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Physic-Chemical Analysis Of Groundwater From Hand Pumps And Motorised Boreholes In Bosu And Njimtilo Areas Of Maiduguri Metropolis, Borno State, North-Eastern Nigeria.

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Abstract:
Groundwater is very essential to humans and as such its importance cannot be over emphasized. This study aims to conduct the qualitative analysis of the physic-chemical parameters of groundwater in BOSU and Njimtilo areas of Maiduguri, Borno State in order to delineate the suitability of the water for drinking and whether its chemistry has direct link to the acute renal diseases reported among the inhabitants of Maiduguri metropolis. Ten (10) samples were collected from motorized boreholes and/or hand pumps, and sent to the laboratory for analysis to determine the concentration of Cd, Pb, Ni, K, Mg, and Ca. The values of the physic-chemical parameters obtained were compared with the WHO (2022) standard permissible limit for drinking water. The concentration of Pb, Ni, Ca, Na, K, and Mg are within the permissible limit and thus safe for drinking while Cd in most of the sampling points have concentration higher than 0.003ppm making it unsafe for drinking. It is recommended that those areas should undergo extensive treatment to prevent consumers from contacting renal/kidney diseases normally associated with high intake of Cadmium.
Keywords: *Groundwater, physic-chemical parameters, Njimtilo, BOSU- Borno State University*

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I. INTRODUCTION

Groundwater occurs almost everywhere beneath the land surface and it is an integral part of a complex hydrologic cycle that involves continuous movement of water on earth. Groundwater plays a crucial role in sustaining stream flow during dry season. Groundwater is a convenient water supply, compared to surface water it is typically free from most pathogens and is less vulnerable to surface derived contaminations. However, the quality of water is controlled by many factors such as the source of recharge of the water, the lithology of the aquifer, the drainage area and the permeability of the zone of aeration (Amadi *et al.,* 2006). Groundwater contamination is nearly always the result of human activity. In areas where population density is high and human use of land is intensive, groundwater is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute groundwater. When groundwater becomes contaminated, it is difficult and expensive to clean up (Ramakrishnaih *et al.,* 2009). The contamination of groundwater can be due to pesticides and fertilizers used, drainage wells, poorly constructed irrigation wells, mining activities, etc. Contamination of groundwater can result in poor drinking water quality which normally causes health related problems like dental fluorosis and chronic kidney disease. Groundwater has unusually higher Total Dissolved Solid (TDS) concentration than the surface water because of mineral pick up from soils and rocks. Groundwater contains various types of pollutants and several other substances are dissolved in it. These substances may be useful to the human body but in a specific limit (Ranjana, 2009). Groundwater is a preferred source of water because of its high quality with respect to portability and the minimum treatment requirement.

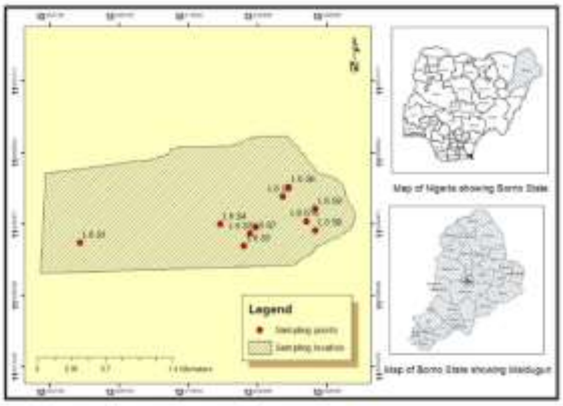

Fig. 1a: Map showing the study area

Fig. 1b: Map showing the satellite image of the study area

Table 1: WHO STANDARD FOR DRINKING WATER QUALITY (WHO, 2022)

WHO STANDARD FOR DRINKING WATER QUALITY		
S/NO	Physic-chemical parameters	WHO (2022) permissible limit for drinking water
1	Cadmium	0.003 mg/l
2	Nickel	0.007 mg/l
3	Lead	0.01 mg/l
4	Magnesium	50 mg/l
5	Calcium	75 mg/l
6	Potassium	20 mg/l
7	Sodium	200 mg/l
8	pH	6.5 – 8.5
9	EC	500 – 1000 µS/cm

