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EFFECT OF MUNICIPAL SOILD WASTE DUMPSITE AND HEAVY METALS ON HUMAN HEALTH

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Abstract: As a result of inadequate water supply at Adumakuma and Ntensere environs, individuals' resort to various means of getting access to their own water supply by drilling of boreholes and sinking of wells in their homes for private use. This study aimed at examining the suitability of such wells water for consumption by evaluating their physio-chemical, bacteriological characteristics and heavy metals content such as Temperature, pH, Color, conductivity, Total suspended solids, Total dissolved solids, Turbidity, Nitrates, E. coli, Total coliform bacterial, cadmium, lead, zinc and copper. The obtained results were compared with World Health Organization (WHO 1993) drinking water standards to determine the suitability of groundwater. The results indicated that except pH and Nitrate, all the other parameters in the samples showed some level pollutants beyond the WHO limit. The overall results indicated that the water from the water sources located in the vicinity of solid waste dumping and quarry sites was unfit for drinking because the quality of water from these wells contained pollutants beyond the limit set by WHO.

Keywords: Municipal solid waste, Heavy Metals, Dumpsite, Water Pollution, Water quality.

I. INTRODUCTION

The two most important sources of water are ground and surface. The wide range of water usage as a key resource in our daily activities goes through domestic, agricultural, transportation, industrial and health care [1]. Usually, in developing countries, small households and small communities rely on ground water, while big communities and urban areas depend on surface water such as rivers and lakes, which are mostly treated at water treatment facilities. Contamination of these water sources would render them unwholesome for consumption and may be costly and difficult to treat. Given that it is the most important resource for sustaining life, water quality is seen as a major worry for humanity. Due to the concomitant rise of human activities adjacent to the rivers during the past few decades, harmful chemical compounds are contaminating water resources at an increasing rate. The long-term persistence of heavy metals in soils and water, which raises geo-ecological risks and disrupts natural biogeochemical cycles, makes them one of the most significant pollutants and a global problem [2]. Any metallic element with a relatively high density that is deadly or toxic even in small amounts is referred to as a heavy metal. Given that they cannot be broken down or eliminated, heavy metals are persistent environmental pollutants and are present in the earth's crust naturally. These substances do exist naturally; however, they are frequently incorporated into inert substances [3].

According to[4], metal pollution in freshwater ecosystems might come from direct atmospheric precipitation, geologic weathering, or the discharge of home, commercial, or agricultural waste products. The level of toxicity is dependent on the type of metal, its biological function, and the kinds of species to which it is exposed. The aquatic flora and fauna are significantly impacted by heavy metals, which through bio magnification enter the food chain and ultimately have an impact on humans. Lead, iron, cadmium, copper, zinc, chromium, and other heavy metals found in drinking water are those most frequently associated with human toxicity. Little amounts of these are needed by the body, but larger levels can be hazardous [5].

Development in the 20th century has changed rural communities into cities and towns resulting in a lot of environmental challenges. Such environmental issues are being addressed at global, regional and local levels [6]. With the recent increase in population [7] coupled with urbanization and industrialization, a wide range of different type of waste is produced every day [8]. Because waste is generated in different forms and types, there are various methods for disposal of the waste materials. The best disposal method for one kind of waste may not be appropriate for another [8]. Waste disposal is the process of permanently removing waste materials from the system [8]. One of the most current environmental issues is solid waste management from domestic, commercial and industrial sources. According to [6], Solid waste management problem was identified during the United Nation Conference on Environment and Development (UNCED. These methods of waste disposal include landfills, sanitary landfills, incineration, composting and open dumping.

Landfills and open dumps have been identified as one of the major threats to ground and surface water resources [8]. Waste placed in open dumps is subjected to either groundwater underflow or infiltration from precipitation. The dumped solid waste gradually releases its initial interstitial water and some of its decomposed by-products get into water moving through the waste deposit. Such liquid containing innumerable organic and inorganic compounds is called „leachate" which is highly concentrated complex effluents containing dissolved inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, and chlorides which accumulates at the bottom of the landfill and percolates through the soil and have high levels of E. coli [8].

Management of solid waste is a major challenge in several countries, especially in developing countries with high rate of population growth. Wastes are materials that are not prime product (that is product produced for the market) for which the initial user has no further use in terms of his/her own purposes of production, transformation or consumption and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. It is also known as any unavoidable material resulting from an activity, which has no immediate economic demand and which must be disposed of [6]. In most developing nations, unwanted solid waste materials from domestic, commercial, and industrial activities are commonly disposed of indiscriminately in open dumps (open landfills), where some of the combustible components are generally incinerated and the remnants are invariably exposed to natural biodegradability processes.

Research shows that about 33% of the population globally is dependent on groundwater for its freshwater demand. However, if we consider the Indian scenario, groundwater is believed to be the chief water supply source in urban areas and in rural areas about 88% of the population is dependent on groundwater as their primary water supply source [9]. Groundwater pollution resulting of leachate from dump site/landfill site has of late become a serious and devastating problem around the Globe [8]. The dumpsite located close to groundwater (wells) recharge areas easily release pollutants to this water bodies. With gradual accumulation pollutants can become harmful to the end users [6]. Contaminated groundwater is extremely difficult, and sometimes impossible, to clean up [8]. Also, Research have revealed that products cultivated close to mine sites, such as fruits, vegetables, and leaves, may acquire contaminants. Moreover, contamination of surrounding farmlands can result in major heavy metal pollution of water resources, which can damage people and animals if consumed [10]. These heavy metals are transported and compartmentalized into bodily tissues, cells, and proteins in the human body. They attach to proteins and nucleic acids, which break down these macromolecules and impair their biological functioning. Hence, exposure to heavy metals can have a variety of negative effects on the body. It may cause blood component damage, as well as harm to the lungs, liver, kidneys, and other essential organs, resulting in mental disorder and fostering a number of medical conditions [11]. The objective of this research was to determine the concentrations of microbial quality (physical, chemical and biological parameters) in ground water (wells) from the dumpsite and to assess heavy metals (cadmium, lead, zinc and copper) contamination using Adumakuma (Sunyani Municipal Assembly) and quarry site at Ntensere respectively as a case study.

II. MATERIALS AND METHOD

The section was presented in two parts namely the methodology used to:

1. ascertain the effect of solid waste on ground water.
2. Determine the effect of heavy metal

2.1 Methodology for Solid Waste Effect

The study was conducted in Sunyani Municipal. Sunyani Municipal is one of the twelve district in Bono Region, originally created as an ordinary district assembly on 10th March, 1989 when it was known as Sunyani District, until the northwest part of the district was split off to create Sunyani west district on 1st November, 2007 (effectively 29 February 2008); thus the remaining part has been retained as Sunyani District, which it was later elevated to municipal district assembly status and has been renamed as Sunyani Municipal District on that same year. The municipality is located in the western part of Bono Region and has Sunyani as its capital town. It lies between latitude 70 20'N and 70 05'N and longitude 20 30'W and 2010'W and share boundaries with Sunyani West District to the north, Dormaa East District to the west, Asutifi District to the south and Tano North District to the east. The municipal has a total land area of 829.3 Square Kilometers (320.1square mils). The map for the study area and dumpsite is as shown in Fig. 1 and Fig. 2 respectively. The area is chosen due to regular use of these water sources for domestic purposes.

