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Quality of Drinking Water in Peri-urban Communities in Ghana: Chemical Parameters Evidence from New Juaben Municipality

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Abstract

This study assessed the quality of drinking water in some peri - urban communities in the New Juaben Municipality in the Eastern Region of Ghana. Ten (10) drinking water sources sampling sites were purposively sampled and their Chemical parameters were assessed over a period of six months. The study revealed that most chemical parameters, mean turbidity value, sediments and soils in the drinking water were within the WHO permissible guideline ranges. The research findings also showed that Manganese, Zinc and Iron were the most prevalent metallic pollutants in all the water, sediment and soil samples examined that, the contamination of these heavy metals were attributed to natural geological conditions, agricultural and runoff. The study recommended that, there should be regular monitoring of the drinking water quality in the New Juaben Municipal Area. Increased accumulation of lead, iron, manganese and arsenic concentration may have adverse effects surfacing. There is therefore the need to check the concentration in further research to observe the future trends and the necessary action taken.

Keywords

Chemical, Parameters, Water, Peri-urban, Communities, Evidence, New Juaben Municipality, Ghana

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1. Introduction and Background

Water is the elixir of life, a precious gift of nature to mankind and millions of other species living on the earth which is fast becoming a scare commodity in most part of the world. It is perhaps the second most common, abundant, and important resource of life after air [1]. Water is essential for life and about 70% of the human body is water. It is also the medium in which all living processes occur. It is the best solvent as well. Water is also unique in many ways, from the vast range of its uses to its profound symbolic significance in many cultures. It is a source of great productive opportunities for agriculture, industry, energy, transport, domestic, environmental and recreational purposes as well as being vital for the health of both people and ecosystems [2].

Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 20th century, more than half the world's wetlands have been lost along with their valuable environmental services. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems. The major concern of people living in developing countries is the provision of potable drinking water. Access to safe (potable) drinking water is important as a health and development issue at the national, regional and local levels. In some

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regions, investments in water supply and sanitation can yield a net economic benefit, since the reductions in adverse health effects and health care costs outweigh the costs of undertaking the interventions. This is true for major water supply infrastructure investments through to water treatment in the home. Interventions in improving access to safe water favour the poor in particular, whether in rural or urban areas, and can be an effective part of poverty alleviation strategies [3].

Sub-Saharan Africa alone, records over a third of this 884 million people who do not have improved sources of drinking water and is also lagging behind in progress towards the Millennium Development Goals (MDGs) target, with only 60% of the population using improved sources of drinking water despite an increase of 11% since 1990. At the current rate of progress, the world is expected to exceed the MDG target of halving the proportion of the population without sustainable access to safe drinking water. Even so, 672 million people will still lack access to improved drinking water sources in 2015. The provision of safe drinking water for the world's billion deprived population has become one of the topmost priorities of many governments in recent years. In the year 2000, more than a hundred and fifty governments in the world over launched an ambitious plan to halve the number of people without access to safe drinking water by the year 2015 [4].

From the World Bank estimates for 2009, the population of Ghana is about 23.8 million with an annual growth rate of 2.1%. 79% of this population has access to improved source of drinking water with 93% coverage in urban areas and 68% in the rural communities. To help attain the MDG target of halving the proportion of the population without sustainable access to safe drinking water by 2015, the Ghana Water Company Limited, which is the main national utility in charge of supply of potable water to urban dwellers in Ghana, has therefore set a target of achieving 85% coverage by 2015. At the end of 2009, the company had achieved 59% coverage. The Community Water and Sanitation Agency which is in charge of rural water supply, has also set a target of 76% drinking water coverage for rural and small town dwellers by 2015. The Agency had achieved 58.97% as at the end of 2009. Based on this information, the overall national coverage as far as the two main sector agencies in charge of drinking water supply concerned is estimated at 58.98% as at the end of 2009 as against a national target of 79.8% [5]. The government of Ghana (GoG) in its effort of improving and providing cheap, safe and potable water for rural communities over the years, has solicited the assistance of and collaborated with some non-governmental organizations (NGOs) and foreign donors such as DANIDA, JICA and World vision to construct boreholes and hand dug wells all over the country.

Water systems in Ghana are based on both surface and ground water resources depending on the size of the community and the availability of the resource. Most urban communities depend on treated surface water (pipe borne) while a lot of the rural communities and some peri-urban communities depend on untreated rivers, streams, lakes, boreholes as well as hand dug wells, ponds, rain water, springs, waterfalls and dams which sometimes may be contaminated or unwholesome for domestic use. The major concern is on how to make these sources safe for human consumption since the quantity and quality of fresh water available is affected by rainfall variability (climate change), rapid population growth, frequent and sometimes lengthy periods of interruption in the supply of treated water to many households, increased environmental degradation, and pollution of water bodies. Anthropogenic activities such as the use of pesticides and fertilizers by farmers to improve crop yields, infiltration of polluted surface water may also have profound impacts [6].

Discharge of toxic chemicals, over pumping of aquifers, long-range atmospheric transport of pollutants and contamination of water bodies with substances that promote algal growth are some of today's major water quality degradation [7]. It is equivocally demonstrated that water of good quality is crucial to sustainable socioeconomic development. Some problems related to water quality deterioration have been present for a long time but have only recently reached a critical or alarming proportion, while others are newly emerging. There is also, the direct and indirect contamination of fresh water with heavy and trace metals from waste dump sites, mining, smelting and industrial manufacturing sectors.