II. GEOLOGY AND HYDROGEOLOGY OF THE AREA

The study area falls within the Nigerian sector of the Chad Basin, locally known as the Bornu Basin being one of Nigeria's inland basins. It represents about one-tenth of the total area extent of the Chad Basin, which is a regional large structural depression common to five countries of Cameroon, Central African Republic, Niger, Chad, and Nigeria. The Bornu Basin falls between latitude 11^{o}N and 14^{o}N and longitudes 9^{o}E and 14^{o}E, covering Borno State and parts of Yobe and Jigawa States of Nigeria. The Chad Basin belongs to the African Phanerozoic sedimentary basins whose origin is related to the dynamic process of plate divergence (Burke, 1976; Petters, 1982). The Plio-Pleistocene Chad formation and the quaternary sediments are the main sources of groundwater supply in Maiduguri area. The Chad formation dips gently east and northeast towards Lake Chad in conformity with the slope of the land surface. Three well-defined arenaceous horizons within the argillaceous Chad formation (Table 2) make up the aquifers and were named by Barber and Jones (1960) as the upper, middle and lower aquifers under perched, semi-confined, and confined conditions. The upper aquifer is found within the superficial deposits which extend across the entire outcrop of the Chad formation. It is composed of alluvium and Aeolian sand and gravels, deposited during the recent times. However, around the type locality (Maiduguri) the upper aquifer includes not only a surface zone of recent sands with unconfined water table, but deeper sand layers of the Chad formation complexly interbedded with confining clay horizons. The upper zone yields water to numerous dug wells throughout the rural areas and also is the major source of the Maiduguri municipal water supply. The middle zone yields water from flowing Artesian well and lower zone also yields water from flowing boreholes.

Table 2: Stratigraphic succession in the Chad Basin, northeastern Nigeria (Carter *et al.*, 1963)

AGE	FORMATION		ENVIRONMENT	HYDROLOGICAL UNIT
Pleistocene	Chad Formation	Upper Zone	Lacustrine	Terminal continental Aquifer
		Middle Zone	Lacustrine	
		Lower Zone	Continental to Lacustrine	Middle to lower Tertiary
Paleocene	Keri-Keri formation		Continental	
Maastrichtian	Gombe Sandstone		Estuarine Deltaic	Hamadian continental Aquifer

Turonian Maastrichtian	Fika Shale	Marine	
Lower Turonian	Gongila Formation	Estuarine and Deltaic	Intercalated continental Aquifer
Albian Turonian	Bima Sandstone	Continental	
Precambrian	Basement		

III. METHODOLOGY

A total of ten (10) samples were collected for chemical and physical analysis from motorized boreholes and hand pumps. The coordinates and elevation of the sampling points were taken using a GPS- Global Positioning System. Water sampling was carried using a transparent plastic rubber which was thoroughly rinsed using distilled water to avoid contaminating the water samples at each point before collecting the water directly from the source. All the physical parameters (TDS, EC, PH and temperature) were measured in-situ at each point. The water sample is then poured into a 120ml rubber bottle which is also rinsed with distilled water at each point. The sampling bottle is then filled to the brim, drops of nitric acid is being added to it for preservation and labeled. The samples were taken to the central Instrumentation Laboratory, Centre for Dry Land Agriculture, Bayero University Kano, for the determination of concentration of some major and trace elements (Cd, Ni, Pb, Na, Ca and Mg).

IV. RESULTS AND DISCUSSION

Table 3: Physical Parameters of groundwater from the study area

Sample ID	Coordinates	Elevation (M)	Source	Temp. (◦c)	pH	TDS (mg/l)	EC (µS/cm)
L6S1 BOSU	11˚ 50' 34" N 13˚ 00' 20" E	305	Hand pump Borehole	29.4	7.1	381	389
L6S2 Njimtilo	11˚ 50' 39" N 13˚ 00' 19" E	312	Motorized Borehole	33.6	6.7	252	437
L6S3 Njimtilo	11˚ 50' 33" N 13˚ 01' 15" E	314	Motorized Borehole	33.6	6.5	192	382
L6S4 Njimtilo	11˚ 50' 40" N 13˚ 01' 07" E	320	Motorized Borehole	33.4	6.5	253	506
L6S5 Njimtilo	11˚ 50' 49" N 13˚ 01' 28" E	318	Motorized Borehole	33.4	6.6	271	542
L6S6 Njimtilo	11˚ 50' 52" N 13˚ 01' 30" E	322	Hand pump Borehole	34.4	6.4	257	514
L6S7 Njimtilo	11˚ 50' 37" N 13˚ 01' 53" E	310	Motorized Borehole	27	6.4	236	474
L6S8 Njimtilo	11˚ 50' 38" N 13˚ 02' 06" E	315	Motorized Borehole	33	6.7	256	512
L6S9 Njimtilo	11˚ 50' 45" N 13˚ 02' 06" E	320	Motorized Borehole	33.8	7.1	249	498
L6S10 Njimtilo	11˚ 50' 41" N 13˚ 02' 48" E	316	Motorized Borehole	32.8	6.7	283	526

