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INFLUENCE OF MUNICIPAL DUMPSITE ON WATER QUALITY IN SUNYANI MUNICIPALITY

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Abstract
Urban waste management is one of the critical environmental challenges in rapidly urbanizing African cities. Exposure of untreated waste into the external environment poses severe environmental and human health risks. Employing data from ground and surface water sampled from the Sunyani municipal dumpsite, this study sought to assess the influence of the Sunyani Municipal waste dumpsite on surface and groundwater quality. The study specifically evaluated the effect of dumpsites on the physical, chemical, and biological properties of ground and surface water. The study revealed a statistically significant water quality difference across all sample sites. Apart from pH, TDS, turbidity, conductivity, and dissolved oxygen which recorded concentrations within the acceptable standards of the WHO, all other parameters (NO_3, BOD, total coliform, faecal coliform, copper, zinc, iron, and lead) examined in the groundwater samples recorded concentration levels above the World Health Organisation permissible limit. Similarly, pH, turbidity, dissolved oxygen, zinc, iron, lead, BOD, total coliforms, and faecal coliform levels in surface water samples were generally high in the midstream and downstream portions compared to the upstream and WHO guidelines. Consequently, water resources around the dumpsite pose significant public health and environmental threats. The study, therefore, recommends the segregation, proper management, and treatment of toxic waste before discharge into the external environment.

Keywords: *Dumpsite, Water Quality, Contaminants, Leachates, Sunyani municipal, Pollution*

Introduction

Despite being essential for life's sustenance, water continues to be polluted in various anthropogenic activities, including domestic, commercial, and industrial utilization. According to WHO (2014), human water consumption must meet acceptable biological, chemical, and physical standards. Regrettably, many countries within the sub-Sahara African region have waste management as one of the most prominent environmental challenges in recent years, owing to the exponential rises in the population of the area. The region is estimated to generate around 62 million tons/year, with a more significant percentage of this waste discharged into water bodies that serve as the primary water source for indigenous communities (Besufekad Mekonnen, 2020; Lissah *et al*., 2021).

In Ghana, only 10% of the 12,710 tons of solid waste generated daily is collected and disposed of at approved dumping sites (Lissah *et al.,* 2021). According to Amoah and Kosoe (2014), Miezah *et al.* (2015), and Douti *et al*. (2017), rapid population expansion, urbanization, and inadequate waste infrastructure are in part the significant factors that hinder proper solid waste management in the country. As a result, open and indiscriminate dumping of municipal solid waste is a common phenomenon in the country, especially in major cities, including Sunyani Municipal. Such indiscriminate disposal of solid waste in uncontrolled dumpsites poses a severe threat to the environment and lives of humans and animals who depend on environmental resources within the catchment for their daily activities (Dong *et al*., 2008).

Sunyani's reputation as the cleanest city in Ghana is being threatened by its rapid population growth and poor management of solid waste in recent years. All garbage generated inside the municipality is disposed of at the municipal's primary open dumpsite. Unfortunately, this dumpsite is located within 700 meters of multiple household boreholes and surface water sources which serve as the primary source of drinking water for the residents of Waterloo and other catchment communities (Kwawuvi *et al*., 2019). The surface water around the dumpsite is also a tributary of Tano river, the primary water source for the municipality (Adusu *et al.,* 2022). The proximity of the dumpsite to these water sources poses severe health threats to the residents of Waterloo and the Sunyani Municipality in General. According to Kanmani and Gandhimathi (2013), waste dumped at dumpsites goes through a sequence of physical, chemical, and microbiological changes, resulting in the release of leachate, which, if not stopped, eventually contaminates ground and surface water systems.

Despite the exposure of these water sources to leachates and effluents from the municipal dumpsite site, limited studies have been undertaken to assess the degree of contamination or otherwise of ground and surface water within the catchment of the dumpsite. This study, therefore, seeks to evaluate the influence of the Sunyani municipal dumpsite on the surface and groundwater quality. The study specifically sought to assess the extent to which the physical, chemical, and biological quality parameters of the surface and groundwater in the study area conform with the WHO drinking water quality standards. The study is expected to contribute to policies aimed at sustainable waste management in Ghana. It is also expected to provide information on the safety of ground and surface water sources around the municipal dumpsite site.

Study Area

The study was conducted at the municipal dumpsite of Sunyani, in the regional capital of the Bono Region of Ghana. The site is near the Sunyani Technical University GETFund Hostel and 15 minutes away from the Central Business District (Boateng, 2014). The dumpsite is 20 years old with an estimated land area of 0.025 square kilometers compared to the municipality's 829.3 km^2 aggregate land area. The municipality has 123, 224 inhabitants, with 84.6 % being urbanites (GSS, 2012). This high urban population of the municipality makes waste management one of the significant environmental challenges in the city. The study area lies within the Wet Semi-Equatorial Climatic Zone of Ghana, with monthly temperatures and rainfall varying between 23ºC and 33ºC and 88.99cm, respectively (GSS, 2012). Its relative humidity averages between 70% and 80% annually. The Municipality falls within the Moist Semi Deciduous Forest Vegetation Zone with two major forest reserves, Yaya and Amoma forest reserves. The municipality also has several water bodies, including the Tano, Amoma, Kankam, Benu, Yaya, and Bisi rivers. These water bodies are seasonal, creating water shortages in the municipality during the dry season. Geologically, the Municipality is underlain by Precambrian and Birimian formations and, therefore, rich in mineral and granite deposits. Soils in the municipality are largely Ochrosols, with few portions having the Birim Chichiwere Association, which gives the municipality dynamic drainage characteristics.