The use of groundwater as the only source of potable water supply is increasing worldwide. Many people in the deprived communities are turning to the use of groundwater as their main sources of drinking water supply [8]. In Africa and Asia, most of the largest cities utilize surface water but many millions of people in peri-urban communities and rural areas are dependent on groundwater. The situation is not different in Ghana, particularly in the rural areas. This is because ground water is normally available throughout the year. The storage point can be near or directly under the point of use and is immediately available on demand through pumping [9]. Ground water is important for domestic use because it has been found to be sufficient in quantity and quality for most rural communities and it is in this direction that the national community water and sanitation program recommended groundwater as first choice to be considered in rural delivery [10]. In Ghana, 62-71% of the rural population depends on groundwater for domestic supply [6]. These non-treated water sources are increasingly being used as drinking water yet, testing to see whether the water is of good quality is almost non-existent The most important point to address therefore, for all water intended for drinking purposes is the quality since this has a direct impact on human health.

Ghana is well endowed with water resources. However, availability of water decreases markedly from season to season and yearly owing to rainfall variability (climate change), rapid population growth, frequent and sometimes lengthy periods of interruption in the supply of treated water to many households, increased environmental degradation, and pollution of water bodies. The New Juaben Municipality cannot be left out because it is noted for perennial water shortages. Hence, access to potable water is irregular, seasonal, inadequate and unreliable [6]. Waste management systems in these communities are also very poor since domestic wastes are dumped, spilled, spread, or stored on the land surface with others buried sometimes in pits. The unhygienic and improper disposal of waste, poor waste, and sanitation management including that of faecal matter can lead to extensive soil contamination, and high levels of ground water and surface water pollution via runoffs and soil erosion. There have been interventions from the Community Water and Sanitation Agency (CWSA), private organizations and the Ghana Water Company Limited (GWCL) through provision of wells, boreholes, public pipes and creating of awareness on Water and Sanitation issues [6]. Although a lot of the inhabitants in the municipality depend heavily on water from boreholes, hand dug wells, pipe borne water and stream water, not much work has been done to assess the quality of drinking especially in the peri-urban communities in the New Juaben Municipality in the Eastern Region of Ghana. The main purpose of the study was to assess the chemical parameters of the drinking water in peri-urban communities in the New Juaben Municipality of the Eastern Region of Ghana.

This paper presents the outcome of the chemical parameters of the drinking water in peri-urban communities in the New Juaben Municipality of the Eastern Region of Ghana. The paper is structured into five (5) main sections namely; the Introduction and Background, Review of the Literature, Methodology, Findings and Discussion and the Conclusion. The first section introduces the structure of the paper, the context and aims and objectives of the paper. The literature review section reviews the relevant literature on issues relating to water treatment that will help change and develop people's attitudes toward the natural environment. The methodology section presents a broad description of the methodology and procedures adopted in the conduct of the study on chemical parameters in drinking water. Findings resulting from the study are presented and discussed in the section following the methodology and conclusions, and recommendations.

2. Review of the Literature

Suspended solids as the undissolved components of solids in water bodies [11]. Suspended solids include organic materials such as plant fibers, biological solids, bacteria and inorganic substances including clay, silt and debris. They are generally particles greater than 2 microns in diameter or less than 0.001cm and can be up to 1mm. The concentrations of suspended solids vary from one location to another depending upon hydraulic forces, vegetative cover, soil and bedrock, and anthropogenic activities such as agriculture, lumbering, mining etcetera. Suspended particles also affect water clarity and light penetration, temperature, the dissolved constituents of surface water, the absorption of toxic substances such as organics and heavy metals, and the composition, distribution and rate of sedimentation of matter. The effects of suspended solid in water can also be physical or chemical and large amount reduces recreational use and aesthetic beauty [11].

Turbidity in water is caused by the presence of suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms [12]. Its measurement is a key test of water quality. Turbidity is the unit of measurement quantifying the degree to which light travelling through a water column is scattered by the suspended organic and inorganic particles. High turbidity in drinking water is an indication that a lot of people are at a higher risk of contracting gastrointestinal diseases especially for immunocompromised people. This is because contaminants such as viruses or bacteria sometimes get attached to the suspended solids to interfere with the disinfection of water with chlorine. Thus, the suspended solid particles act as shields for the virus and bacteria by protecting them from ultraviolet (UV) sterilization of water [13]. In water bodies such as lakes, rivers and reservoirs, high turbidity levels affect the ability of fishes to absorb dissolved oxygen and also reduce the amount of light reaching lower depths. As a result, growth of submerged aquatic plants is inhibited. Turbidity is determined with a nephelometer in nephelometric turbidity unit (NTU) [14].