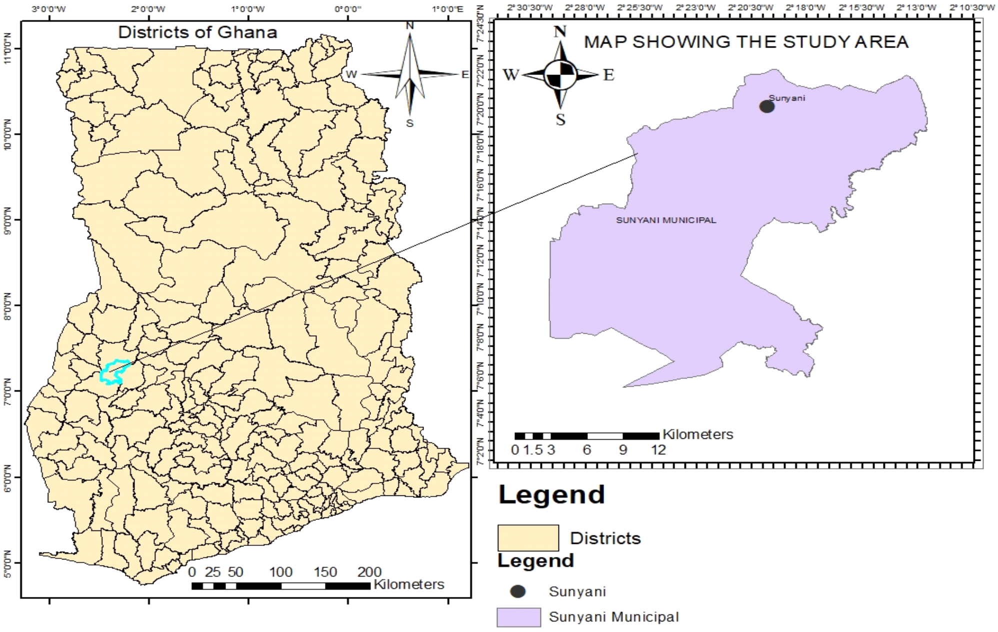


Fig. 1 Shows the Study Area Map

Fig. 2 Adumakuma Dumpsite (Sunyani municipal)

A total of five (5) wells close to the dumping site was purposively selected. For the purpose of this study, a total of five (5) sampling points were used and five wells, equidistance from the dumpsite, was selected. The groundwater (wells) samples will be collected in 1.5 litre water bottles. The sampling bottles were cleaned with 70% alcohol and then rinsed three times with the sampled water at the sites. Sampling equipment included fifteen-foot rope and 2.5L container and designated as W1, W2, W3, W4, W5, for the water samples. After sterilization of the sampling equipment, each the 1.5 litres sample bottle was filled directly from the well. Each sampling container was corked after filling with the sampled water using lids and kept in a cool box for transfer to Sunyani Ghana Water Company for analysis. Fig. 3 (a) and (b) shows the sampling procedure and designation.

Fig. 3 Sample Preparation

The parameters selected for the study were turbidity, Ph, color, conductivity and total coliform. All laboratory analysis were carried at the Ghana Urban Water Limited (Regional Water Quality Assurance Laboratory at Sunyani). In the laboratory, pH meter (HANNA model 209) was used to determine the pH of water samples after calibration, the temperature was determined using HANNA model 209 by pressing the temperature knob. The temperature measurement was repeated three times for all the samples. The apparent color of water samples was determined by HACH Lange Spectrophotometer (Model DR-5000) after calibration and also, conductivity meter (HANNA model HI 9032) was used to determine the conductivity of water samples in the laboratory. Turbidity of water samples was determined with HACH turbid meter (model CO 150), Palintest photometer (model 5000) was used to determine nitrate-nitrogen after the meter was calibrated and lastly, a multifunctional HANNA meter (model HI 9032) was used to determine the total dissolved solids in the water samples in the laboratory after calibration.

The bacteriological quality of the drinking water samples was assessed by using the total coliforms and Escherichia coli as indicators [12]. Total coliforms and Escherichia coli were identified using single strength MacConkey broth and tryptone water by the three tube Most Probable Number method.

The data obtained from the results was subjected to ANOVA and analyzed using statistical package for social sciences (SPSS) version 21 and exported to Microsoft Excel for further interpretations and presented in data charts (pie charts and/or bar charts). The data obtained from the results was also compared with WHO standard for drinking water.

2.2 Methodology for Heavy Metal Effect

Ntensere is a community located in the Ashanti Region of Ghana. The area is known for its quarrying activities, which have been ongoing for several years. The quarrying site is located near a lake, and there are concerns about the potential for heavy metal contamination in the water. Ntensere is primarily an agricultural community, with the majority of its population engaged in farming. The town's main crops include cassava, plantain, yam, maize, and vegetables. The fertile soils of the area are ideal for these crops, and the town benefits from the abundance of rainfall that the region receives. The map of the study area is as shown in Fig. 4.