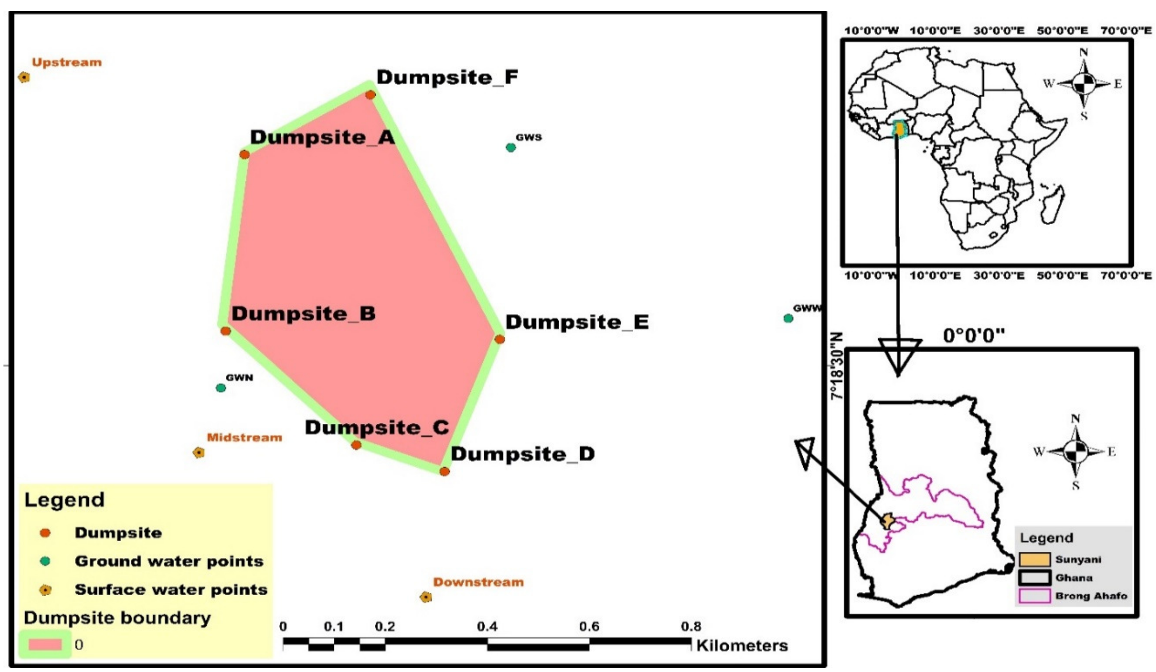

Fig 1: Map of the Studied Area with the distance area for the data collection = 34,947.6661 Square Kilometres, with a Perimeter of 0.7706 kilometre

Surface and Groundwater Sampling

Surface water quality around the dumpsite was assessed by stratifying the study area into upstream, mid-stream, and downstream sections. Surface water samples were collected from upstream, midstream, and downstream locations of the stream using 500ml sample bottles. The sampling method was adopted considering the dumpsite's location and assessing the dumpsite's potential contribution to the stream's pollution. To cater for sample variations at different periods of the day, replicate samples were collected in the morning, afternoon, and evening on the 15^{th}, $16^{th,}$ and 17^{th} January 2020 respectively. Before collecting each sample, sample bottles were washed thoroughly with distilled water followed by water from the different streams to prevent sample contamination. Samples were put into clearly labelled 500ml sample bottles, kept in an ice chest containing ice, and transported to the Central Lab of the Kwame Nkrumah University of Science and Technology for biological and Physico-chemical analyses. Similarly, underground water quality was assessed using three (3) purposively sampled hand-dug wells within 200m radii of the dumpsite's three cardinal directions (North, South, and East), as indicated by Ewemoje *et al*. (2017). Three (3) water samples were taken at monthly intervals in each of the three wells to examine the influence of the dumpsite on underground water. Samples were drawn directly from the wells using drawing buckets linked with ropes. To minimize changes in characteristics caused by light and guarantee that the microbes remained alive while dormant, the samples were stored in a light-proof insulated box with ice packs. The samples were subsequently sent to the Central Lab of the Kwame Nkrumah University of Science and Technology's Biochemistry Department and Central Laboratory in Kumasi for examination. Samples were analysed for the concentration of physical, chemical, and biological water quality parameters such as Total Dissolved Solids (TDS), pH, Turbidity, Biological Oxygen Demand (BOD), Total Coliform (TC), Electrical Conductivity (EC), Faecal coliform, Iron (Fe), Lead (Pb), Copper (Cu), Zinc (Zn), and Dissolved Oxygen (DO). Also at each sample location, Garmin eTrex hand-held Global Positioning System (GPS) receiver was used to record coordinates for the assessment of the spatial distribution of contaminants within the area.

Analysis of Water Samples

The pH of the water samples was determined using a HANNA HI 83141 pH meter with a temperature probe with 0.01 degree of accuracy. The conductivity of the water samples was measured in the laboratory within two hours after collection using a high-powered microcomputer conductivity meter HANNA HI 9828 with a 0.01 degree of precision. The turbidity of the water samples was measured with a microprocessor turbidity meter WAGTECH 7100. The Most Probable Number (MPN) method was used to determine total and fecal coliforms in the samples. The heavy metals concentrations (Fe, Pb, Zn, and Cu) in the water samples were determined using the digested samples in an Atomic Absorption Spectrophotometer (AAS).

Data Analysis

Data obtained for the laboratory analysis of ground and surface water samples were analyzed using the Statistical Package for Social Scientists (SPSS) version 16.0. Test of significant difference in the mean concentration of chemical in surface and ground water samples were conducted using one-way ANOVA and Tukey HSD all pairwise comparison tests at 95 percent confidence level ($p < 0.05$). Geo-Statistical Analysis was used to interpolate the heavy metals using the Inverse Distance Weighted method in ArcGis software. A desktop literature review was conducted to identify existing legal and policy framework on waste management.