Hydrogen ion concentration (pH) pH is a very important variable in water quality assessment since it affects a lot of biological and chemical processes within water bodies and all processes associated with water treatment and water supply. pH is a measure of the acid balance of a solution and is defined as the negative logarithm of the hydrogen ion concentration [H^+]. It is the concentration of hydrogen ions. extends from O (very acidic) to 14 (very alkaline) with the value of 7 corresponding to exact neutrality at 25°C [12]. The pH at a given temperature indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution. In unpolluted water, the pH is principally controlled by the balance between the carbon (IV) oxide, carbonate and bicarbonate ions as well as other natural compounds such as humic and fulvic acids. Industrial effluents and atmospheric deposition of acid forming substances, acid mine drainage, acid rain and, anions such as SO_4^{2-}, PO_4^{3-} and S^{2-} can affect the natural acid- base balance in water [12].

A change in pH depicts the presence of certain effluents, particularly, when continuously measured and recorded, together with the conductivity of water body. The range in pH for most waters is between 4.5 and 8.5 which encompasses the pH value of 5.6 for rainwater in equilibrium with atmospheric CO_2, also pH range is between 6.0 and 8.5 although, lower values can occur in diluted waters high in organic contents and high values in eutrophic waters and ground waters [15]. However, the pH of most natural waters is determined or dictated to some extent by the geological influences of the watershed which is governed by the carbon (IV) oxide/bicarbonate/carbonate equilibria; biotic activities. pH of water is measured on the field using a pH meter [12]. The natural background concentration level of pH is 7, acceptable limit is between 6.5 and 8.5. The reason for measuring pH is to minimize corrosion and encrustation in pipes and fittings as well as ensure that chlorine based disinfection is working effectively. The pH of drinking water should be between 6.5 and 8.5 pH units [16, 17].

Phosphate is a nutrient for plants (including algae). In lakes, phosphate ion usually functions as the limiting (or controlling) nutrient for algal growth, since commonly there is an excess of other dissolved nutrients. Phosphate ions form insoluble compounds with ions such as Fe^{3+}, Al^{3+} and Ca^{2+}. These insoluble precipitates normally sink to the bottom of lakes and trapping the phosphate ions in the sediments. Sources of Phosphate includes chemical weathering of mineral rocks and organic matter; farm run-off which carry fertilizer into water bodies, raw sewage (human/animal waste) that get into water, detergents which contain phosphate as tripolyphosphate, ashes from solid waste disposal dump sites and municipal wastewater discharges. Orthophosphates are bio-available. Once assimilated, they are converted to organic phosphorus and into condensed phosphates. Upon the death of an organism, the condensed phosphates are released into the water. They are not available for biological uptake, however, until they are hydrolysed into orthophosphates by bacteria. The availability of phosphorus to biota depends on the uptake and release rates by biota, chemical speciation (e.g. organic or inorganic bound phosphorus), the relative abundance and residence time of the dissolved phosphorus fraction.

Ground waters contain only very small amounts of phosphates, usually less than 0.1 mgL^{-1}. Exceptions are waters from phosphate-containing soil, or polluted by organic matter [18]. The presence of phosphate above the natural background concentration level of 0.02 mgL^{-1} and the WHO maximum permissible limits of less than 0.3 mgL^{-1}, may pose serious health problems [12]. Sodium tripolyphosphate, STP, ($Na_5P_3O_{10}$), has been used widely as a builder in laundry detergents, where it acts as a water softener and improving detergent performance [12]. $Na_5P_3O_{10}$ is added to water to remove Ca^{2+} and Mg^{2+} by forming soluble complexes. It therefore acts as water softener.

It also makes the water alkaline for proper functioning of the detergent:

$$P_3O_{10}^{5-} + H_2O \rightarrow P_3O_{10}^{4-} + OH^-$$

In water, the tripolyphosphate reacts slowly to produce phosphate which causes

eutrophication:

$$P_3O_{10}^{5-} + 2H_2O \rightarrow 3PO_4^{3-} + 4H^+$$

Phosphate in detergents has been largely replaced by other substances such as Nitrilotriacetic acid (NTA), which acts similarly to STP. Other builders are sodium citrate, sodium carbonate, sodium silicate and zeolite. Phosphate can be removed from water, by the addition of Ca $(OH)_2$ which leads to the precipitation of calcium phosphate:

$$3Ca(OH)_2 + 2PO_4^{3-} \rightarrow Ca_3(PO_4)_2 + 3OH^-$$

Phosphate concentration is determined using stannous chloride method [19].

Nitrate, the most highly oxidized form of nitrogen compounds in the environment, is commonly present in rural waters, because it is the end produce of the aerobic decomposition of organic nitrogenous matter. Significant sources of nitrate are chemical fertilizers from cultivated land; drainage from livestock feed lots, as well as domestic and some industrial waters. The main source of nitrate is agricultural run-off into streams and rivers. Other sources are from oxidized animal waste (manure), unabsorbed NH_4NO_3 and other nitrogenous fertilizers. Intensive cultivation even without fertilizer application facilitates the oxidation of (reduced) N_2 in the soil. The determination of nitrate helps to follow the character and degree of oxidation in streams, in ground water penetrating through soil layers, in biological processes and advanced treatment of waste water. [18].