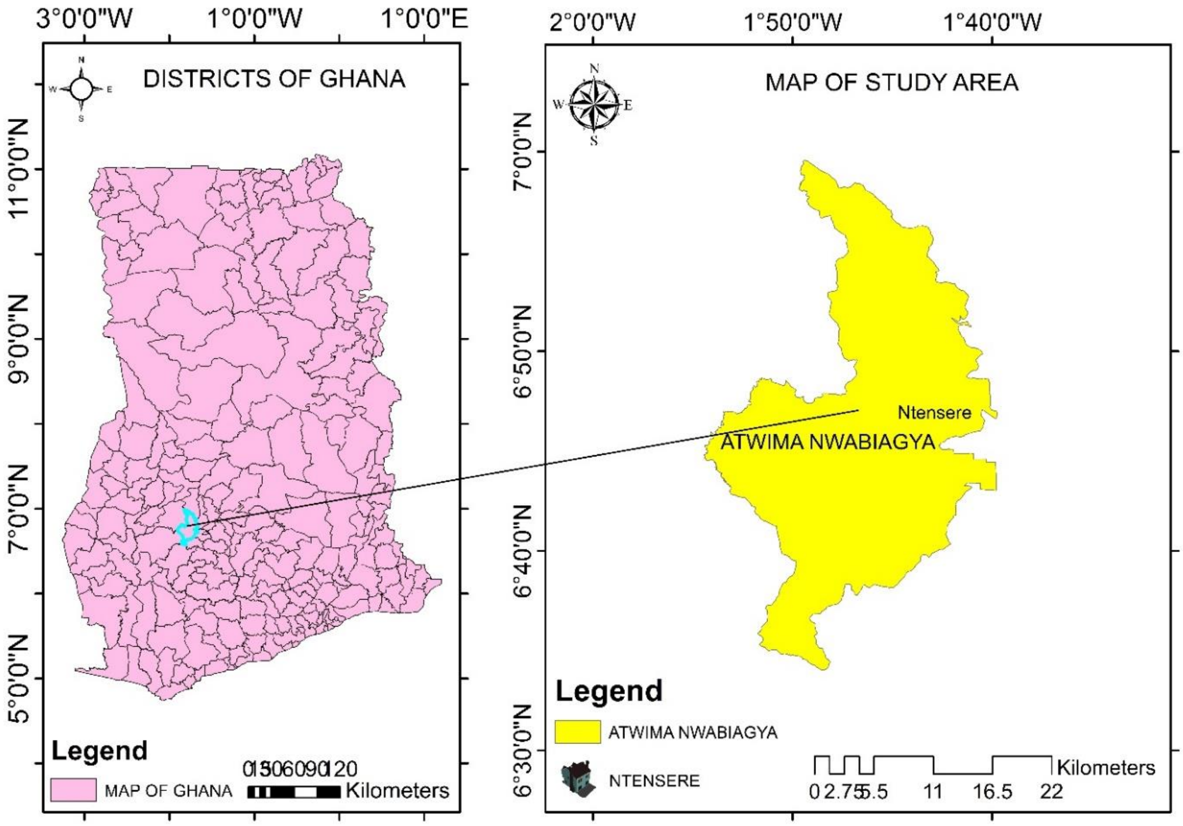


Fig. 4 Map of the Study Area

To assess heavy metals mainly are cadmium, lead, zinc, and copper in the lake, heavy metal concentrations in mg/L (milligrams per liter) was measured. A detailed experimental design using simple random sampling design for picking or collecting the water samples, that is randomly selecting sampling locations that reflects the concentration of heavy metals in the lake by considering the landscape. This design was selected to minimize the chances of inaccuracies or errors, to save time and easy to apply. Samples were collected at six sites along the Ntensere Lake, and the sections were divided into three groups: upstream (W1 and W2), middle (W3 and W4), and downstream (W5 and W6). Four trace metals, cadmium, lead, zinc, and copper were examined in samples taken from the lake. Using 1L polyethylene bottles with screw tops, water samples were taken 50 cm below the surface. While being transported, all samples were stored in cooling boxes at 4°C, and once they arrived at the lab, the analysis were immediately performed.

The collected water samples were digested using a 1:1 (v/v) solution of HNO3:HClO4 (merck nitric acid, 65%, and hydrochloric acid, 37%) until a complete digestion was confirmed by a gentle boil on a thermostated hot plate. The digested samples were quantitatively transferred to a 100 mL volumetric flask, chilled, and completely mixed after being filled to the appropriate level with distilled water. Additionally, a blank determination was made. Using the Solar M5 equipment from Thermo Company, the levels of Cd, Pb, Zn, and Cu in the processed samples were measured using flame atomic absorption spectrophotometry.

Exposure assessment was deduced using estimated daily intake (EDI) according to the relation:

$$EDI = \frac{C \times IR \times EF \times ED}{BW \times AT} \tag{1}$$

Where EDI (mg/kg/day) is the estimated daily dose intake through ingestion, C is the concentration of metal (mg/kg) in the food, IR is the ingestion rate (kg/day), EF is the Exposure frequency, ED is the exposure duration, BW (Kg) is the Standard body weight and AT is the time duration of human exposure. The parameters for calculating the estimated daily intake are presented in Table 1.

Table 1: Mean Concentration (mg/kg) at Different Depth

Element	Mean Concentration (mg/kg) at different depth		
	Upstream (W1 &W2)	Middle (W3 & W4)	Downstream (W5 & W6)
Cd	0.0055	0.0075	0.0095
Pb	0.0125	0.0225	0.0325
Zn	5.27	5.55	5.8
Cu	1.425	1.7	1.85

Table 2: Parameters for calculating EDI

Parameter	Value
IR	0.2g/day for children and 0.1g/day for adults
EF	180 days/year
ED	6years for children and 24 years for adults
BW	70 kg for adults and 15 kg for children
AT	365 *ED

The hazard quotient (HQ) was calculated according to the equation. Table 3 shows the reference doses.

$$HQ \equiv \frac{EDI}{RD} \qquad (2)$$

Table 3: Reference Doses (RD) of the Metals (Cd, Pb, Zn & Cu)

	Ref Dose (mg/kg/day)
Cd	0.001
Pb	0.04
Zn	0.3
Cu	0.04

The hazard index for a mixture of pollutants was determined using equation:

$$HI = \sum HQ$$

If the HI value is less than one, the exposed population is unlikely to experience obvious adverse health effects. If the HI value exceeds one, then adverse health effects may occur.

Data collected from the field was sent to the Kwame Nkrumah University of Science and Technology (KNUST) for laboratory analysis. The data obtained from the results was subjected to ANOVA and analysed using statistical package for social sciences (SPSS). Microsoft Excel was also used for further interpretations. Data was descriptively analysed and presented using statistical tools such as mean, frequency, percentage. The results presented in tables and charts for easy understanding.

III. RESULTS AND DISCUSSIONS

Water samples were evaluated to understand the effects of the dumpsite and concentration of the selected heavy metals on the quality of water in the surrounding areas. The data has been represented in chats form, figures and text for effective data and result presentation.

5.1 Effect of Solid Waste on water

5.1.1 Physical and Chemical Properties Test

Table 4 shows the obtained results from the study to know the physical and chemical properties of the tested samples.