Results and Discussion

Effect of Dumpsite on Physical, Chemical, and Biological Quality of Ground Water

The general objective of this study was to evaluate the influence of Municipal dumpsites on water quality in Sunyani Municipality. Groundwater samples from the study region were assessed and compared to WHO drinking water quality standards (Table 1). Groundwater pH ranged from 7.8 to 9.31, with an average of 8.47. Compared to the WHO guidelines, the pH levels recorded in groundwater samples fell within the acceptable ranges (6.5-8.5) but were slightly alkaline. This indicates that though the dumpsite may have impacted the pH of groundwater in the study site, the water remains safe for drinking in terms of acidity or alkalinity levels. The observed trend of pH may be attributed to the alteration of the acid-base equilibrium of underground water by the leeching of rainwater containing alkaline substances (Bhalla *et al*., 2012; Amano *et al.,* 2021). This may have reduced the buffering capacity of the underground water and, hence the marginal rise in pH. The results conform to other studies that have reported alkaline leeching into underground water around old dumpsite sites (Vathsalan *et al*., 2017; Ololade *et al.,* 2019). Amano *et al.* (2021) also reported the alkaline pH of borehole water near a dumpsite site in Ghana.

Similarly, TDS levels in the groundwater samples varied from 7.08 to 11.4 mg/L, with a mean of 9.44 mg/L, suggesting that all samples had acceptable TDS levels based on WHO guidelines (500 mg/L). According to WHO guidelines, TDS concentration up to 500 mg/L is suitable for drinking water, while up to 1,500 mg/L is the highest acceptable level (Ololade *et al.,* 2019). This indicates that the area's underground water contains acceptable levels of dissolved ions. This may be attributed to the fact that the boreholes in the study area are engineered to prevent the transport of sediments and nutrients from dumpsite and other adjoining land uses (Kwawuvi *et al.,* 2019). This result conforms to the findings of Davis and De Wiest's (1966). They reported that 82 percent of groundwater samples have acceptable TDS levels and are suitable for drinking due to natural filtration and cleansing processes during surface water infiltration to recharge groundwater sources.

The turbidity of water is a measure of the amount of suspended particles in the water (Amano *et al.,* 2021). High turbidity levels in water make it unsafe for drinking as it poses serious human health risks. Water resources with high turbidity, therefore, require treatment before consumption. Turbidity levels in ground water samples varied from 1.83 to 7.49, with a mean of 4.32 NTU. Compared to WHO guidelines, the results show acceptable turbidity levels in the study's groundwater samples. Though Kwawuvi *et al.* (2019) recorded high turbidity levels in underground water in a similar study in Ghana, samples used in their study were collected from open dug wells, which allowed for the influx of sediments into groundwater via overland flow. On the other hand, the engineering of the wells from which samples were collected for this study prevents the entrance of sediments in runoff water from the dumpsite which may have contributed to the low turbidity of the water.

Conductivity measures ionic content or dissolved solids concentration in water (Soujanya and Saxena, 2017). It also indicates the level of mineralization and corrosivity. Conductivity levels in the groundwater samples ranged from 84.8 to 103 us/cm, with a mean of 96.95 us/cm. This indicates that the dumpsite has no adverse effects on the area's subsurface water's electrical conductivity. Also, groundwater samples were within the WHO-permitted conductivity limits (500us/cm). Though other studies have indicated high conductivity levels in leachate and ground water samples from other dumpsite sites (Nyarko, 2008; Soujanya and Saxena, 2017; Mekonnen *et al.,* 2020), the geology of the area may have contributed to the reduced levels of dissolved inorganic reaching the underground water.

Nitrate (NO_3) concentrations in the groundwater samples were above the WHO's permissible limit of 10 mg/L. The NO_3 values ranged from 9.21 to 16.72 mg/L with a mean of13.29 mg/L. This high concentration of NO_3 in the groundwater samples may be attributed to water infiltration from decomposed organic material from the dumpsite into the groundwater samples (Bolarinwa *et al.,* 2017). Other potential sources of nitrate in the ground water samples could be water infiltration from farms and septic tanks around the study area (Nyarko, 2008; Mekonnen *et al.,* 2020). According to Nyarko (2008), many nitrogenous fertilizers are converted into mobile nitrates by natural processes which contaminate water. Therefore, high nitrate concentrations (NO_3) in groundwater may negatively impact human health, especially in young children (WHO, 2011). According to McCasland *et al.* (2017), short-term exposure to drinking water with high nitrate levels is a possible health threat to humans, especially babies with immature digestive systems, for converting nitrate to nitrite. Mekonnen *et al.* (2020) obtained a similar finding in a study around a dumpsite site in Ethiopia.

Biological Oxygen Demand (BOD) measures the amount of oxygen required for the microbial decomposition of organic matter into inorganic form (Bolarinwa *et al.,* 2017). Similarly, BOD levels were higher than the WHO's allowed limit of 6.9 mg/L. BOD levels in the groundwater samples ranged from 7.69 to 12.72 mg/L with a mean of 9.89 mg/L. This indicates severe pollution from leachates from the dumpsite site. The high BOD levels in the groundwater samples may be due to the leachate of decomposed organic waste during the rainy season. The high decomposition rate of organic material at the site results in increased BOD levels as the microorganisms take up more oxygen, hence oxygen deficiency for other aquatic life (Jafar *et al*., 2017). According to Taylor and Allen (2006), wastewater from dumpsites becomes a part of the prevailing hydrological system triggering a series of biochemical reactions and water percolation into underground water sources.