Methemoglobinemia is a disease that affects bottle fed infants of less than 3 months due to a particular enzyme deficiency and the consumption of water containing higher levels of nitrate. It occurs when increased level of nitrate concentrations ranges between 11 and 40mgL^{-1}. Under specific conditions, bacteria in unsterilized baby feeding bottle or in the saliva and stomach of the baby reduce nitrate (NO_3^-) to nitrite (NO_2^-):

$$NO_3^- + 2e^- + 2H^+ \rightarrow NO_2^- + H_2O$$

The NO_2^- oxidizes the iron atoms in haemoglobin from ferrous ($Fe^{2+)}$ ion to ferric (Fe^{3+}) ions, rendering it incapable of binding and transporting oxygen. This process can lead to generalized lack of O_2 in the tissues of the organ and the dangerous condition called methemoglobinemia (or blue-baby syndrome). The baby may seem healthy, but turns blue around the mouth hands and feet and suffers from respiratory failure. These babies may vomit and have diarrhoea as well. In extreme cases, there is marked lethargy, an increase in the production of saliva, loss of consciousness and seizures [20]. Blue-baby syndrome is rare in developed countries, but there is concern in developing countries.

In adults the oxidized haemoglobin is reduced to its normal state very quickly. Methemoglobinemia can be treated with methylene blue, which reduces ferric iron (Fe^{3+}) in affected blood cells back to ferrous iron ($Fe^{2+)}$. An excess or high level of NO_3^- in drinking water has been linked with stomach cancer although epidemiological investigations have failed to establish any positive link. The suspicion arose from the fact that ingested NO_3^- which is converted to NO_2^- in the stomach can react with amines and amides in the stomach to produce N-nitroso-amine and N-nitroso-amide compounds, which are known to produce cancer in animals. The dimethyl derivative, N-nitrosodimethyl amine (NDMA) has been proved to be carcinogenic. Of major concern is the fact that water treatment via chlorination or chloramination of organic nitrogen-containing (waste) water can lead to the production of NDMA at potentially harmful levels in the drinking water. NDMA is also produced at low levels in cigarette smoke, foods and beverages (cheese, fried bacon, roasted or smoked meat / fish, and beer). Removal of NO_3^- is by the reduction of nitrate to nitrogen gas (denitrification).

Denitrification is effected by denitrifying bacteria and under anoxic conditions.

The reduction steps are as follows:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

$$2NO_2^- + 6e + 8H^+ \rightarrow N_2 + 4H_2O$$

Fluorides originate from the weathering of fluoride-containing minerals and enter surface waters through run-off and ground waters by direct contact [18]. Some fluoride compounds, such as sodium fluoride and fluorosilicates, dissolve easily into ground water as it moves through gaps and pore spaces between rocks. Most water supplies contain some naturally occurring fluoride. Fluoride is frequently found in certain industrial processes and consequently in resulting wastewaters. Significant industrial sources of fluoride are coke, glass and ceramic, electronics, pesticide and fertilizer manufacturing factories, steel and aluminium processing factories, glass and electroplating operations. More commonly, fluoride is added to drinking water to assist in the control of dental caries without harmful effect on health. Such additions require close control of fluoride concentrations (roughly 1.0 mgL^{-1}) as higher fluoride levels cause mottling of the teeth. The guideline value of 1.5 mgL^{-1} in drinking water has been proposed by [21].

Iron is an abundant element in the earth's crust, but exists generally in minor concentrations in natural water systems. The form and solubility of iron in natural waters are strongly dependent upon the pH and the oxidation-reduction potential of the water. Iron is found in the +2 and +3 oxidation states [18]. In a reducing environment, ferrous (+2) iron is relatively soluble. An increase in the oxidation reduction potential of the water readily converts ferrous ions to ferric (+3) and allows ferric iron to hydrolyze and precipitate as hydrated ferric oxide. Since the precipitate is highly insoluble, ferric iron is found in solution only at a pH of less than 3. The presence of inorganic or organic complex-forming ions in the natural water system can enhance the solubility of both ferrous and ferric iron. Surface waters in a normal pH range of 6 to 9 rarely carry out more than 1mg of dissolved iron per litre. However, subsurface water removed from atmospheric oxidative conditions and in contact with iron-bearing minerals may readily contain elevated amounts of ferrous iron. For example, in groundwater systems affected by mining, the quantities of iron routinely measured may be several hundred mg/litre [18].

It is the formation of hydrated ferric oxide that makes iron-laden waters objectionable. This ferric precipitate imparts an orange stain to any settling surfaces, including laundry articles, cooking and eating utensils, and plumbing fixtures. Additionally, colloidal suspensions of the ferric precipitate can give the water a uniformly yellow-orange, murky cast. This coloration along with associated tastes and odours can make the water undesirable for domestic use when levels exceed 0.3 mg/litre.

Manganese is a relatively common element in rocks and soils where it exists as oxides or hydroxides in the (II), (III) or (IV) oxidation state. These compounds strongly absorb other metallic cations and, along with iron oxides, are of great importance in controlling the concentrations of various trace metals present in natural water systems. The solubility of manganese in natural water is largely a function of pH and the oxidation-reduction potential. In relatively anoxic systems of near neutral pH, considerable concentrations of dissolved manganese may develop, but oxidation and precipitation may result from slight shifts in pH and potential.

