physiochemical and heavy metals concentration in ground water for irrigation purposes and to determine the degree of deviation of these from World Health Organization (WHO) guidelines.

1.2 Irrigation Water Quality Criteria and Usage

Water use for irrigation can vary greatly in quality depending highly upon the type and quality of dissolved salts, [11]. The salts are present in irrigation water in a relatively small but significant amount. Quite a lot of variation in the quality of water for irrigation exists, due to differences in crops, soils, and water to be used, [12, 13, 14,15]. The amount of water to be used compared with losses due to evaporation is very important especially in arid areas where there is a need to avoid salt accumulation in the soil. [16], simplified irrigation water requirement quality parameter, which could be broadly divided as follows and is used as a guide in this study. Dissolved solids in irrigation water are measured by electrical conductivity which is an indication of chloride content. This is a parameter, which influences water availability to crops due to osmotic pressure. Range of tolerable values are 250 – 2,000 mmoh/cm and 4-12 meq/l respectively, [17,18]. However, [19] suggested the values of 500 and 200 mg/l as the desirable and permissible criteria of total dissolved solids and chloride. [20], also in India proposed that the conductivity of 750mmoh/cm can be conveniently classified in the low salt group. Various scientists used different terms to quantify salt content in irrigation water. For example, the term Concentration Factor (CF) which is the ratio between electric conductivity of soil extract and irrigation water has been used to quantify the degree of conductivity of irrigation water, [21, 10]. The use of CF in place of electric conductivity generally increase water quality by one class along measured by EC_w . An EC_w greater than 4.6 mmoh/cm on light-textured soil was found to affect the yield of wheat and maize [2]. Elements that may be toxic to plants notably boron in the range of 1 - 4 mg/l and bicarbonates at 1.5 - 8.5 mg/l level may constitute a problem to plants; [22]. The maximum boron level in water of normal quality is 1.0 - 1.5 ppm. Boron content is highly correlated to EC_w and Sodium Adsorption Ratio (SAR), [21]. Elements in the irrigation water are critical. Elements in irrigation water may impair the soil quality directly or indirectly in the presence of sodium (Common in arid regions). Its presence in irrigation water could result in its adsorption by the soil causing poor physical conditions. This is best assessed by sodium adsorption ratio (SAR). The mathematical expression is given by [23, 24] as:

$$SAR (Adj) = \frac{Na}{\sqrt{\left(\frac{Ca+mg}{2}\right)}} \quad (1)$$

Where $PHc = PH$ calculated value. The above mathematical equation was used in this study to calculate the SAR of water samples analysed. The tolerance of SAR varies with crop and soil in the range of 4-18. [25, 26, 27], suggested SAR values of 4 and 6 respectively as permissible and desirable. [28] Observed through extensive laboratory and field studies that water containing more than 2.5 mg/l (residual calcium) is unsuitable for irrigation. Suspended solids that generally influence the choice of irrigation method are also very important. A suspended solid measure is a

very vital parameter in irrigation water quality, [29]. The PH of irrigation water is also an important criterion. It determines the use of irrigation water requirements. Permissible and desirable range recommended by [19] is 4.5-8.4. [28] Examined the subject of water quality aspect of irrigation and concluded that it is presently impossible to set a precise standard of wide applicability for irrigation water quality because suitability depends on the specific condition under which water is utilized, including crops, soils, and irrigation management. According to [22, 30, 31] irrigation water can be placed in the following classes based on EC (dsm-1) with corresponding TDS values (mg/l) as given by [32].

C1 – low salinity water: EC_w, 0 – 0.25 TDS < 200

C2 – Medium salinity water: EC_w, 0.25 – 0.75, TDS 200 – 500

C3 – High salinity water: EC_w, 0.75 – 2.2.25, TDS > 500 – 1,500

C4 – Very high salinity water: EC_w, > 2.25, TDS > 1500

1.3 Composition of Refuse Waste Dumps

Studies have shown that dumpsites consist of metals, nylons, cans, electronics waste, animal waste, municipal, commercial, hospital and mixed industrial wastes that threaten the quality of groundwater, which is the main source of agricultural, industrial and domestic water for surrounding community, [10, 18, 33]. Many studies have been conducted on the effect of heavy metals on groundwater around dumpsites for drinking water quality, but few have investigated the effect on irrigation water quality. This study will, therefore, help to fill this gap with the findings on irrigation water quality due to the uncontrolled dumping of refuse wastes. The evaluation of water quality is thus necessary for planning, design, and operation of irrigation systems and important in both large and small-scale irrigation water to ensure that no deleterious salts or compounds occur in the irrigation water.