Dissolved oxygen concentration is an indicator of the health status of water. High dissolved oxygen levels indicate low pollution levels and vice versa (Bolarinwa *et al.,* 2017). The dissolved oxygen (DO) range was 2.0–3.21 mg/L, with a mean of 2.64 mg/L. According to the research, the average Dissolved Oxygen (DO) value (of the groundwater samples) was found to be within WHO permissible range approved levels. Therefore, the concentration of DO is unaffected by the dumpsite, and the water is suitable for drinking. This may be because waste discharges containing a lot of organic matter and nutrients result in a high level of biological oxygen demand, which lowers groundwater concentrations (Chapman, 2021). These results confirm the assertion of other studies which have revealed an inverse relationship between BOD and DO in water quality studies around dumpsite sites (Soujanya *et al.,* 2017; Bolarinwa *et al.,* 2017).

Coliforms are established indicators for detecting fecal water contamination (Ololade *et al.,* 2019). The range of total coliform counts was 164 to 347, with a mean of 273.17 (cfu/100ml). Total Coliform levels in groundwater samples were higher than the WHO-allowable limit (cfu/100 ml). This indicates that the groundwater may be polluted with faecal matter by waste management companies and other domestic waste. This may pose serious health risks as their presence indicates the potential existence of other disease-causing parasites, viruses, and bacteria. They have also been widely reported to be associated with intestinal infections such as diarrhea when contaminated water is used without treatment (Nyarko, 2008; Bolarinwa *et al.,* 2017; Ololade *et al.,* 2019). The results are consistent with other studies which have revealed faecal contamination of water around dumpsite sites (Bolarinwa *et al.,* 2017; Ololade *et al.,* 2019)

Similarly, with a mean value of 188.73 (cfu/100ml), the groundwater samples recorded fecal coliform levels ranging from 89 to 314.41 cfu/100ml. The faecal coliform counts exceeded the WHO-allowable limit (0 cfu/100 ml). This high count of faecal coliform indicates significant faecal contamination of groundwater from leachates from human waste disposal at the dumpsite site by waste management companies (Bolarinwa *et al.,* 2017). According to the Water Research Centre (2017), the presence of faecal coliform in water indicates that the water has been polluted by human or animal faeces as the fecal coliform bacteria is spread through these mediums. This also suggests that ground water in the study area may contain other faecal pathogens, bacteria, and viruses. Therefore, residents who depend on this water for domestic activities or consumption risk contracting infectious water-borne diseases, including typhoid, bilharzia, and diarrhea (Bolarinwa *et al.,* 2017).

Copper, zinc, iron, and lead contents in groundwater samples are all exceed the WHO-permitted levels. The average copper concentration in groundwater samples ranged from 3.25 to 4.52 mg/L, exceeding the WHO permissible limit of 2 mg/L. The high levels of copper in the groundwater samples may be attributed to the leachate migration from the dumpsite into underground water samples 3. This result is consistent with other studies that have reported high levels of copper in leachate from dumpsite sites (Kwawuvi *et* *al.,* 2019). Though copper is an essential nutrient, high concentrations of copper in water samples may be harmful the brain, central nervous system and many internal organs of humans (Ayandiran and Dahunsi, 2016; Ediene and Umoetok, 2017). It has also been reported to be associated with minor health problems, including nausea, vomiting, stomach cramps, and diarrhea (ATSDR, 2004).

With a mean of 4.32 mg/L, zinc values in groundwater samples ranged from 3.40 to 5.11 mg/L. Compared to the WHO drinking water quality standards, zinc levels in the water samples exceed the allowed limits (3 mg/L) set by the WHO. The levels of Zinc in the water samples may be attributed to exposure of water samples to leachates containing smelter wastes, fertilizers, and wood preservatives (Mekonnen *et al.,* 2020). According to the WHO (2011), human exposure to such a high amount of Zinc (Zn) may cause irritation, discomfort and stiffness in the muscles, nausea, and lack of appetite. High zinc levels have also been reported to be associated with undesirable astringent taste in water (Soujanya and Saxena, 2017). Studies by Omar *et al*. (2008) and Mekonnen *et al.* (2020) have also reported high zinc levels in water samples around dumpsite sites.

Iron levels in groundwater samples ranged from 0.26 to 0.42 mg/L, with a mean of 0.34 mg/L, indicating that the samples had higher iron levels than the WHO allowed limit of 0.3 mg/L. The concentration of iron may be due to pollution primarily due to the discharge of significant amounts of iron to ground fluids from the dumpsite (Bhalla *et al*., 2012; Amano *et al.,* 2021). Other studies have also revealed that windlass used for drawing water from wells and scrap metals disposed at the dumpsite could be a potential source of iron contamination (Kwawuvi *et al.,* 2019). Higher levels of iron from contamination have serious health risks, including anorexia, oliguria, diarrhea, and fatal metabolic acidosis (Bolarinwa *et al.,* 2017). It has also been associated with coloration of drinking water (Soujanya and Saxena, 2017). This result is consistent with many studies that reported high iron concentrations in groundwater in dumpsite sites in Ghana (Nyarko, 2008; Bolarinwa *et al.,* 2017).

Lead concentrations in groundwater samples ranged from 0.028 to 0.231 mg/L, with a mean of 0.111 mg/L. The results demonstrate that the groundwater samples exceeded the WHO's allowed limits (0.01 mg/L) set. Possible sources of lead contamination may be batteries, photographs, old lead-based paints and lead pipes, electronic waste, lead batteries, lead-based paints, pipes, and plastics disposed at the dumpsite (Ediene and Umoetok, 2017; Kwawuvi *et al.,* 2019; Mekonnen *et al.,* 2020). These high levels of Lead observed at the study site is of great concern as Pb has been documented to be carcinogenic and pose many health risks. Lead adversely affect mental and neurological functions as well as altering metabolic processes in the human body system (Adeyi and Majolagbe, 2014; Kwawuvi *et al.,* 2019). Engwa *et al*. (2018) found that acute lead exposure can result in symptoms like loss of appetite, fatigue, sleeplessness, hallucinations, vertigo, renal dysfunction, hypertension, arthritis, and kidney disfunction. According to research by Mortada *et al*. (2001), children exposed to Lead may also have intellectual decline.