Lead is a relatively minor element in the earth's crust but is widely distributed in low concentration in uncontaminated sedimentary rocks and soil [18]. Lead concentrations in fresh water are generally much higher and this is from the atmospheric input of lead originating from its use in lead gasoline or from smelting operations. Industrial and mine or smelter operations may contain relatively large amounts of lead. Many commonly used lead salts are water soluble. The lead in drinking water may be due to the use of lead pipes or of plastic pipes stabilized with lead compounds. Although the contributions of lead from food and from air are more significant, the World Health Organization has established 0.05 mg/litre as a guideline value for lead in drinkingwater. Lead is toxic to aquatic organisms but the degree of toxicity varies greatly, depending on water quality characteristics as well as the species being considered.

Zinc on the other hand is described as an abundant element in rocks and ores but present in natural water only as a minor constituent because of the lack of solubility of the free metal and its oxides [18]. It is present only in trace quantities in most alkaline surface and ground waters, but more may be present in acid waters. The main industrial use of zinc is in galvanizing and it may enter drinking water from galvanized pipes. Another important use of zinc is in the preparation of alloys, including brass and bronze. Average zinc concentration in surface water is about 10 mgL^{-1}, with a range from 0.2 mgL^{-1} to 1 mgL^{-1}.

Zinc is an essential element in human nutrition. The daily requirement is 4-10 mg depending on age and sex. Food provides the most important source of zinc. Long-term ingestion of quantities considerably in excess of these amounts does not result in adverse effects. The guideline value of zinc in drinking-water is, therefore, based on aesthetic considerations. Water containing zinc at concentrations in excess of 5.0 mgL^{-1}, has an undesirable astringent taste and may be opalescent, developing a greasy film on boiling. Although drinking-water seldom has a zinc concentration greater than 0.1 mgL^{-1} levels in tap water can be considerably higher because of the zinc used in plumbing materials. The World Health Organization has proposed that the guideline value for zinc in drinking-water should be 5.0 mgL^{-1} based on taste considerations. Zinc may be toxic to aquatic organisms but the degree of toxicity varies greatly, depending on water quality characteristics as well as the species being considered.

Copper is a widely distributed trace element but, because most copper minerals are relatively insoluble and because copper is adsorbed to solid phases, only low concentrations are normally present in natural waters. Equilibrium with copper oxide or hydroxy-carbonate minerals limit the concentration of uncomplexed copper in aerated water to about 04 mgL^{-1} at pH 7.0 and about one-tenth that value at pH 8.0. Because of the presence of sulfide, copper will be less soluble in anoxic systems [18]. The presence of higher concentrations of copper is usually attributed to the corrosion of copper pipes, industrial wastes or, particularly in reservoirs, the use of copper sulfate as an algicide. Copper is required for the function of several enzymes and is necessary in the biosynthesis of chlorophyll. Higher levels are toxic to organisms but the response varies greatly between species. Copper in public water supplies and increases the corrosion of galvanized iron and steel fittings. Copper is extensively used in domestic plumbing systems, and levels in tap-water can therefore be considerable higher than the level present in water entering the distribution system. The guideline value is 1.0 mgL^{-1} based on its laundry and other staining properties [18].

Arsenic is poisonous and toxic after 100 mg of the element is ingested. It is present in rocks, soils, water, and living organisms at concentrations of parts per billion to parts per million [15]. Soil arsenic levels are normally elevated near arseniferous deposits, and in mineralized zones containing gold, silver, and sulphides of lead and zinc. Natural weathering of rocks and soils adds about 40,000 tons of arsenic to the oceans annually, accounting for < 0.01 mgL^{-1} input to water on a global basis [17]. Arsenic is introduced into the aquatic environment through atmospheric deposition of combustion products and through runoff from fly-ash storage areas near power plants and nonferrous smelters [15]. Agricultural applications provide the largest anthropogenic source of arsenic in the environment [15]. Inorganic arsenicals (Arsenic trioxide; arsenic acid; Arsenates of calcium, copper, lead, and sodium, and Arsenites of sodium and potassium) have been used widely for centuries as insecticides, herbicides, algicides, and dessicants. Chronic toxicity can result from a build-up of lower intakes. An arsenic concentration of 0.05 mgL^{-1} is recommended as WHO guideline value [21].

3. Methodology

Research design for the study was a survey. Purposive sampling technique was used to select communities in the municipality for the study. Selection of the sampling points were influenced by factors such as ease of accessibility and proximity (for the entire study period) to obvious sources of pollution, such as dumpsites, latrines, septic tanks, farms and drainages.

Two streams, a pipe- borne, three bore holes and four wells that supply the communities with water, were selected. Among these, four sites (2 wells, a pipe borne, and a borehole) were selected in the Korle community. In Agavenya, three sampling points consisting of two wells, a stream and a bore hole were selected. Two sampling points were selected at Akyekyeso which includes a bore hole and a well. For Wawase, the sample was taken from a steam which is the only source of drinking water in the community.

Prior to sampling for chemical analysis, sampled bottles were cleaned by soaking them in detergent for 24 hours, followed by rinsing several times with tap water until they were free of detergent. The bottles were then rinsed with 5% Nitric acid and then rinsed thoroughly with distilled water [10]. Samples for metal analyses were preserved with 5ml concentrated Nitric acid (HNO_3). To avoid or reduce probable bias in monthly changes, sampling were done approximately at the same time at each site, starting in the morning (8.00 am) and finishing midday at the last site. Chemical parameters were analyzed at the Environmental Chemistry laboratory of the Water Research Institute.