2 MATERIAL AND METHOD

2.1 Study Area

The study area is located between longitude 12° 22' and 12° 28' E and latitude 9° 16' and 9° and 19' north; which is bounded to the North East by river Benue flows in a westward (Figure 1). While it is bounded to the South and southeast by Jimeta town of Adamawa state. The area has two distinct seasons dry and wet season with temperature and humidity varying with the seasons. The wet season begins in April and ends in November seventy percent of the total rainfall in the area falls within June to August. The mean annual rainfall for the area is 982mm, while the temperature ranged from 27°C to 40°C. The vegetation is the savannah type (Sudan Savanah). The soil is fertile alluvial with poorly developed soil deposits due to the probable geological youthfulness of the soil [34, 35]. It is situated along the Jimeta Bye-pass within the flood plain of the Upper Benue River just before the Jimeta Bridge, Fig. 1. According to [36], the climate of the region is characterized by a cool dry season (October-March), hot season April to May, and raining season (June to September). The area is vulnerable to desertification, [37]. The study area dominantly derives its groundwater sources from the Benue alluvial aquifer in which tube wells and shallow boreholes are used for domestic and agricultural water supply.

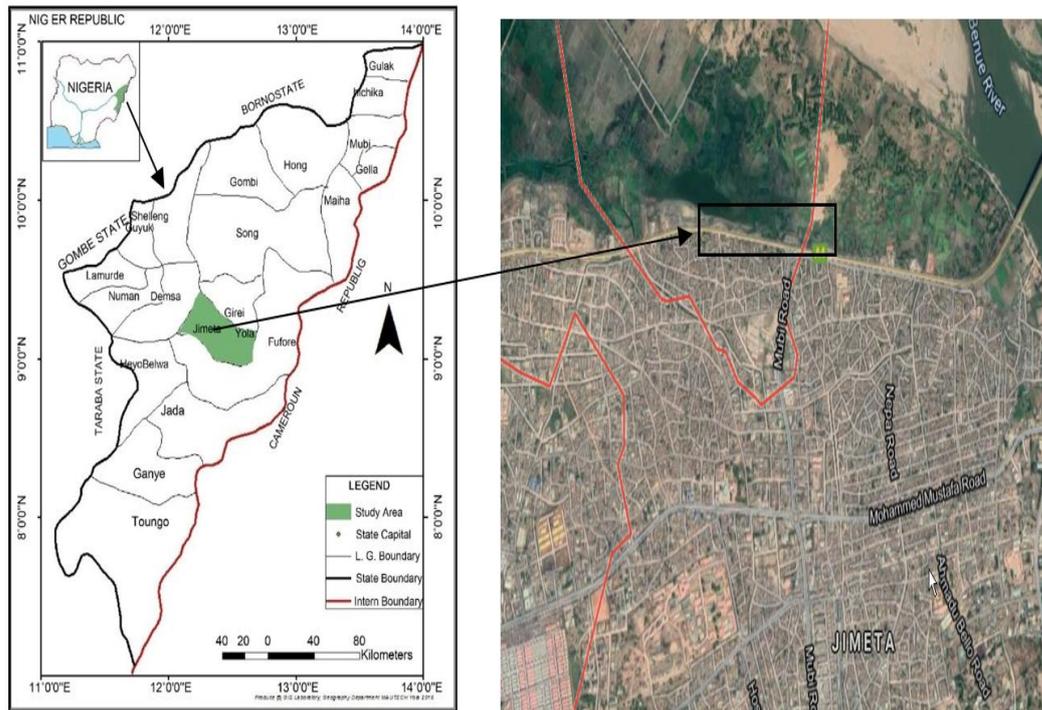


Figure 1. Map of Adamawa state showing the study Area.