Table 1: Physical, Biological, and Chemical Parameters, Descriptive Statistics of Analysed Groundwater Samples Compared with WHO (2011).

GW Parameter	Range	Mean	Min	Max	Std. Deviation	WHO
pH	1.51	8.47	7.8	9.31	0.57	6.5-8.5
TDS mg/L	4.32	9.44	7.08	11.4	1.68	500.00
Turbidity nTu	5.66	4.32	1.83	7.49	2.48	5.00
Conductivity us/cm	18.2	96.95	84.8	103	0.19	500.00
NO3 mg/L	7.51	13.29	9.21	16.72	2.92	10.00
BOD mg/L	5.03	9.89	7.69	12.72	2.15	6.90
DO mg/L	1.21	2.64	2.00	3.21	0.50	7.50
Total Coliform (cfu/100ml)	164	273.17	164	347	70.63	0
Faecal Coliform (cfu/100ml)	225.41	188.73	89	314.41	104.90	0
Cu (mg/L)	1.27	3.99	3.253	4.521	0.44	2.00
Zn (mg/L)	1.72	4.32	3.401	5.107	0.69	3.00
Fe (mg/L)	0.15	0.34	0.263	0.417	0.07	0.30
Pb (mg/L)	0.20	0.11	0.028	0.231	0.07	0.01

Effect of Dumpsite on the Physical, Chemical and Biological Surface Water Quality

The pH of the water collected at various sample locations was discovered to be slightly basic ($p>0.05$) (Table 2). Surface water samples recorded higher pH values (downstream = 8.96±0.13; midstream = 8.81±0.23; and upstream = 8.51±0.27), all of which were above the WHO permissible range (6.5-8.5). The discharge of acid-forming chemicals into the water, such as sulfate, phosphate, and nitrates, may cause higher pH levels. The pH of water decreases because of the microbial degradation of organic waste, increasing acidity, according to Arimoro *et al*. (2006). Many studies have reported that effluents and leachates from old dumpsite sites usually have a pH above 7.5. (Bolarinwa *et al.,* 2017; Amano *et al.,* 2021).

According to Subba Rao *et al.* (2012), such high pH in aquatic ecosystems negatively impacts many organs of aquatic organisms. Other studies have also linked changes in pH levels of aquatic ecosystems to reduced plant growth rate, photosynthesis, and nutrient absorption (Amano *et al.,* 2021).

Total dissolved solids concentration showed a significant difference ($p<0.05$) across the sample sites. Total Dissolved Solids concentrations were within the WHO standard (500 mg/L). The highest mean total dissolved solids were recorded at the midstream sample site (49.13±0.65). This was followed by downstream and upstream sampling locations recording 47.13±0.537 and 43.91±0.16. This high TDS at the midstream and downstream compared to the upstream indicates that the dumpsite may have contributed to the increase in TDS levels in the downstream despite being within the WHO limit. Such high TDS levels indicate poor water quality. The rise in TDS level may be attributed to the indiscriminate waste disposal, erosion, and sedimentation of organic and inorganic materials in runoff from the dump site. Other potential factors contributing to increases in TDS levels include the removal of grassland near waterbody for agricultural purposes (Agyare *et al.,* 2017). These high levels of dissolved particles increase the water's density, decreasing oxygen solubility and endangering the life of aquatic organisms in the water (Bangash *et al*., 2013). Agyare *et al.* (2017), also reported that drinking water with high TDS levels might have long-term health impacts on humans.

Turbidity showed a significant difference ($p<0.05$) among sample sites. The mean turbidity in the various sample locations was higher than the WHO standard. The upstream sampling point recorded a turbidity level of 7.01±0.19 while the midstream and downstream sampling point recorded turbidity levels of 7.98±0.09 and 7.98±0.18 (5NTU), respectively. This suggests that dumpsite may be the main contributor to the river's increased turbidity levels. Human activity, decomposing plant matter, algae blooms, suspended sediments, and plant nutrients all change water's turbidity levels. These particles may have been transported through runoff from the dumpsite as the river is close to the dumpsite. The WHO (2011) asserts that high turbidity levels can stimulate the growth of bacteria and other microorganisms that are harmful to human health (Amano *et al.,* 2021). It negatively impacts aquatic plants as increased turbidity reduces light penetration and rate of photosynthesis. The results appear to be consistent with (Amano *et al.,* 2021), who reported extremely high turbidity levels in surface water around dumpsite sited

EC measures the amount of dissolved inorganic materials in water (Mekonnen *et al.,* 2020). The conductivity test showed a significant difference ($p<0.05$) between the sample sites. The mean conductivity in the upstream sample point was much higher (75.20±0.529). Conductivity at the midstream sample site (70.77±0.50) and downstream sampling locations (73.67±0.657). Mean conductivity levels at all sample sites were much lower than the WHO standard (500 us/cm). The low EC at the midstream compared to the upstream and downstream sampling points indicates that the source of variation in EC may not be the dumpsite site but other sources. According to Nyarko (2008), water with high EC levels has a high concentration of salts. Human consumption of such water can result in heart and kidney-related diseases. However, the low EC levels of the water compared to WHO standards indicate a limited amount of salt in water hence its suitability for human usage.