Table 4: Chemical Parameters of groundwater from the study area

SAMPLE ID	Coordinates	Cd(mg/l)	Pb(mg/l)	Ni(mg/l)	Mg(mg/l)	Ca(mg/l)	K(mg/l)	Na(mg/l)
L6S1	11˚ 50' 34" N 13˚ 00' 20" E	0.125	0.009	0.0015	0.41	2.44	1.69	94.42
L6S2	11˚ 50' 39" N 13˚ 00' 19" E	0.105	0.002	0.003	0.58	4.95	1.29	33.78
L6S3	11˚ 50' 33" N 13˚ 01' 15" E	0.09	0.005	0.001	0.48	4.37	1.17	16.96
L6S4	11˚ 50' 40" N 13˚ 01' 07" E	0.06	0.003	0.0025	0.64	5.41	1.47	34.59
L6S5	11˚ 50' 49" N 13˚ 01' 28" E	0.015	0.004	0.001	0.67	6.34	1.24	38.94
L6S6	11˚ 50' 52" N 13˚ 01' 30" E	0.025	0.005	0.002	0.76	7.34	1.30	30.65
L6S7	11˚ 50' 37" N 13˚ 01' 53" E	-0.02	0.005	0.0025	0.63	7.56	1.18	30.24
L6S8	11˚ 50' 38" N 13˚ 02' 06" E	0	0.005	0.0015	0.68	5.71	1.57	37.51
L6S9	11˚ 50' 45" N 13˚ 02' 06" E	0.01	0.002	-0.002	0.86	9.54	1.32	23.77
L6S10	11˚ 50' 41" N 13˚ 02' 48" E	-0.065	0.006	0.0015	0.43	3.71	1.33	42.88

Groundwater temperatures generally are controlled by the depth of burial of the aquifer. This is a function of two main factors: the geothermal gradient and the ambient temperature at the land surface (Stuart *et al.,* 2010). Within the near surface zone temperature is influenced by seasonal heating and cooling of the land surface. Shallow ground water temperature is generally 1-2° higher than the mean annual surface temperature (Busby et *al.*, 2009). The temperature of the samples ranges from 27 – 34.4 ºC in the study area (fig. 2), which is within the permissible limit (Table 1).

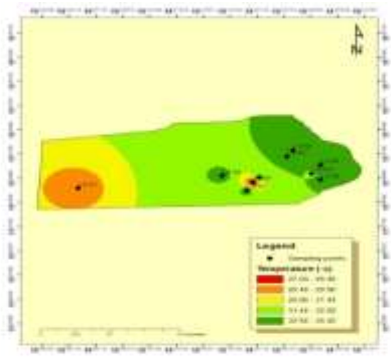

Fig 2: Showing the temperature values of the study area

A pH value of, less than 7 indicates acidity, a pH value of 7 indicates neutrality and the pH value of greater than 7 indicated basicity. In pure water, the concentrations of hydrogen and hydroxide ions are equal to one another having the value of 7 and it is defined to be neutral. The pH ranges from 6.7 – 7.1 in the study area (fig. 3) which is within the permissible limit (Table 1).

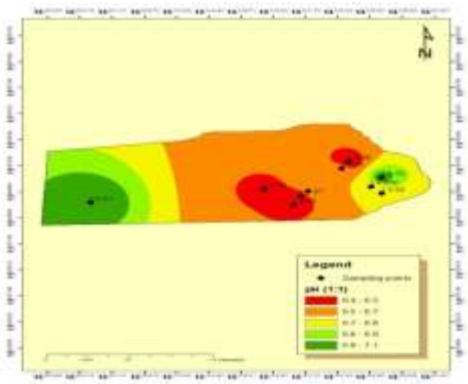

Fig. 3: showing the pH values of the study area

Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in ionized, molecular, or micro granular suspended form. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. The major application of TDS is the study of water quality for water bodies. TDS is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of chemical contaminants. TDS comprise of inorganic salts, principally calcium, magnesium, potassium, sodium bicarbonates, chlorides and sulphates and some small amounts of organic matter that are dissolved in water. The values for TDS in the samples analyzed ranges from 192 – 381 (fig. 4) which is between the permissible limit (Table 1).