Table 4: Results for Physical and Chemical Properties

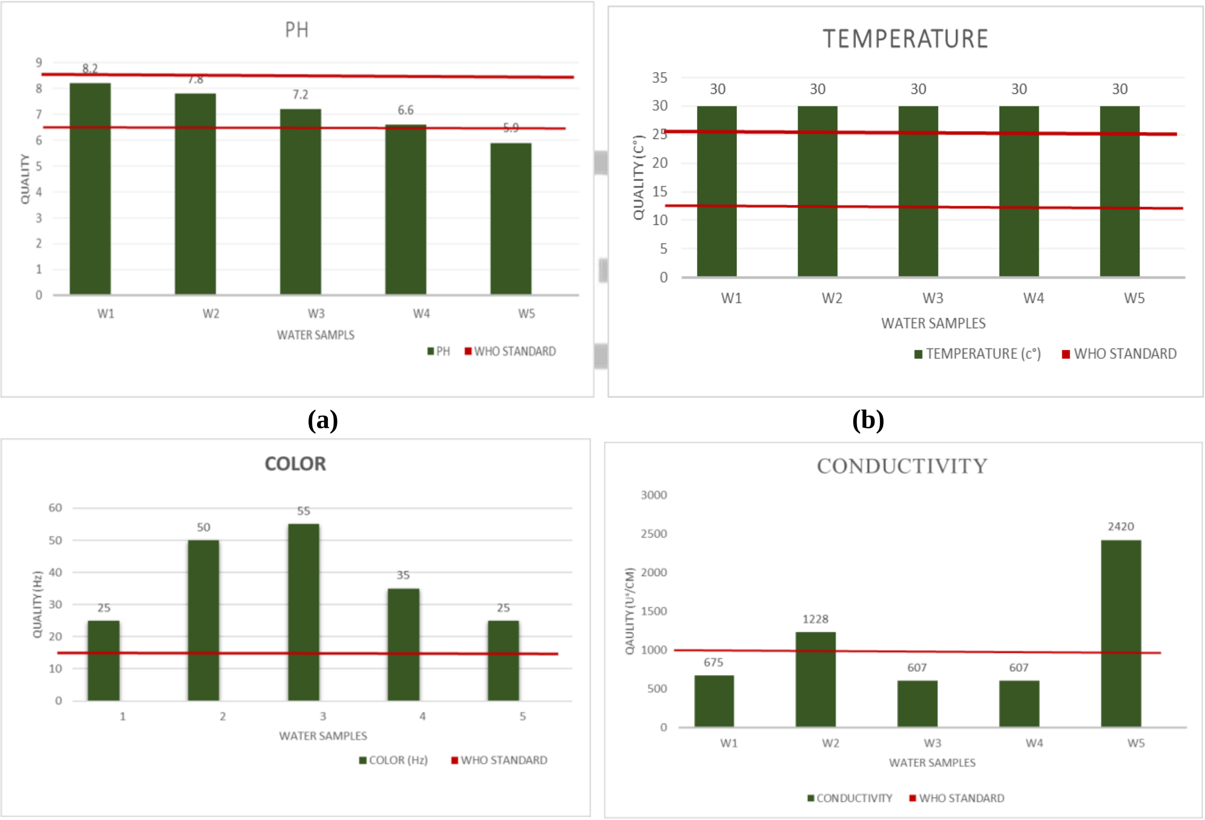
Physical and Chemical Parameters	**Measurements (Mg/L)**					**Who Standard**
	W1	W2	W3	W4	W5	
pH	8.20	7.80	7.2	6.6	5.9	6.5 - 8.5
Temperature (°c)	30.00	30.00	30.00	30.00	30.00	12—25
Color (Hz)	25.00	50.00	55.00	35.00	25.00	15
Conductivity (us/cm)	675	1228	607	607	2420	1000
Total Suspended Solids (TSS)	6.00	1.1	95	95	9.00	75
Total Dissolved Solids (TDS)	338	616	303	303	1210	1000
Turbidity (NTU)	38.00	22.00	17.00	11.00	38.00	5
Nitrate	1.2	2.4	14.9	14.90	3.6	50

A graph of pH, temperature, color and conductivity is as shown in Fig. 5 (a) to (d). The pH values obtained from the sample ranged between 5.9mg/L - 8.2mg/L. The pH decreases from W1 to W5 with W1 to W4 falling within the WHO stranded value of 6.5 – 8.2 and W5 which recorded the lowest value of 5.9mg/l falls below the standards as shown in Fig. 5 (a). Indication of high acidity, which might be caused by the deposition of acid forming substances in the dump site and by precipitation leaching into the wells water. pH is important in water quality assessment as it influences many biological and chemical processes within a water body [13]. The pH values recorded were slightly alkaline with little variations among the study sites. However, most of the sampled sites had pH values slightly higher than natural background level of 7 for tropical surface water. It is a known fact that variations in pH affect chemical and biological processes in water and low pH increases the availability of metals and other toxins for intake by human. On the other hand, the slightly high alkaline pH values recorded at the study sites would tend to decrease the availability of metals and other toxins for intake by human as well as domestic animals. The high pH may be due to the presence of other pollutants introduced into the water due to the study sites located near landfills/dumpsites. The overall result indicates that the well around the dump site is within the desirable and suitable range. Basically, the pH is determined by the amount of dissolved carbon dioxide (CO2), which forms carbonic acid in water. The present investigation was similar with reports made by other researchers' study [14] and [15] who found pH to fall within the minimum limit.

Temperature is a physical property which measures the hotness or coldness of water in a given area. It can alter the physical and chemical properties of water and also influences several other parameters. From the results shown in Fig. 5 (b), both wells, that is W1, W2, W3, W4 and W5 has equal temperatures of 30. The values recorded all exceeded the WHO standards for drinking water. Temperature affects sediment and microbial growth among other characteristics of water and it is also a known fact that the rate at which chemical reactions occur increase with increasing temperature and the rate of biochemical reactions usually double for every 10.0˚C rise in temperature. Physically, less oxygen can dissolve in warm water than in cold water. This is because increased temperature decreases the solubility of gases in water. Increased temperature increases respiration leading to increased oxygen consumption and increased decomposition of organic matter [13]. It is for these reasons that the temperatures of the water samples were determined for the wells. The values recorded all exceeded the WHO standards for drinking water. Since water temperature affects the concentration of biological, physical, and chemical constituents of water, the relatively high temperatures recorded would speed up the decomposition of organic matter in the water. Hence, population of bacteria and phytoplankton would double in warm weather in a very short time [13].

The values for color in all the samples were above detection limit as shown in Fig. 5 (c). The color measured ranged from 25Hz to 55Hz, with W3 recording the highest value of (55hz) and W1, W5 records the value (25hz) which is considered to be the lower values, which are all above the WHO standard guidelines for drinking water of 15Hz. Drinking-water should ideally have no visible color. Levels of color below 15Hz are usually acceptable to consumers, but acceptability may vary. Although, color itself is not usually objectionable from health perspectives, its presence is aesthetically objectionable and suggests that the water may need additional treatment [16] and may lead to greater consumer complaints**.**

Conductivity measures the number of dissolved ions in the water. From Fig. 5 (d), it is noted that W5 has the highest value conductivity of 2420 than that of W2 which had a value of 1228. The results also mean that, the conductivity of W5 and W2 exceed the guidelines provided by the WHO standard for drinking water whiles W1, W3 and W4 falls below the standards of whichW3and W4 had the same values of 607. Pure water is not a good conductor of electric current Rather’s a good insulator. Increase in ions concentration enhances the electrical conductivity of water. It is a valuable indicator of the amount of material dissolved in the water. Generally, the number of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current. According to WHO standards, EC value should not exceed 1000µS/cm. The high value of EC can be related to the effect of the leachate seepage towards the bore-wells. According to [13]. The importance of the electrical conductivity is its measure of salinity, which greatly affects the taste and thus has a significant impact on portability of water. This study result was found to be higher than a similar studies in Juba (South Sudan) where they recorded values of 89 µS/cm and 229 µS/cm. According to researchers [17] and [18] a high level of EC in wells water is attributed to the impact of a nearby landfill site.