A statistically significant variation in nitrate levels ($p<0.05$) was found among the sample locations. The highest mean nitrate concentration values were recorded at the midstream sample location (2.70±0.115). The mean nitrate concentrations at the upstream and downstream sampling locations were 2.64±0.106 and 2.52±0.27, respectively, with all samples below the WHO limit of 10 mg/L. However, the high nitrate concentration at the midstream compared to the upstream indicates the contamination of the river by leachates and runoff from the dumpsite. Also, farming activities along the banks of the river, as observed on the field during data collection may have contributed runoff containing organic fertilizers to the river resulting in increased nitrate levels (Mekonnen *et al.,* 2020). According to Chapman (2021), the measurement of nitrate in surface waters gives a broad indicator of the extent of organic contamination and nutrient status. While nitrate is not a toxicant, research has revealed that its conversion to nitrite increases its affinity to blood haemoglobin resulting in a medical condition known as methemoglobinemia (Soujanya and Saxena, 2017). Nitrate levels in our study were lower compared to a study conducted by (Bolarinwa *et al.,* 2017). near a dumpsite in southwest Nigeria.

According to VanLoon and Duffy (2011), biochemical oxygen demand is the quantity of dissolved oxygen needed by aerobic biological organisms to break down the organic material in a body of water during a certain time and temperature. Biological Oxygen Demand showed a significant difference ($p<0.05$) across sample sites at a 5% significance level. Significantly higher mean BOD levels were recorded at the midstream (7.940±0.021) and downstream sample locations (8.140±0.134). The mean biological oxygen demand at the upstream sample locations was 6.720±0.032, below the WHO limit (6.9 mg/L). This indicates that the dumpsite affects the BOD content of surface water. This may be attributed to the discharge of untreated human waste from the dumpsite into the river, as evident during the data collection exercise. Microbes' decomposition activities uptake and deplete oxygen in the river (Bolarinwa *et al.,* 2017). Other studies have also revealed that agricultural wastes such as organic manure increase microbial activities in water, hence the BOD (Jafar *et al.,* 2013). Similar studies conducted in Nigeria by Nkwocha *et al*. (2011) and Iwuoha *et al*. (2013) validate this study's findings.

A significant difference in Dissolved Oxygen concentration was recorded at the three sampling points ($p<0.05$). Dissolved oxygen levels were generally highest downstream (8.52±0.06) (Table 2). This was followed by the midstream (7.43±0.09) and upstream (3.44±0.02) sample locations. Compared to the WHO guidelines, only the downstream sampling point recorded dissolved oxygen levels higher than the WHO limit (7.5 mg/L). Compared to the WHO guidelines, only the downstream sampling point recorded dissolved oxygen levels higher than the WHO limit (7.5 mg/L). The findings imply that dumpsites contribute to variations in DO concentration in surface water. This low DO concentration at the midstream can be attributed to the high level of biological oxygen demand because waste discharges high in organic matter and nutrients lead to a decrease in DO concentrations. On the other hand, the increased DO concentration downstream is likely due to the high rate of dissolved ambient oxygen in the water and low rate of microbial degradation (Jafar *et al.,* 2013). Comparable levels of dissolved oxygen were recorded in similar studies in Nigeria (Bolarinwa *et al.,* 2017).

Copper levels showed a significant ($p<0.05$) variation among sampling locations, with the midstream sampling point recording the highest concentration (2.19±0.11). This was followed by the downstream sampling locations, which recorded a copper concentration of (2.06±0.07) while the upstream sampling point recorded the lowest concentration (0.92±0.06). Among all the sample locations, only the upstream sample point recorded copper concentration below the WHO standard (2 mg/L), as shown in Table 2. According to Obasi and Akudinobi (2020), Copper is an essential nutrient for plants but a drinking-water contaminant in excess quantities (Ediene and Umoetok, 2017). Gallagher (2001) stated that at levels above 2.5 mg/L, copper imparts an undesirable bitter taste to water; at higher levels, the color of the water is also impacted. Our results are consistent with Agyare *et al.* (2017) who reported that water dumpsite sites contain trace metals like copper.

The Zinc content of water in the various sampling locations was statistically significant (p<0.05). The downstream sample location (4.12±0.14) has much more Zinc than the midstream sampling point (3.33±0.22) and the upstream sampling point (3.03±0.39). As shown in Table 2, all samples from various sampling locations exceeded the WHO limit (3.0 mg/L). This high concentration of Zn in the surface water in the study area may be attributed to pollution from dumping activities (Ediene and Umoetok, 2017). According to Mekonnen *et al.* (2020), smelter slag wastes, fertilizers and wood preservatives are potential sources of Zinc contamination in waterbodies near dump site. Although WHO (2011) does not state a permissible limit for Zinc, a high concentration may be toxic to humans as well as compromise the taste of water (Soujanya and Saxena, 2017). Toxicity in humans may occur if zinc concentration approaches 400 mg/kg.

The iron content of water samples was statistically significant (p<0.05), with the downstream sample site recording a higher mean iron concentration (0.42±0.02). This was followed by the midstream and upstream sample sites recording mean iron levels of 0.32±0.03 and 0.21±0.08, respectively. Only the iron content of upstream sampling locations was below the WHO limit (0.3 mg/L), as indicated in Table 2. The findings imply that the dumpsite contributes to the increased Fe concentration in the area's surface water. The high iron content of the midstream and downstream locations may be attributed to increased runoff of contaminated iron waste from the dumpsite into the water (Kensa, 2012). Other studies have also reported that increased turbidity and pH levels due to the discharge of waste into rivers contribute to increasing Fe content and harm to aquatic organisms (Bolarinwa *et al.,* 2017). The findings are contrary to Mebrahatu and Zerabuk's work (2011), where their study found that about 62.69% of the water samples were within the desired concentration of iron in drinking water (300ug/L) set by WHO (2008), whereas 37.31% of the samples have shown iron concentration above the limit. 8 also reported that Ghanaian water has generally high levels of iron.