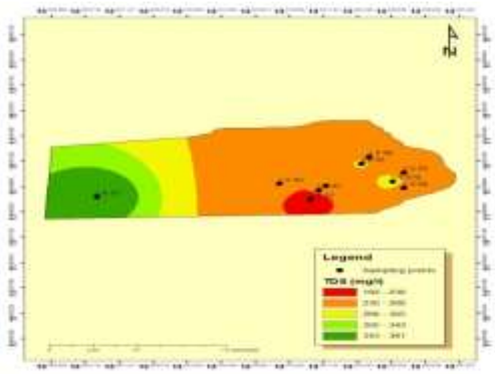

Fig. 4: Showing the TDS values of the study area

Electric conductivity (EC) is a measure of the ease with which electrical current can pass through water. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphates and phosphate anions. Organic compound like oil, phenol, alcohol and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Groundwater conductivity is affected primarily by the geology of the area in which the aquifer is found. The EC values of the samples ranges from 382 – 512 (fig. 5) which is not within the permissible limit of 250µS/cm (Table 1).

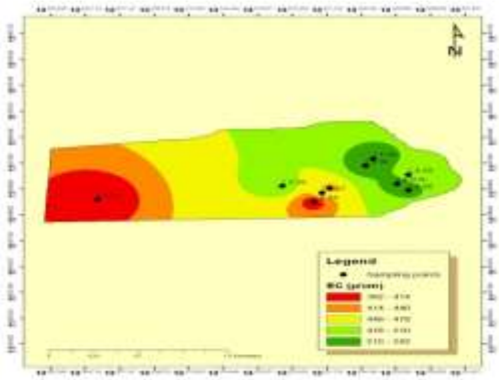

Fig. 5: showing the EC values of the study area

Potassium is an essential element in humans and is seldom, if ever found in drinking water at levels that could be a concern for healthy humans. Potassium occurs widely in the environment including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment. Although potassium may cause some health effects in susceptible individuals, potassium intake from drinking water is well below the level at which adverse health effects may occur. Health concerns would be related to the consumption of drinking water treated by potassium-based water treatment, affecting only individuals in high risk groups (i.e. individuals with kidney dysfunction or other diseases, such as heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, pre-existing hyperkalemia; people taking medications that interfere with normal potassium dependent functions in the body; older individuals or infants). Potassium is an essential element and is present in all animal and plant tissues. The primary source of potassium for the general population is the diet, as potassium is found in all kind of foods, particularly fruits and vegetables. Some of the food additives are also potassium salts e.g. potassium iodide. The concentration of potassium in the study area ranges from 1.17 – 1.69ppm (fig. 6) which tends to be within the permissible limit (Table 1).

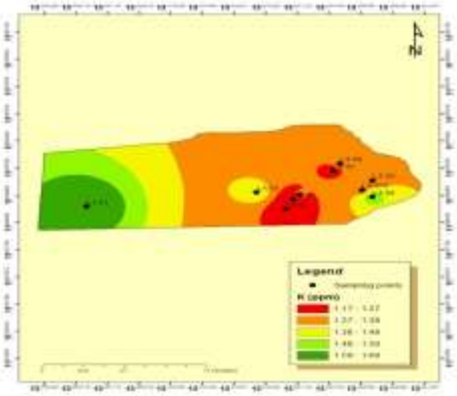

Fig. 6: Showing the concentration of potassium in the study area

Sodium is a common element in the natural environment and is often found in food and drinking water. Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water. They are nonvolatile and will thus be found in the atmosphere only in association with particulate matter. Sodium salts are not usually toxic because of the efficiency with which mature kidneys excrete sodium. However acute effects like nausea, convulsion, vomiting, muscular twitching and rigidity have been reported. The concentration of sodium (Na) in sample L6S1-10 ranges from 16.96 – 94.42 mg/l, with sample L6S1 having higher value than sample L6S2-L6S10 having the value of 94.42 as shown in table 3. The concentration of sodium in sample L6S1-L6S9 indicates that the water is a soft water, whereas sample L6S10 water source is hard in nature though they are all within the permissible limit (Table 1).