2.2 Materials

Acquisition of maps, reports, and literature from the Upper Benue River Basin Development Authority (UBRBDA), Ministry of Land and Survey, and Modibbo Adama University of Technology Yola (MAUTECH) were materials used for desk study. A sterilized 750ml plastic bottle container was used to collect water samples with fetchers from shallow hand-dug wells and shallow boreholes. Markers and masking tape were used for labeling. Polythene bags (small and large) were used as containers for soil and waste samples. Auger and core cutters were used to collect both disturbed and undisturbed soil samples, while PH and EC meters were also used to measure PH and EC of samples in situ.

2.3 Method of Data Collection

Desk study of the area was conducted through the acquisition of maps, reports, and pieces of literature from the Upper Benue River Basin Development Authority (UBRBDA), Ministry of Land and Survey, and Modibbo Adama University of Technology Yola (MAUTECH). The materials were used to review the work. Verbal communications with the people were also conducted. The history of the study area was also investigated to get adequate knowledge and background information about the project area. A geochemical survey of cations, anions, and heavy metals in the groundwater around the exposed dumpsite was conducted to determine the impact on groundwater and the environment. The groundwater in the study area was used for domestic and agricultural purposes. Sterilized 750 ml plastic bottle container was used to collect water samples from hand dag wells and shallow boreholes. Samples totalling fifteen (15) were collected, labelled, and transported to MAUTECH Soil and Geology laboratory for analysis. The sample staking was spread across the refuse dump area (Demsawo and Shinko wards) The parameters analyzed were physiochemical and heavy metals and is indicated in table 1,2, and 3. The method used was that of the procedure described by [16, 20, 38]. Total dissolved solids (TDS) were determined by the evaporation-changing method. The PH and EC were read at 25⁰ c on a PH meter and conductivity meter respectively. Calcium and magnesium were estimated by the EDTA titration method, while K and Na by flame photometry. Carbonate and bicarbonate were obtained by volumetric titration method. The anions Cl, SO₄, and NO₃ were read on an LED photometer while Boron was determined by the calorimetric indigo- carmine method. The parameters

examined for heavy metals concentration in the samples include copper (Cu), Zinc (Zn), Iron (Fe), manganese (Mn), Chromium (Cr) mercury (Hg) and lead (Pb). The qualitative analysis was carried out at the laboratories of the Adamawa State University (ADSU). The concentrations of heavy metals such as Cu, Zn, Fe, Mn, Cr, and Pb in the water and waste samples were determined with flame atomic absorption spectrophotometer (model analyst 400). The results obtained (table 1,2, and 3) were compared with the World Health Organization [5] water standards limit. Five (5) waste samples were taken from two (2) dumpsites each totalling Ten (10). Physical analysis (the composition of the waste) was carried out. The weight percentage analysis of the waste was carried out for various components namely: - leaves, polythene, garbage metals, etc. The results are shown in Table 4. For heavy metals, five (5) composite waste samples were collected and been taken to the laboratory and analyzed the heavy metals.

2.4 Data Analysis

A Simple statistical method of analysis, mean, and range was used to analyze the data obtained from the research. Standard empirical equations were used for the determination of indices for irrigation water quality. Results of data analysis were compared with standards of FAO and WHO limit. Analyzed data are presented in tabular form under the discussion section.

3 RESULT AND DISCUSSION

3.1 Physicochemical and Geochemistry of Water Samples

The results of the examined water samples from that of boreholes, hand-dug wells were colorless, odorless, and tasteless which met the requirement given by the world health organization domestic water use water quality. It should also be far from any form of contamination or toxic chemical compounds, [39]. The pH of wells and boreholes water ranged from 6.9-7.3, which is within the WHO standard limit of 8.5. Table1. The mean concentrations of physicochemical characteristics were compared with FAO and WHO standards, Tables 1, 2, 3 &5. These samples under discussion were found to be good for irrigation especially the borehole samples while that of hand-dug wells is slightly contaminated. The following anions, cations (Ca^{2+} , Mg^{2+} , K^+ , SO_4^{2-} , NO_3^{-1}) present in the water samples are all within the limit of FAO irrigation water quality standard. The high values of bicarbonate and carbonate might be caused by the discharge of carbonate-rich products in the dumpsite. The high presence of chlorine (Cl^-) and sodium (Na^+) may be attributed to domestic effluent, septic tanks, and leachate from sewage in the dumpsite.