(a) **(b)**

(c) **(d)**

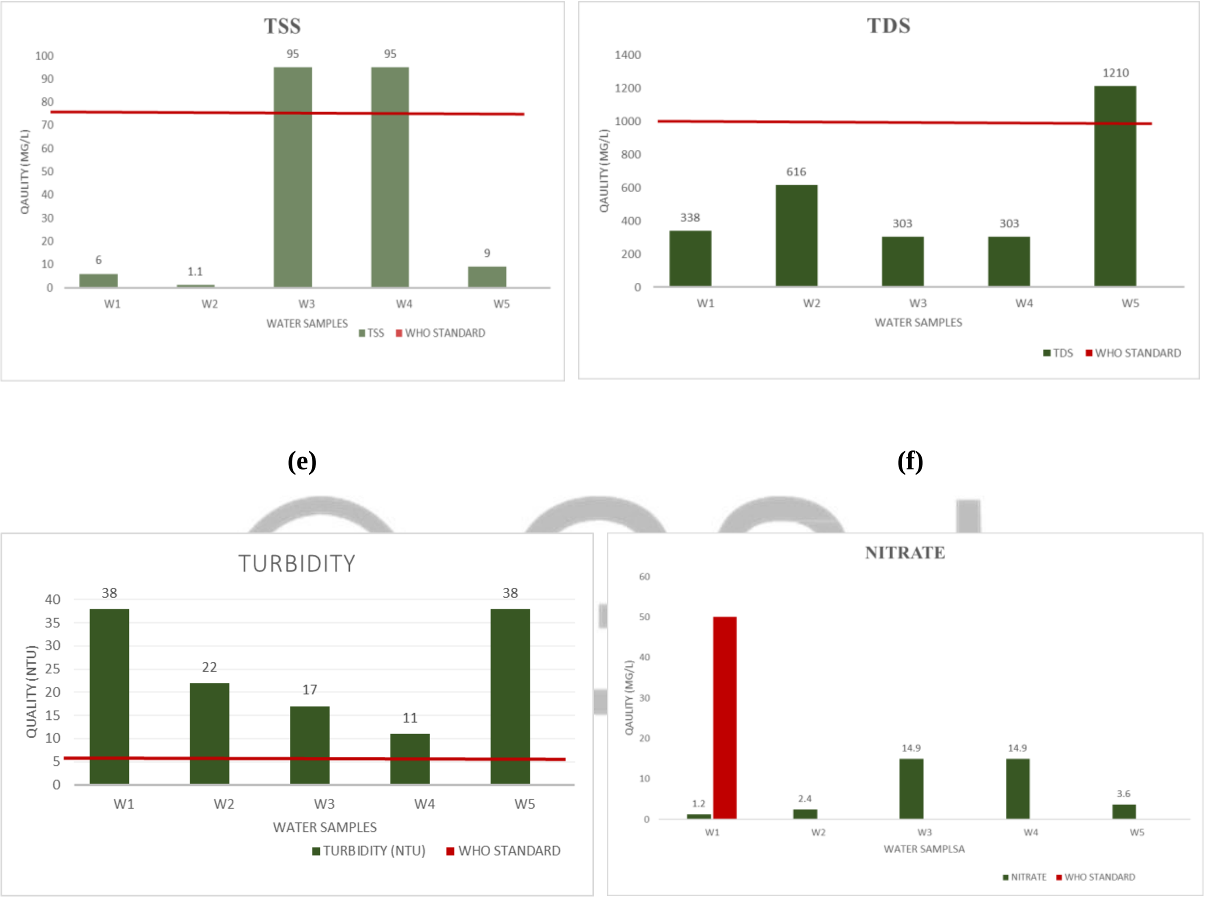
Fig 5: pH, Temperature, Color and Conductivity Values for the Five Sampling Points (W1 -W5)

A graph of total suspended particles, total dissolved solids, turbidity and nitrate is as shown in Fig. 6 (e) to (h). Total suspended solids measure the number of quantifying particles larger than 2 microns found in water. The study determines the concentration of TSS in the wells of the dumpsite (adumakuma) area as shown in Fig. 6 (a). TSS in W1 had a measured value of 6mg/L, W2 which had the smallest value of 1.1mg/L, W3 and W4 which had the highest values of 95mg/L of which both exceeds the WHO standards and W5 had a value of 9mg/L. Suspended material is a major pollutant carrier. Organic pollutants, toxic heavy metals, nutrients and pathogens are found in composites of suspended matter. The type of suspended matter determines turbidity and transparency of water. The high values of TSS may probably be due to gradual accumulation from the municipal wastes and that from the dumping site. This finding agrees with [19] who found higher concentration levels of TSS from tea farms in Kericho, Kenya.

Total Dissolved Solid measures the number of materials in the water that affects light scattering and transparency of the water. The desirable limit for TDS is 1000 mg/l which prescribed for drinking purposes. From the results indicated in Fig. 6 (b), W5 has the highest value of 1210mg/L. The highest value of TDS has an indication for high amount of organic and inorganic salts and other dissolved materials [19]. Moreover, TDS in W1 is 338mg/L, W2 is 616mg/L, in W3 and W4 have the same values of 303mg/L, of which W1, W2, W3 and W4 are all below the WHO standard for drinking water. The concentration of TDS in the present study was observed in the range of 303 and 1210 mg/l. Similar value was reported by [20]. High values of TDS in ground water are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects [21] and [22].

With regards to turbidity as shown in Fig. 6 (c), W5 and W1 recorded the highest with 38 NTU, followed by W2, W3, and W4, with values 22NTU, 17NTU and 11NTU respectively. The values of both wells were higher than the WHO guidelines for drinking water quality of 5 NTU. The origin of turbidity in drinking water is due to inadequate filtration of water [23]. Sample W1 and W5 (38 mg/L) recorded the highest value of turbidity in the water samples and could be the cause of the presence of suspended matter such as clay, silt, organic and inorganic matter, plankton, bacteria and other microscopic organisms that are leached from the dumpsite as stated in a report of [24]. While W4 recorded the least value due to its far distance from the dump site, samples W1 and W5 recorded the highest turbidity and this is because of their closeness to the open dump site. Although the result was higher than the limited permissible level, these values were found to be lower than similar research by [22] who had turbidity values of 40 to 160 NTU.