The Nephelometric method was employed to determine the turbidity of the water sample within 24hours after sampling and according to the standard method described by Turbidity measurements were done using a turbid meter with a Partech model- DRT 100B employing the principles of nephelometry [22]. About 15ml sample was poured into a glass cell holder of the instrument. Readings were taken directly in Nephelometric turbidity units (NTU).

Lead, iron, zinc, manganese and copper were the metals analyzed in sediments and soil samples. All sediment and soil samples were air dried and sieved through a 0.5 mm sieve before analysis. Using the Atomic Absorption Spectrometer (AAS), 1g of soil was weighed and a mixture of nitric acid and perchloric acid in the ratio of 1:1.5 added and digested for about an hour. This was then filtered into a 100 ml volumetric flask and topped with distilled water to the mark [22]. Two (2) mL aliquot was pippeted into a 50 mL volumetric flask and then the colour developed by adding 20mls of distilled water followed by 2 drops of P-nitrophenol, then 1-2 drops of ammonia. This was topped up to the 50 ml mark with distilled water. The lead, iron, zinc manganese, arsenic and copper concentrations were read using the Milton Roy Spectronic 301 spectrophotometer at 712 nm. The calculation is as follows:

$$\frac{\text{Reading on spectrophotometer x volume of extract}}{\text{Weight of soil x Volume of aliquot taken}}$$

The formula used in calculating the concentrations in µg/g is as follows:

$$\text{Concentration in µg/g} = \frac{\text{Reading on AAS x Vol.of extract (mL)}}{\text{1000 mL}}$$

Vol. of extract in this case is 100 mL

4. Findings and Discussions on Chemical Parameters in Drinking Water

The main objective of the study was to assess the quality of drinking water in peri-urban communities in the New Juaben Municipality of the Eastern Region of Ghana. The chemical parameters of the drinking water sources in the study area including concentrations of some heavy metals (arsenic, copper, lead, mercury, zinc) in selected sources of drinking water, in sediment of water samples and soil samples collected around the sources of water in the study areas were also examined.

4.1. Total Hardness

In conformity with current practice, total hardness is defined as the sum of the calcium and magnesium concentrations both expressed as calcium carbonate, in milligrams per litre [22]. Water quality target for freshwater aquatic ecosystems is 500 mg/L. These notwithstanding, all the freshwater sampling sites fell within the WHO guidelines and EPA value for drinking water quality even though they fell far below the recommended value of 500 mg/g $CaCO_3$ [23].

Table 1. Monthly mean total hardness values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	104.5	109.2	110.1	103.8	99.8	87.1

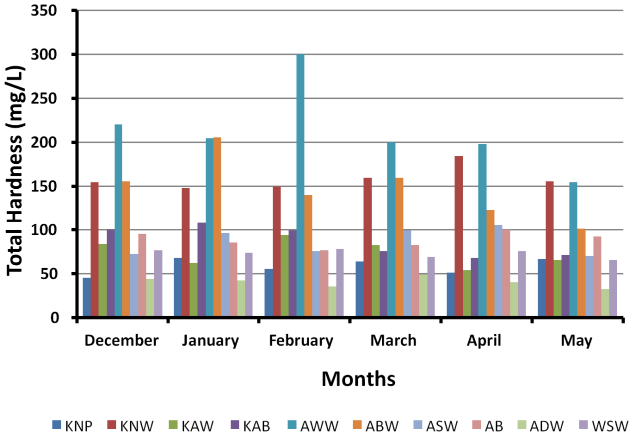

Figure 1. Monthly Variations in Total Hardness at the Various Sites in the Study Area.

4.2. Nitrate

Nitrate occurs naturally in soils as a product of microbial mineralization of dead plant and animal tissues [24]. Nitrate is seldom abundant in natural surface waters because it is incorporated into cells or is chemically reduced by microbes and converted into atmospheric nitrogen [12]. Table 2 had shown the mean nitrate values ranged from a minimum of 0.055 mg/L at KAB to a maximum of 0.613 mg/L at AWW, which also recorded the highest value of 1.820 mg/L over the study period, in December. April recorded the lowest mean value of 0.168 mg/L while, December recorded the highest mean value of 0.298 mg/L. Nitrate in addition to its health hazards is a major indicator of the rate of effluent infiltration through the soil. Nitrate cannot be retained by soil and is easily leached out of the soil by percolating water [25]. Nitrate is also not utilized by plants and may remain concentrated in water and soils. Various surveys in India and Africa indicated that nitrate levels in groundwater have increased in many parts of the world as a result of intensification of farming practice [17].

The low levels of nitrate for each corresponding month suggest the absence of sewage effluent infiltration from nearby household toilet facilities into wells and other water sources in the study communities. High nitrate concentrations in the range of 59 to 98 mg/L for wells that are 6 feet (1.8m) close to pit latrines poses threat to human life [26]. Generally, seasonal mean values obtained at KNP, KAB, ABW, AB and WSW was below the natural background concentration limit of 0.23 mg/L. Although the mean values at KNW, KAW, AWW, ASW and ADW were above the natural background concentration limit of 0.23 mg/L for drinking water and below the WHO limits of 10 mg/L, it will not pose a health problem. However, values above the natural background concentration limits indicate a trend towards pollution. The water quality range for which there is no adverse health effect for nitrate is 0-6 mg/L.