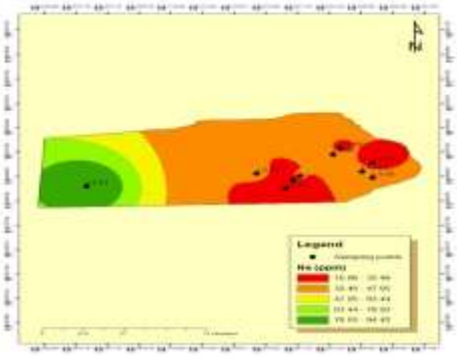

Fig. 7: showing the concentration of sodium in the study area

Cadmium is a natural occurring metal, it is a soft silverfish – white metal that is found in the earth's crust and is commonly associated with copper, lead, and zinc ores and therefore it is a common byproduct of mining and rare earth mining. Cadmium becomes a problem when an individual is exposed to sources of cadmium through environmental exposure which can be through air, contaminated water, contaminated food, etc. Cadmium contamination of a water source can be through natural erosion of cadmium – containing rocks, industrial dust or waste, fertilizer (contaminant in phosphate rock), mine tailings or spoil, corrosion of galvanized pipes, etc. Cadmium has been linked to kidney disorders, anemia and lung damage. For children, a number of studies show that they are vulnerable to the absorption of cadmium and may be vulnerable to decreased bone strength. Low level exposure to cadmium decrease bone density and disrupts bone composition. Both shorter, higher exposures and lifetime low level exposures to cadmium can cause kidney disease in adult. The US EPA'S regulatory limit of Cd in drinking water is 0.005 parts per million (ppm). (Martins *et al.,* 2009) while the WHO's recommended safe limits of Cd in both wastewater and soil for agriculture is 0.0003ppm (Paschal *et al.,* 2000). The cadmium concentration of sample L6S7, L6S8 andL6S10 shows that it is safe for drinking while the cadmium concentration in the rest of the samples is above the standard of water quality for drinking water which makes the inhabitants of that area prone to cadmium related diseases like chronic kidney disease.

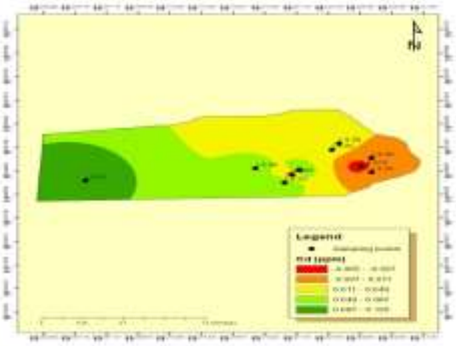

Fig. 8: showing the concentration of Cadmium in the study area

Lead (Pb) is a common metal found throughout the environment in lead – based paint, air, food, and certain types of pottery, porcelain, pewter and in drinking water. Lead can pose a significant risk to human health; it can cause damage to the brain, red blood cells and kidneys. Signs of lead intoxication may include irritability, headaches, kidney damage, dullness, restlessness, etc. Damage to kidney includes acute proximal tubular dysfunction and is characterized by the prominent inclusion bodies of a lead – protein complex in the proximal tubular epithelial cells at blood lead concentrations of 40 -80 mg/dl (milligram per deciliter). The concentration of lead of the analyzed sample which was collected at the study area indicates the presence of lead which ranges between 0.002 – 0.009 mg/l (fig. 9), which is less than the permissible limit (Table 1), thus the consumers of such water are not vulnerable to disease associated with excess accumulation of lead.

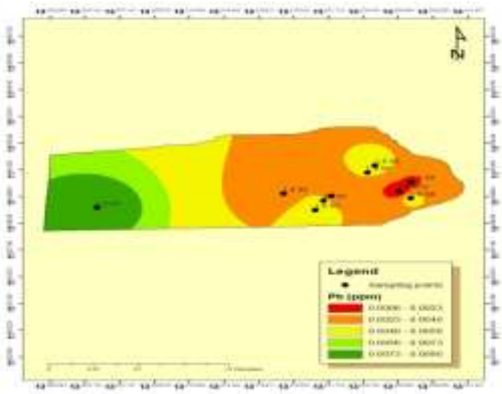

Fig. 9: Showing the concentration of lead (Pb) in the study area

Magnesium is the eight most abundant natural element. It makes up 2.5 percent of the earth's crust and is commonly found in such minerals as magnetite, dolomite, olivine, serpentine, talc and asbestos (Day *et al.*, 1963) and present in all natural waters. Ferromagnesian minerals, igneous rocks and magnesium carbonates in sedimentary rocks are generally considered to be the principal sources of magnesium in natural water. Increased intake of magnesium may cause a temporary adaptable change in bowel habits (diarrhea) but rarely causes hypomagnesaemia (a renal insufficiency associated with a significantly decreased ability to excrete magnesium) in persons with normal kidney function, water. Magnesium ions are of particular importance in water pollution in such a way that it may contribute to water hardness. Symptoms of high magnesium intake include muscle weakness, fatigue, nausea and vomiting, trouble in breathing and cardiac arrest. The concentration of magnesium in the analyzed samples of the study area ranges from 0.43- 0. 86 which is safe for drinking because it is within the WHO's standards (Table 1).