The acceptable as well as permissible limit of nitrate is 50 mg/L as per WHO. From the results shown in Fig. 6 (d), W1 has a nitrate concentration of 1.2mg/L, W2 had a value of 2.4mg/L, W3 had a value of 14.9mg/L, W4 also had a value of 14.9mg/L and W5 had a value of 3.6mg/L. The results also mean that all the values of the wells water are all below the guideline provided by the WHO standard for drinking water. Excess amounts of bioavailable nitrogen in marine systems lead to eutrophication and algae blooms. It is with regards to the key role nitrates play in water quality determination that its assessment has been undertaken in this study. Certain ground waters might show presence of nitrate due to leaching effect from vegetation. The artificial sources of nitrate in groundwater may be decaying organic matter, domestic wastes, and fertilizers. When nitrate is present in excessive concentration, it is a potential health hazard and may lead to health problems such as blue baby syndrome in infants and also cause gastro-intestinal cancer. This study agreed with a study under review that recorded concentration values lower than 50 mg/L of WHO for Nitrate.This study is similar to [13].



(e) (f)

(g) (h)

Fig 6: Total Suspended Particles, Total Dissolved Solids, Turbidity And Nitrate Values for the Five Sampling Points (W1 -W5)

5.1.2 Bacteriological Water Quality Analysis

Bacteriological water quality analysis is a process of analyzing water to estimate the number of bacteria present and if needed, to find out the consortium of bacteria. Summary of results is as shown in Table 5.

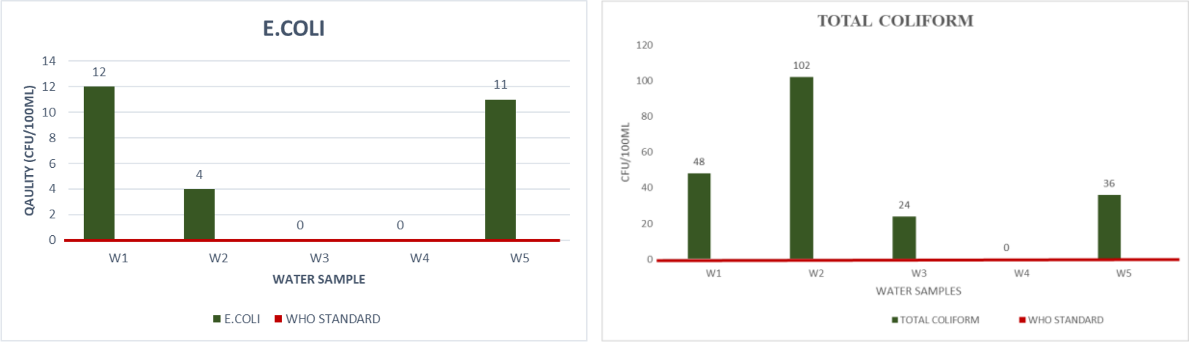
Table 5: Results for the Bacteriological Status of Wells Water

Bacteriological Parameters	**Measurements (Mg/L)**					**Who Standard**
	W1	W2	W3	W4	W5	

E. Coli (CFU/100ml)	12	4	0	0	11	0
Total Coliform (CFU/100ml)	48	102	24	0	36	0

Bacteriological examinations of water samples are done to determine the sanitary quality and the degree of contamination with waste [25]. E. coli is a type fecal coliform bacteria that is commonly found in the intestines of animals and humans. E. coli in water is a strong indicator of sewage or animal waste contamination. From Fig. 7 (a), W1 is recorded to have the highest value of E. coli of 12ml, W2 recorded a value of 4ml, W5 a total value of 11ml and W3 and W4 record 0 ml which falls within the standards of WHO for drinking water. W1, W2 and W5 exceed the guidelines provided by the WHO standard for drinking water which is (0). The high counts of faecal coliforms may be due to run-offs from the municipal landfills and urban solid waste disposal sites which contain domestic animal and human faecal materials [13]. It may also be attributed to their closeness to the refuse dumpsite.

Total coliform gives a clear indication of the general sanitary condition of water since this group includes bacteria of faecal origin. However, many of the bacteria in this group may originate from growth in the aquatic environment. This is used to evaluate the general sanitary quality of drinking and related water use [26]. The WHO standard for total coliform in drinking water is (0). From Fig. 7 (b), W1 records a total coliform of 48ml, W2 records the highest a value of 102ml, W3 recorded a value of 24ml, and W4 recorded 0 ml total coliform which falls within the guidelines provided by WHO standards for drinking water. W5 recorded a total coliform of 36ml which also exceeds the standards. The high concentration of TC could also be due to indiscriminate defecation, sewage, land and urban run-off and domestic waste waters [13]. The presence of coliform group of organisms is an indication of faecal contamination. The high TC counts observed at sampled sites, W1, W2, W3, and W5 make the wells unsuitable for domestic uses such drinking and cooking, according to the World Health Organization (WHO) limit [13]. Comparison of TC counts in the various sampled sites with the natural background and WHO limit of 0.0cfu/100 ml indicated gross contamination with bacteria at all the sites making the water unsafe for drinking by humans and livestock except W4 which recorded a value of 0cfu/100ml. According to [27], if water is found to contain faecal indicator bacteria, it is considered unsafe for human consumption.



(a) **(b)**

Fig 7: E. Coli and Total Coliform Values for the Five Sampling Points (W1 -W5)

Distance is another important factor that determines the extent of groundwater contamination. Fig. 8 shows the level of pollutants with variation to distance and from the results obtained. W5 has the lowest distance value of 70m, with E. coli and Total coliform concentration of 11 and 36 (CFU/100ml) respectively, and which mean that it is closer to the dumpsite as compared to the others. W1 which also had a distance value of 98m shows its closeness to the dumpsite with concentration values of 48CFU/100ml E.coli and 12CFU/100ml TC, W2 measured a distance value of 125m away from the dumpsite with concentration values of 102CFU/100ml TC and 4CFU/100ml E.coli, W4 measured 200m away from the dumping site with concentration values of 0CFU/100ml E.coli and 0CFU/100ml TC which falls within the standard limit and W3 which measured the highest distance value of 250m away from the dumpsite has concentration values of 0CFU/100ml E.coli and 24CFU/100ml TC, which means E.coli was below the standard and TC was above it and considering the distance value, it means that W3 is a bit far away from the dumpsite compared to W1, W2, W4 and W5. Even though there were some variations with respect to distance, it was not consistent, meaning it has a negative correlation. This study in terms of E. coli does agree with [28]. In their study, the concentrations of contaminants vary inversely with the distance hence samples with high contaminant concentrations were found to be close to the landfill. Therefore, groundwater contamination drops as one moves away from the landfill sites. Specifically, groundwater contamination occurs within 900–1000 m of the dumpsite/ landfill radius and most of the serious contamination takes place within 200 m. As one moves away, the percolation of leachate becomes gentler. This has been accounted for by the natural attenuation, mainly controlled by factors like dilution, sorption, ion exchange and degradation processes [29]. But for total coliform it did not agree with their findings as we recorded 102CFU/100ml level of concentration in W2 which was further from the dumpsite than W1, and W5. The concentration level does not follow any pattern and even recording more values from far distance. This may be due to some factors such location and slope of that environment.