Table 1. Physio-chemical properties of irrigation water source from the study area

parameters	Unit	Borehole	H/Well	Laboratory Determinants (FAO)
PH	1-14	7.30	6.90	6.5-8.5
TDS	mg/l	165.00	153.00	0-1,000
Ec _w	dsm ⁻¹	0.26	0.24	0-3
Ca ⁺⁺	mg/l	25.60	14.50	0-20
Na ⁺	mg/l	48.50	55.60	0-40
Mg ⁺⁺	mg/l	ND	3.72	0-5
K ⁺	mg/l	ND	1.00	0-2
CO ₃	me/l	1.21	1.73	0-1
HCO ₃	me/l	15.00	19.30	0-10
Cl ⁻	mg/l	40.30	45.40	0-30
SO ₄ ⁻	me/l	ND	11.20	0-20
NO ₃	me/l	ND	51.00	0-20
NH ₄ -N	me/l	-	-	0-10
PO ₄	me/l	-	-	0-5
B	me/l	0.50	0.48	0-15

Irrigation water indices such as EC_w, TDS, soluble salt percentage (SSP), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), and Kelley ratio (KR) were used to assess the suitability of groundwater in the study area for irrigation purpose. Table 2.

Table 2. Indicators of irrigation water quality in the study area

parameters	Borehole	H/Well	Laboratory Determinants (FAO)
Ecw (<i>dsm⁻¹</i>)	0.20	0.24	0-3
SAR	0.51	0.48	0-26
TDS(<i>mg/l</i>)	165.00	153.00	0-1000
SSP	50.50	60.20	0-80
MAR	25.60	30.50	0-50
KR	0.70	0.85	0-1

SSP = Soluble Salt percentage, SAR= Sodium Absorb Ratio, MAR = Magnesium Absorption Ratio, KR= Kelly Ratio, EWc = Electrical Conductivity of Water, TDS Total di size.

To determine the amount of ionic salt present in groundwater, EC_w was used, which also measures salinity hazard to crops, as it affects the TDS in groundwater. The results showed that EC_w and TDS in all of the groundwater samples were lower than 250 and 1000 mg/l, respectively, and groundwater is therefore now safe for irrigation purposes. Soluble salt percentage evaluates the sodium hazard and is calculated using equation 2.

$$SSP = \frac{(Na + K) \times 100}{(Na + K + Mg)} \quad (2)$$

Where SSP is the soluble salt percentage. The result revealed that all the samples are slightly high but can still be considered permissible for use in irrigation. Sodium adsorption ratio is the best parameter to determine the suitability of groundwater for irrigation, as it evaluates the alkali/sodium hazards in crops, [38, 40]. The sodium adsorption ratio was measured using equation 1. The result revealed that all the samples were suitable for irrigation. The magnesium adsorption ratio was calculated using equation 3.

$$MAR = \frac{(Mg \times 100)}{(Ca + Mg)} \quad (3)$$

The findings showed that all the samples were suitable for irrigation. The Kelly ratio values were calculated using equation 4.

$$KR = \frac{NA}{(Ca + Mg)} \quad (4)$$

Where KR is the Kelley ratio. Kelley ratio values < 1 showed suitability, while KR > 1 showed unsuitability for irrigation purposes. All the samples were safe for irrigation (Table 2).

3.2 Heavy metals mean concentrations of the ground (borehole/wells) water samples

The water samples were analyzed for heavy metals concentrations which include: Iron (Fe), Zinc (Zn), Manganese (Mn), Chromium (Cr), Mercury (Hg), Copper (Cu) and Lead (Pb) as indicated in table 3, which are characterized as undesirable metals when it is above WHO standard limit. Iron (Fe) levels ranged from 0.043-0.055 mg/l with an average of 0.059 mg/l, it is above the WHO standard limit. The presence of Zn in water can lead to a change in the colour of groundwater and extreme dissolved iron concentration [29]. The concentration of Zinc (Zn) varies from 4.0-16.0 mg/l with an average of 5.0mg/l; all are within the WHO standard limit, which indicates that presently the source of water for irrigation is safe. [12] reported that the consumption of Zinc (Zn) above the WHO recommended value might lead to gastrointestinal disturbances such as pain, cramping, nausea, and vomiting, and pancreatic toxicity. Copper (Cu) ranges from 0.3-1.4 mg/l

with an average of 0.14mg/l, and all are within the WHO standard limit. Cu is a key mineral in many different body systems. It is central to building strong tissues, maintaining blood volume, and producing energy in cells. Yet for all its critical importance, it might be harmful to the body if the value exceeds the WHO standard limit. The presence of manganese (Mn) which ranged from 0.03-0.05 with an average of 0.04 mg/l in all water samples were slightly above the WHO standards limit. Manganese (Mn) is among the essential element for good human health, metabolism and it should be available in the recommended quantity. However, if more of that essential element is present in water, above certain limits, the water may not be suitable for domestic and agricultural purposes. In all the water samples analyzed lead (Pb), chromium (Cr), and mercury (Hg) were not detectible. This result agreed with [35] as illustrated in Table 3.