Table 2. Monthly Mean Nitrate Values Recorded in mg/L at the Sampling Sites.

Months	December	January	February	March	April	May
Mean	0.298	0.252	0.242	0.204	0.168	0.246

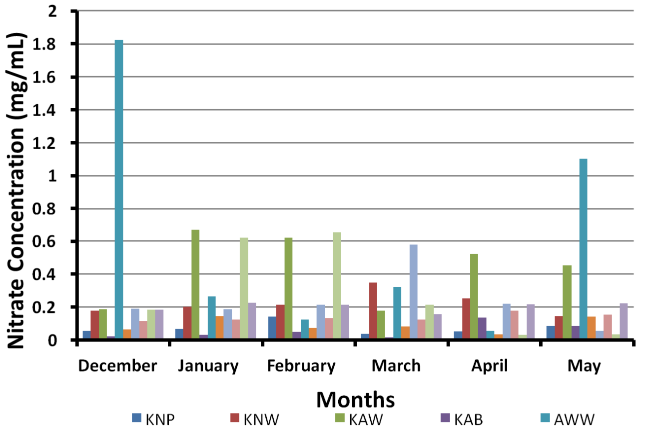

Figure 2. Monthly Variations in Nitrate at the Various Sites in the Study Area.

4.3. Phosphate

Phosphorous occurs in natural waters and in wastewaters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates) and organically bound phosphates. They occur in solution, in particles or detritus, or in the bodies of aquatic organisms. Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm runoff. They are major constituents of many commercial cleaning preparations [22]. Mean values ranged from a minimum of 0.264 mg/L in KAB to a maximum of 0.669 mg/L in AWW. ABW had the minimum phosphate value of 0.128 mg/L in December while AWW again recorded the highest phosphate value during the study period. Figure 3 has shown April recorded the highest mean value of 0.479 mg/L while table 3 has also tabled that December recorded the lowest mean value of 0.323 mg/L. High level of phosphate in a water sample is due to the discharge of domestic effluents [27].

He further stated that organic matter in sewage effluents release phosphates. The high phosphate concentration recorded at WSW and ASW is attributed to the use of fertilizers such as NPK and phosphate of ammonia on the farmlands close to the water source by the farmers. These materials rich in phosphate might have been carried into the water through runoffs. Also, waste organic materials that remained on the field after harvesting which includes leaves and grass clippings when decomposed by bacteria releases phosphate into the soil which leach into ground waters by infiltration and may quickly reach the water table or get into surface waters by runoffs. The highest value of 0.523 mg/L at WSW in the dry season may be attributed to decrease in volume of water which resulted from excessive evaporation and withdrawal of water from the stream as well as the clearing of vegetation at the bank of the water for farming activities. One major source of phosphorous in drinking water resources is from detergents commonly found in municipal and domestic waste water. Most of the domestic wastewater discharge directly into the water bodies without any prior treatment and the pollutants in this water tend to increase the pollution loads of the water [28]. Besides, the waste products of personal care products, household products and pharmaceuticals, are disposed of onto the land surface without treatments and large portion of the chemicals passes right into the local waterway via runoffs and deteriorate their quality [23].

Phosphate is inherently toxic and excessive phosphate in water results in uncontrolled algal growth. The range of phosphorous levels in natural waters is between 0.005 mg/L and 0.02 mg/L [15]. The phosphorus concentrations recorded from the study areas were generally higher than the natural background levels. These water sources that serve the communities under study with drinking water need to be checked since further increase may have health implications to the users. Phosphorus levels of < 0.2 mg/L give rise to oligotrophic conditions with moderate levels of species and no nuisance growth of aquatic plants [23]. Figure 3 given clear description that, KAB, ABW, ASW and AB recorded 0.147 mg/L, 0.128 mg/L, 0.189 mg/L and 0.145 mg/L values of phosphate which fell below 0.2 mg/L in the months of April, December and January. The rest of the sites fell within 0.2 mg/L and 0.831 mg/L which support mesotrophic conditions with usually high levels of species diversity.

High concentrations of phosphates indicate the presence of pollution but WHO and GSB guideline values are not available for comparison [15]. However, the mean seasonal phosphate concentrations recorded in the water indicated that water samples taken at all the sites were polluted since the values were beyond the natural background limit of 0.02 mg/L.

Table 3. Monthly mean phosphate values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	0.323	0.424	0.352	0.393	0.479	0.393

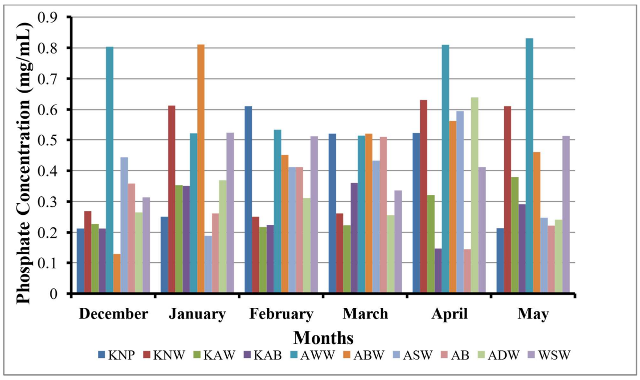

Figure 3. Monthly variations in phosphate at the various sites in the study area.