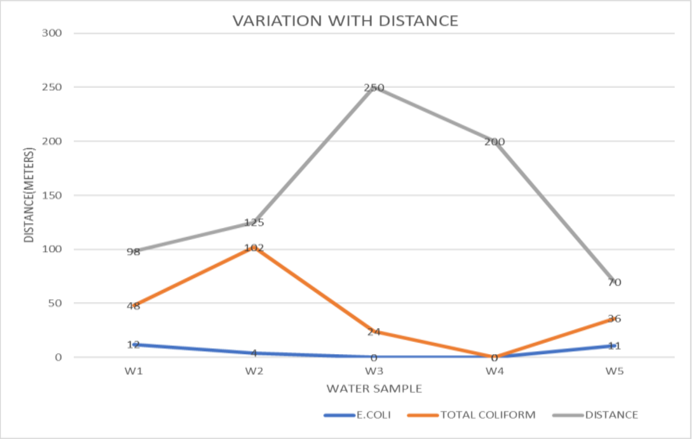


Fig. 8 Concentration of Pollutants (E. Coli And TC) With Variation to Distance for the Five Sampling Points (W1 -W5)

5.2 Concentration Levels of Selected Heavy Metals in Water Samples

5.2.1 Concentration of Metals Analysis

Water samples were evaluated to understand the concentration of the selected heavy metals in the lake. The data was represented in chats form, figures and text for effective data and results presentation. The various element concentration for cadmium, lead, zinc and cupper are as shown in Table 6 with their mean concentration in upstream, mid-stream and downstream shown in Table 7.

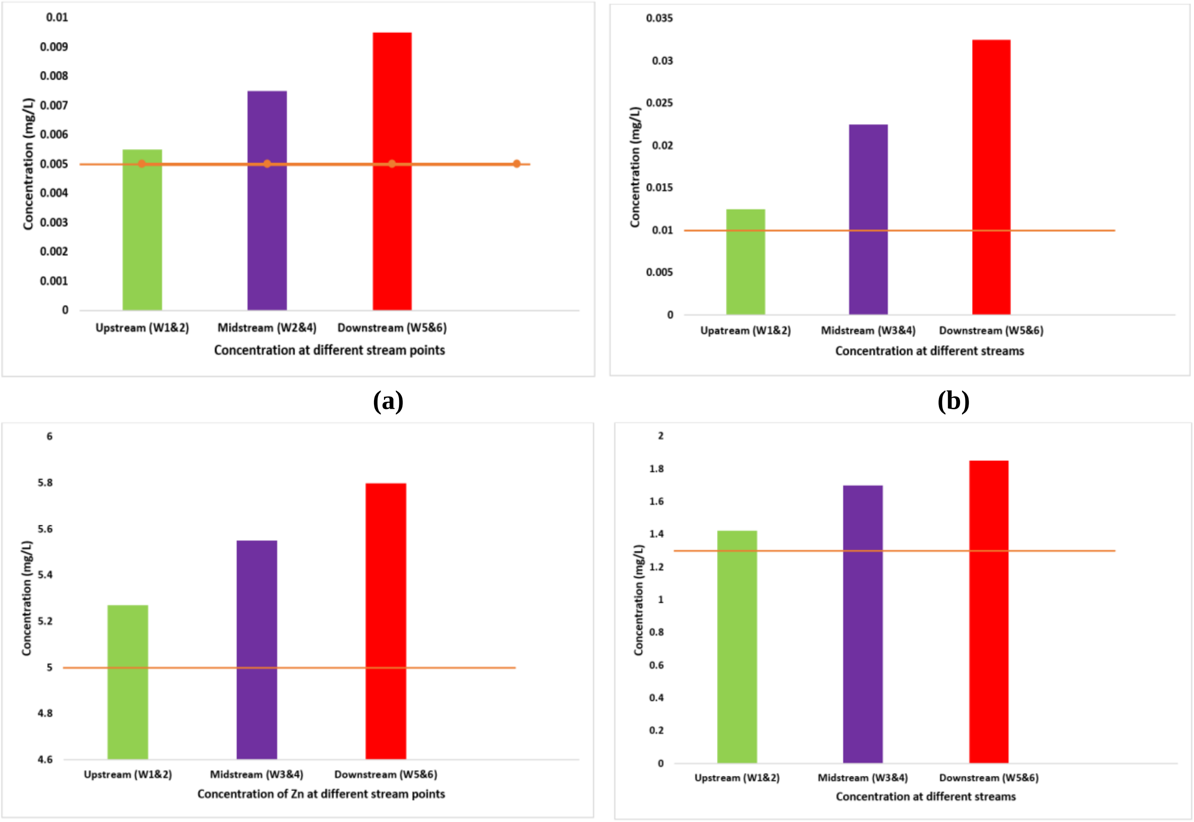
Table 6: Concentration of Metals in the Water Samples

W/S	**Cd(mg/L)**	**Pb(mg/L)**	**Zn(mg/L)**	**Cu(mg/L)**
W1	0.006	0.01	5.3	1.4
W2	0.005	0.015	5.24	1.45
W3	0.008	0.025	5.5	1.7
W4	0.007	0.02	5.6	1.7
W5	0.009	0.03	5.8	1.8
W6	0.01	0.03	5.8	1.9

Table 7: Mean Concentration of Metals in Different Streams of the Lake

Streams of the Lake	**Mean Concentration of Elements**			
	Cd	Pb	Zn	Cu
Upstream (W1&2)	0.0055	0.0125	5.27	1.425
Midstream (W3&4)	0.0075	0.0225	5.55	1.7
Downstream (W5&6)	0.0095	0.0325	5.8	1.85

The mean concentration of cadmium (Cd), Lead (Pb), Zinc (Zn) and Cupper (Cu) in the different streams of the lake in comparison to the EPA standard for maximum concentration to be present in any water body for human activities are as shown in Fig. 9 (a) to (d).



(a) **(b)**

(c) **(d)**

Fig. 9 Concentration of Cadmium, Lead, Zinc and Copper in the Lake at Different Streams

The average Cd concentration in the water samples is 0.0075 mg/l, with a range of 0.005 to 0.01 mg/l as shown in Fig. 9 (a). Cadmium has a very low maximum contaminant level (MCL) in drinking water, which is 0.005mg/l due to its toxicity [26] and are extremely harmful and accumulate in the ecosystem even at low levels. "Itai-Itai" sickness may be brought on by cadmium buildup. According to [30] humans suffer fractures and bone tempering as a result. Renal damage caused by cadmium is visible at greater doses. Following long-term or high dose exposure, cadmium was declared to induce kidney defects as well as bone softening, and excessive levels of cadmium have been declared to cause prostate cancer. Lung cancer is riskier due to cadmium.