At a 5% significance level, analysis of variance testing of lead revealed a significant difference (p<0.05) across sample locations. The downstream sample location (0.19±0.02) had considerably higher mean lead levels, followed by the midstream sampling location (0.13±0.01), whereas the upstream sampling stations recorded a mean lead concentration of 0.06±0.01. However, the lead content of all samples was over the WHO limit (0.01 mg/L). The observed high Pb levels may be due to the exposure of the water to effluents containing Lead based waste such as lead batteries, electronic waste, paints, and lead pipes disposed of at the dumpsite (Agyare *et al.,* 2017; Ediene and Umoetok, 2017; Mekonnen *et al.,* 2020). Lead is a highly toxic metal whose exposure to mediums such as water causes extensive environmental contamination and numerous health problems (Ediene and Umoetok, 2017). Being a carcinogenic substance, human exposure to high levels of lead impacts mental and neurological functions resulting in permanent brain damage (Agyare *et al.,* 2017). Lead poisoning has also been reported to interfere with human blood haemoglobin formation, kidney function, and general metabolism. According to Lidsky and Schneider (2003), children exposed to high lead levels may have behavioural disturbances and learning and concentration difficulties. In severe cases of lead encephalopathy, the affected person may have acute psychosis, confusion, and reduced consciousness. This study recorded lead levels are higher than other studies in Southwest Ethiopia, with low lead levels in surface water around dumpsite site (Mekonnen *et al.,* 2020).

At a 5% probability level, the results of total coliform testing revealed a significant difference ($p<0.05$) across sampling locations. The mean total coliforms were highest at the midstream sampling point 483.04±0.21. The downstream and upstream sampling sites recorded total coliform levels of 427.80±0.44 and 96.17±0.74, respectively. In addition, as shown in Table 2, the mean total coliforms for the sample locations were higher than the WHO standard (0 cfu/100ml). The higher count of total coliform at the midstream and downstream can be attributed to the bacterial contamination of the water by human and animal waste transported through surface runoff as erosion control barriers around the site have been removed through anthropogenic activities (Nyarko, 2008; Ololade *et al.,* 2019). According to Ololade *et al.* (2019), surface water flowing through dumpsites carry along harmful chemicals. Using water from these sources for domestic purposes could increase infectious disease transmission. Similar studies on the influence of a solid waste dumpsite on river water quality revealed high levels of total coliform bacteria in water samples (Nkwocha *et al*., 2011; Bolarinwa *et al.,* 2017)

At a 5% significance level, faecal coliforms revealed a significant difference ($p< 0.05$) across sample locations. The downstream sample point (632.07±0.10) had significantly higher mean levels of faecal coliforms followed by the midstream 514.13±0.01). The lowest mean faecal coliforms count was recorded at the upstream sample sites (129.73±0.19). Also, the faecal coliforms count of all samples was greater than the WHO guideline (0 cfu/100ml). The findings imply that the dumpsite is the main cause of faecal contamination in surface water around the area. The high count of faecal coliform at the midstream and downstream can be attributed to indiscriminate defecation and waste disposal coupled with surface runoff down the stream especially during rainy seasons (WRC, 2003). In addition, the high fecal coliform count increases the risk of transmitting infectious disease if consumed or used for domestic purposes (WRC, 2003). Other studies also recorded a high count of faecal coliform at the midstream and downstream portions of a river around a dumpsite in Nigeria (Bolarinwa *et al.,* 2017).

Table 2: Physical, Biological, and Chemical Parameters, Descriptive Statistics of Analyzed Groundwater Samples Compared with WHO (2011).

Variable	**Treatments/ SP**	**Upstream**	**Mid-Stream**	**Down stream**	**WHO Std.**	***P.* value**
Physical CC	TDS Mg/L	43.91±0.16b	49.13±0.65a	47.13±0.537a	500	0.001
	Turbidity NTU	7.01±0.19b	7.98±0.09a	7.98±0.184a	5.00	0.008
	pH	8.51±0.27a	8.81±0.23a	8.96±0.125a	6.5-8.5	0.40
	Conductivity us/cm	75.20±0.53b	70.77±0.49a	73.667±0.66a	500	0.004
Chemical CC	NO_3 mg/L	2.64±0.11a	2.70±0.12a	2.52±0.27a	10.00	0.783
	BOD mg/L	6.72±0.03b	7.94±0.02a	8.14±0.13a	6.90	0
	DO mg/L	3.44±0.02c	7.43±0.09b	8.52±0.06a	7.50	0
	Cu (mg/L)	0.92±0.06b	2.19±0.11a	2.06±0.07a	2.00	0
	Zn (mg/L)	3.03±0.39a	3.33±0.22a	4.12±0.14a	3.00	0.068
	Fe (mg/L)	0.21±0.08b	0.32±0.03ab	0.42±0.02a	0.30	0.053
	Pb (mg/L)	0.06±0.01c	0.13±0.01b	0.19±0.02a	0.01	0.001

Spatial Distribution of Heavy Metals on Both Ground and Surface Water

The Inverse Distance Weighted (IDW) interpolation method is used with the distance parameter raised to the second power to compute the likelihood of pollution in the study location. The data for geo-statistical analysis, as shown in figures 2 and 3, moderate pollution (Green), moderate to strong pollution (Yellow), and extreme pollution (Red) of Zinc and lead copper and iron respectively, at both the ground and surface water located at Waterloo. Most of the heavy metal content was highest in ground and surface water close to the municipal dumpsite in Sunyani, and significantly higher in the other directions, showing a flaky spreading distribution. The contours are geometrically transformed into the national coordinate system to examine the final accuracy of the interpolated elevations and their spatial distribution. According to Mahboob *et al.* (2020), spatial distribution characteristics of heavy metals, based on the selection standard of the heavy metal interpolation method, is simple kriging. The extremely high values recorded could be due to the intensity of activities by informal e-waste recyclers at the dumpsite. The geographical distribution of heavy metals in water is influenced by the progress of industrialization and urbanization, as well as industry and urban activities (Zeng *et al.*, 2019).