Table 3. Heavy metals mean concentrations of groundwater (Boreholes/Wells) samples and their comparison with WHO standard (mg/l) in the study area

Sample	Fe	Zn	Pb	Cu	Mn	Cr	Hg
WHO	0.03	75.0	0.01	2.0	0.01	-	-
Borehole	0.043	4.0	ND	0.30	0.03	ND	ND
Wells	0.055	16.0	ND	1.40	0.05	ND	ND

3.3 Composition of Solid Refuse Waste Dump Site

For the classification of waste, ten waste components were considered. These were food/putrescible, vegetables, paper, plastic, glass/ceramic, fabrics, wood, metal, electronic waste, and “others”. Others represent solid waste that is not identified or does not fall into the first nine categories. Sorting and weighing of collected waste were done at the dumpsite.

Table 4. Composition of Refuse dump from Two Representative Public Dumpsite in the study (on Fresh Weight Basis)

Components	Site I	Site II
Leaves (%)	3.37	4.23
Papers (%)	8.41	6.64
Rags (%)	3.35	0.00
Garbage (From Waste (%))	22.80	70.60
Wood (%)	1.10	0.00
Metals (%)	1.50	3.79
Glass (%)	0.70	0.95
Grit And Dust (%)	51.70	9.01
Polythene and Other Plastics (%)	7.10	4.78
TOTAL	100.00	100.00

3.4 Heavy Metal Concentrations in Refuse waste dump Site

The result of the analysis indicates that heavy metal concentration of iron, zinc, copper, and manganese as well chromium are all slightly above the standard limit of WHO and may likely affect the groundwater quality as well in the future. Lead, Chromium and mercury were not detected. Table 5.

Table 5. Heavy Metals mean Concentration of refuse waste dumps in Study Area

Sample	Fe	Zn	Pb.	Cu	Mn.	Cr	Hg
WHO	0.03	75-200	0.01	2.0	0.01	-	-
Dump Site I	0.05	8.00	ND	0.80	0.04	ND	ND
Dump Site II	0.06	19.00	ND	0.30	0.06	ND	ND

Iron (Fe), Zinc (Zn), Copper (Cu), and Manganese (Mn) mean values of 0.55mg/l, 13.5mg/l, 0.55, and 0.1mg/l respectively are all slightly above the WHO standard limit, which indicates a source point pollution from the dumpsite. The concentrations of Pb, Cr, and Hg were not detectable in refuse waste dump sites I & II. Fe, Zn, and Mn concentrations value of 0.06, 19.0, and 0.06 respectively in dumpsite II is slightly higher than I, which means site II is slightly polluted and therefore management strategies for waste disposal are needed.

4 CONCLUSION

pH ranges from 6.9-7.3 which indicates alkalinity and good for irrigation. EC_w, TDS, SAR, SSP, MAR and KR mean values of 0.25dsm⁻¹, 159mg/l, 0.47me/l, 55.35mg/l, 28.05 and 0.78 respectively are all slightly above FAO and WHO standard. Iron (Fe), Zinc (Zn), Copper (Cu), and Manganese (Mn) mean values of 0.55mg/l, 13.5mg/l, 0.55 and 0.1mg/l respectively are all slightly above the WHO standard limit, which indicates a source point pollution from the dump site. The concentrations of Pb, Cr, and Hg were not detected in all the samples of both irrigation water and refuse waste. Presently based on the results there might not be high concentrations of heavy metals in the groundwater now, however, further studies should be conducted over a longer period. The research revealed that presently there is slightly point source pollution from the refuse waste dump and would have a negative impact on groundwater quality for irrigation. It is also recommended that further evaluation of the groundwater be carried for at least two (2) years or more, for a conclusive result.

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