Fig. 9(b) shows that lead levels in water samples from the research area vary from 0.01 to 0.035 mg/l, with an average of 0.02250 mg/l. The EPA maximum recommended concentration for Pb was recently reduced to 0.015mg/l because of concerns about chronic toxicity, although its concentration rarely exceeds in natural waters [31]. Lead poisoning can be either acute or chronic, and both can result in birth defects, mental retardation, autism, psychosis, allergies, paralysis, weight loss, dyslexia, and other conditions. Acute lead exposure can cause headaches, loss of appetite, abdominal pain, fatigue, sleeplessness, hallucinations, and vertigo. Chronic lead exposure can result in these conditions as well as renal dysfunction, hypertension, and arthritis [32].

The research area's average zinc content was 5.54 mg/l, which is quite high and ranges from 5.24 mg/l to 5.80 mg/l as shown in Fig. 9(c). According to the EPA, the usual threshold value for zinc in water is 5 mg/l, yet all of the samples had zinc concentrations that were greater. The signs of severe poisoning include lethargy, sideroblastic anemia, disorientation, abrupt gastrointestinal bleeding, kidney injury, pancreatic function destruction, liver failure, and dehydration. Particularly in the event of industrial exposure, zinc inhalation may result in dyspnea, airway inflammation, and acute respiratory distress symptoms [32].

The research area was determined to have high copper values. The average concentration in the local water samples, which range from 1.4 to 1.9 mg/l as shown in Fig. 9(d) was 1.658 mg/l. The standard water threshold value is 1.3 mg/l. The use of nuclear chemicals to blast the rocks (mountain) and the usage of agrochemicals by surrounding farming activities may be to blame for the copper buildup in the water. Additionally, cognitive issues, hypertension, liver, and kidney malfunction may result from copper overdoses.

5.2.2 Health Quotient of the Metals in the Lake

When the Health Quotient (HI) for Cd, Pb, Zn, and Cu is approximately 0.00591mg/kg/day, 0.00045mg/kg/day, 0.00001mg/kg/day and 0.00055mg/kg/day respectively. This indicates that there may be a potential health risk associated with exposure to cadmium at the given level. The Table 7 shows the HI of the metals in the lake.

Table 7: Health Quotient of Metals in the Lake

Metal	**Health Index (HI)**
Cd	0.00591
Pb	0.00045
Zn	0.00001
Cu	0.00055

The estimated daily intake (EDI) for the metals at the Upstream of the lake increased in an ascending order as Zn<Cd<Pb<Cu respectively. In the midstream, the EDI for the metal increased in an ascending order as Zn<Cd<Pb<Cu respectively. At the downstream, the EDI for the metal increased in an ascending order as Zn<Cd<Cu<Pb respectively. The Table 8 highlights the EDI of the metal at the different streams of the lake.

Table 8: EDI of the Metals at the Different Lake Streams

Water Depth	**Estimated Daily Intake**			
	Cd	Pb	Zn	Cu
Upstream	1.49×10^{-6}mg/kg/day	3.09×10^{-6}mg/kg/day	1.23×10^{-6}mg/kg/day	6.24×10^{-6}mg/kg/day
Midstream	1.94×10^{-6}mg/kg/day	6.17×10^{-6}mg/kg/day	1.30×10^{-6}mg/kg/day	7.43×10^{-6}mg/kg/day
Downstream	2.48×10^{-6}mg/kg/day	8.93×10^{-6}mg/kg/day	1.35×10^{-6}mg/kg/day	8.10×10^{-6}mg/kg/day

Based on the analysis of the metals in terms of their EDI, HQ and HI, this study could deduce that when farms close to the lake use the water from the lake for their farming irrigation, they risked exposing themselves to these heavy metals each time they used the water on their farms as well as exposing their customers to these metals. The concentration of these metals compared to EPA permissible standards for these heavy metals in water bodies were above these standards. Although the concentrations of these metals may not cause immediate health repercussions, constant exposure to these metals over long periods. Exposure to lead poses risks to living organisms and, owing to its persistence, has the potential to persist in the environment for an extended duration. [30] in their study stated that lead in the human body targets bones, brain, blood, kidneys, and thyroid glands.

Neurological disorders, hypertension, and cognitive impairments have all been associated with lead exposure. Lead disrupts the activation of enzymes, impedes the absorption of essential minerals, hampers the synthesis of structural proteins by binding to sulfhydryl proteins, and depletes the levels and availability of sulfhydryl antioxidant reserves in the body. The skin, oral cavity, and respiratory system serve as accessible entry points for lead into the human body. It is stored in various bodily compartments such as bones, teeth, liver, lungs, kidneys, spleen, and the brain. Additionally, lead can penetrate the blood-brain barrier and traverse from maternal to fatal blood compartments.

Cadmium enters the body primarily through the skin, intestines, and lungs. Subsequently, the Cadmium-Metallothionein complex is distributed by the kidney tubules to various tissues and organs, where it binds with metallothionein's (MTs) before being reabsorbed. Since there is no mechanism for its ultimate elimination, the Cadmium-Metallothionein compound that eventually accumulates in organs such as the kidney, liver, lungs, and pancreas persist for a prolonged period. Cadmium hinders the transfer of epithelial and cell membranes, thereby impacting cell function and homeostasis.

IV. CONCLUSION

This study offers a thorough analysis of heavy metal contamination and solid waste in water bodies, concentrating on a particular instance in Ntensere and Adumakuma respectively. From this study, it was observed that most of the physico-chemical and bacteriological characteristics such as Temperature, pH, Color, conductivity, Total suspended solids, Total dissolved solids, Turbidity, Nitrates, E. coli, and Total coliform bacterial in wells water samples were at their maximum and higher than the highest desirable limit in all the locations. Based on WHO minimum limit, the results indicated that except pH, all the other parameters showed some level pollutants, the distance from the water sources (wells) to the dump site had a significant effect on the levels of the other physico-chemical and Bacteriological properties. Lead, copper, cadmium, and zinc heavy metals' effects on human health was examined by computing the variables such the estimated daily intake (EDI) for adults, hazard quotients (HQ) and hazard indices (HI). Based on the findings of the study, Zn had the highest concentration of 5.8mg/L followed by Cu with concentration of 1.9mg/L and lastly Cd and Pb with the same concentration of 0.01mg/L. Comparing these sampled concentrations to the EPA permissible concentration standards showed that the mean concentrations of the metals were above the EPA permissible standard. The HI of the metal was 0.00591 for Cd, 0.00045 for Pb, 0.00001 for Zn and 0.00055 Cu. Although the HI of these metals were not above the standard as analysed in this study, the continuous exposure the over long periods of time could posed significant health threats to farmers and their direct customers. Therefore, it is necessary to protect farmers and consumer health by raising public knowledge and awareness about the negative consequences of using the water the lake for agriculture irrigation in order to achieve sustainable Development Goal 3 (good health and well-being).

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