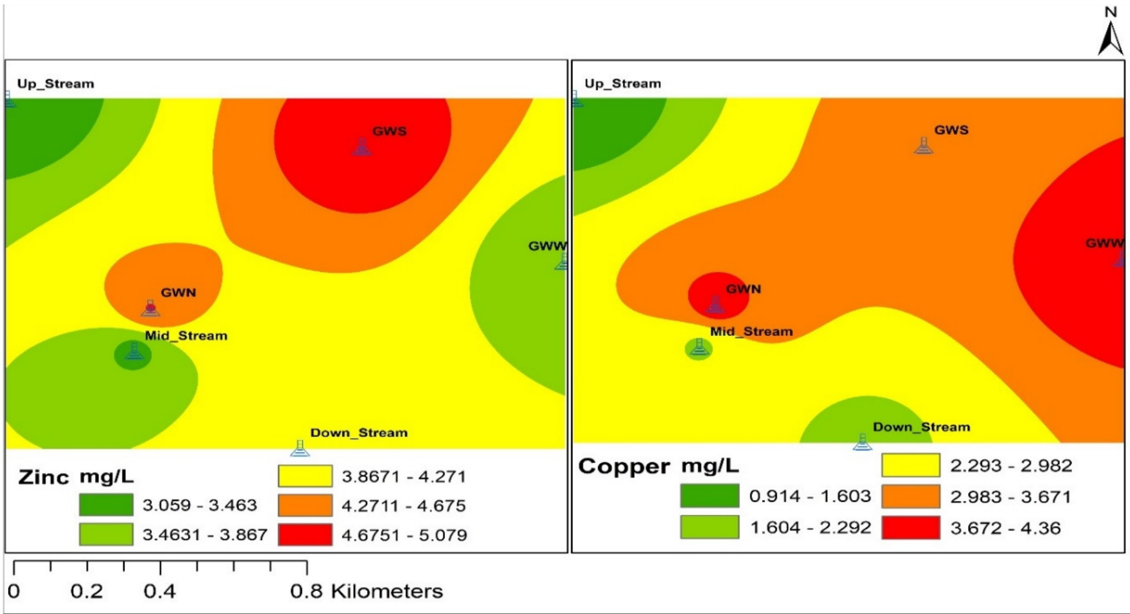

Fig. 2: Inverse Distance Weighted Interpolation of Zinc and Copper

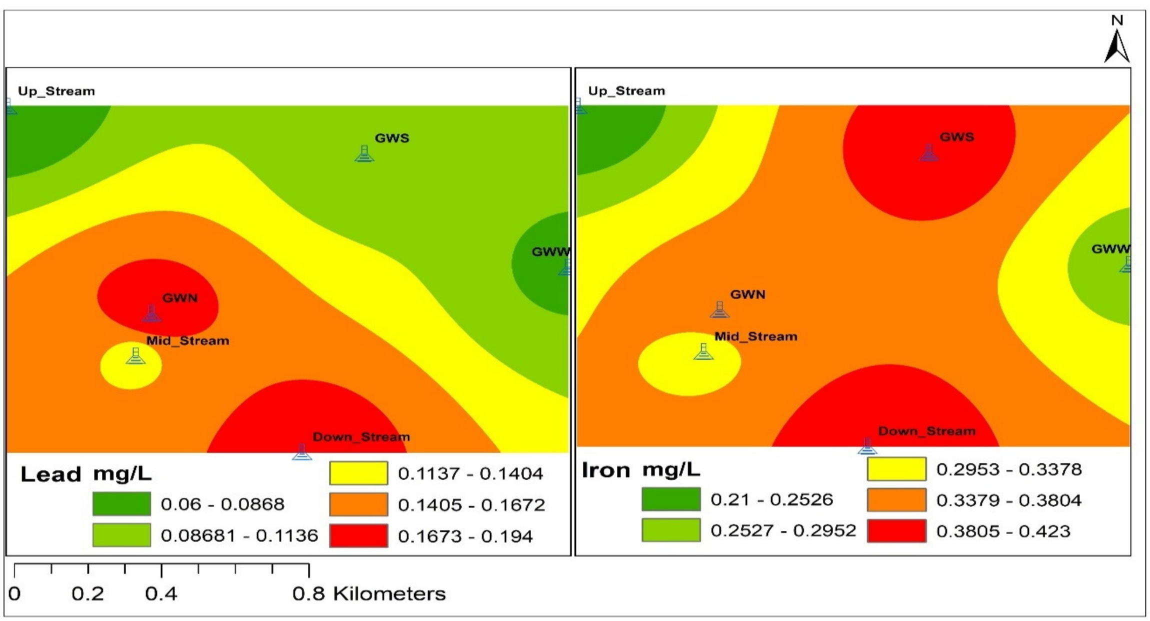

Fig. 3: Inverse Distance Weighted Interpolation of Lead and Iron

Conclusion

The study sought to assess the influence of the Sunyani Municipal waste dumpsite on surface and groundwater quality. The study revealed a negative impact of the dumpsite on the physical, chemical, and biological properties of both surface and groundwater resources in the study area. Apart from pH, TDS, turbidity, conductivity, and dissolved oxygen which recorded concentrations within the acceptable standards of the WHO, all other parameters (NO_3, BOD, total coliform, faecal coliform, copper, zinc, iron, and lead) examined in the groundwater samples recorded concentration levels above the WHO's permissible limit. Similarly, pH, turbidity, dissolved oxygen, zinc, iron, lead, BOD, total coliforms, and faecal coliform levels in surface water samples were generally high in the midstream and downstream portions compared to the upstream and WHO guidelines. Consequently, water resources around the dumpsite pose significant public health and environmental threats. The study, therefore, recommends the segregation, proper management, and treatment of toxic waste before discharge into the external environment.

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