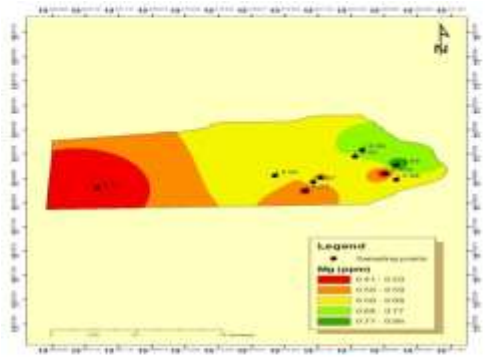

Fig. 10: showing the concentration of sodium in the study area

Calcium is the fifth most abundant natural element. It enters the freshwater system through the weathering of rocks, especially limestone, and from soil through seepage, leaching and run–off (Day, 1963). The concentration of calcium in water depends on the residence time of the water in calcium–rich geologic formations. Undesirable effects due to the presence of calcium in drinking water may result from its contribution to hardness. The concentration of calcium in the samples analyzed ranges between 2.44 -9.45 mg/l (fig. 11), the values which are within the desirables limit of 75mg/l WHO (2022) and therefore can be recommended for drinking.

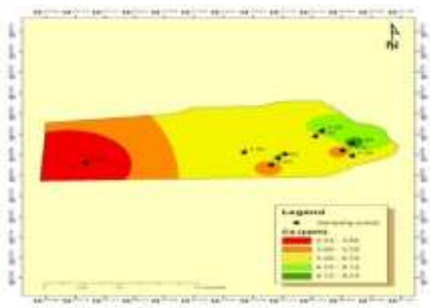

Fig. 11: showing the concentration of calcium in the study area

Nickel is a naturally occurring lustrous white, hard, ferromagnetic metal that is ubiquitous in the environment. Nickel enters ambient water primarily as nickel- containing particulate matter carried by rainwater, and through the degradation of nickel – containing rocks and soils (IPCS, 1991). The main anthropogenic sources of nickel in water are primarily nickel production, metallurgical processes, combustion and incineration of fossil fuels, chemical and catalyst production, and discharge of industrial and municipal waste (EFSA 2015). The concentration of nickel in the sample analyzed from the study area ranges from -0.002 – 0.0025ppm which is within the standard limits of drinking water quality (Table 1).

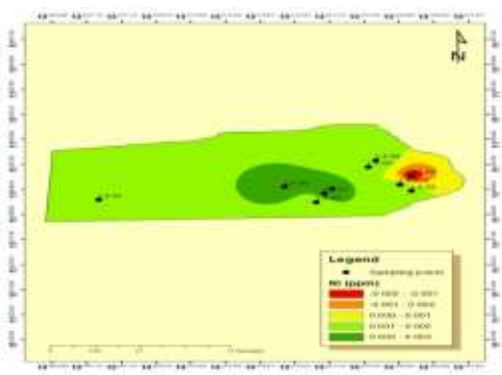

Fig 12: showing the concentration of nickel in the study area

V. CONCLUSION

Considering the results obtained from the analysis made and also the crucial role that groundwater plays in the existence and life of people, analyzing the quality of the groundwater scheme in the study area revealed that all the values of the elements with the exception of cadmium values in some locations are within the permissible limit of drinking and as such can be recommended for drinking except for those areas containing high values of cadmium which is poisonous and harmful to humans. To make the water also suitable and healthier for drinking, such water ought to be treated immensely. Remediation technologies available for reducing the harmful effects of heavy metal contaminated sites include stabilization of the metals in the soil on site, physical removal of the contaminated material, and the use of growing plants to stop the contamination or to extract the metals from the soil (phytoremediation). The seeds of moringa *oliefera*, peanuts, cowpeas, urad and corn were used for water purification. Some plants are used for phytoremediation to extract and detoxify some pollutants. They have the ability to accumulate heavy metals such as Cd, Cr, Pb, Co, Ag, Se and Hg in their tissues. Phytochelating activity has an important role in metal detoxification by the sequestration of Zn and Cd.

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