4.4. Fluoride

Fluoride is the most reactive of all elements [24]. Fluoride may occur naturally in water or it may be added in controlled amounts [22]. Fluoride originates from the weathering of fluoride-containing minerals and enters surface waters through runoff and ground waters through direct contact [15]. Figure 4 has shown that Fluoride values ranged from a minimum of 0.002 mg/L at KAB in December to a maximum of 0.373 mg/L at AWW in January. Mean values ranged from a minimum of 0.082 mg/L at KNP to a maximum of 0.246 mg/L at AWW. Table 4 has also depicted December recorded the lowest mean value of 0.026 mg/L while May recorded the highest mean value of 0.214 mg/L. the range for which no adverse health effects or tooth damage is 0-1.0 mg/L and WHO permissible limit is 1.5 mg/L. Since all samples from the various sampling sites falls within this range, they will therefore pose no health effect to the inhabitants who depend on these sources of water.

Table 4. Monthly mean fluoride values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	0.026	0.183	0.129	0.136	0.197	0.214

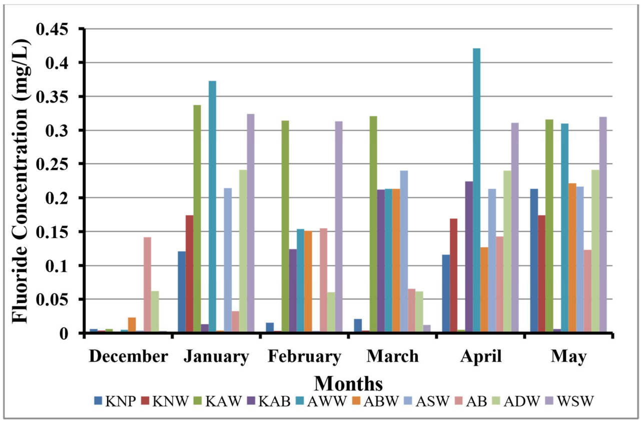

Figure 4. Monthly Variations in Fluoride at the Various Sites in the Study Area.

4.5. Lead

Lead is a serious cumulative body poison. Natural waters seldom contain more than 5ug/l, although much higher values have been reported. Lead in a water supply may come from industrial, mine, and smelters discharges or from the dissolution of old lead plumbing [22]. In addition to other sources, the lead in drinking water may be due to the use of lead pipes or of plastic pipes stabilized with lead compounds. Although the contributions of lead from food and from air are more significant, the World Health Organization has established 0.05 mg/litre as a guideline value for lead in drinking-water. Lead is toxic to aquatic organisms but the degree of toxicity varies greatly, depending on water quality characteristics as well as the species being considered.

Lead values ranged from a minimum of 0.001 mg/l at KAB and ADW all in May to a maximum of 0.005 mg/l at WSW in December. From table 5 and Figure 5 below, mean values ranged from a minimum of 0.003 mg/l recorded at all the sampling sites except for KNP which recorded the maximum value of 0.004 mg/l. 0.003 mg/l of lead was recorded throughout the study period. The presence of lead in the water may be due to the discharge of industrial effluents from petroleum productions [29]. lead is sometimes used as fertilizer or occurs as an impurity in fertilizers [24].

Lead values for which there is no danger of any adverse effects from exposure to water is 0-10 mg/l. Drinking water with lead concentration level > 0.01 mg/l has adverse effect on the users [30]. Increased lead intake in adults have been associated with nervous disorders, anaemia and decreased haemoglobin synthesis, cardiovascular diseases, disorders in bone metabolism, renal functioning and reproduction. In children, it promotes low cognitive and behavioural development and brain retardation [31, 32]. Long term exposure effects include stroke, kidney disease and cancer. Though these effects were not readily on clinical records of the study communities, increased accumulation of lead concentration may have adverse effects surfacing. There is therefore the need to check the concentration in further research to observe the future trends and the necessary action taken.

Table 5. Monthly mean lead values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	0.003	0.003	0.003	0.003	0.003	0.003

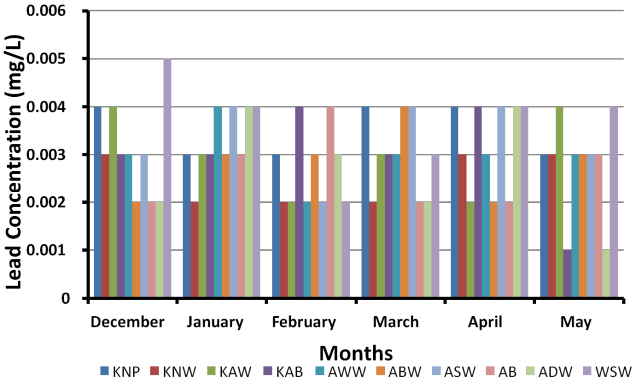

Figure 5. Monthly Variations in Lead at the Various Sites in the Study Area.

4.6. Copper

Heavy metals, especially copper in particular, may be toxic to fish as well as harmful to human health. The sources of contamination may be due to petrochemical industries and agricultural runoff, which contains both pesticides and fertilizer residues [29]. Copper is an essential micronutrient for plants [33]. From figure 6 below, mean values of copper ranged from a minimum of 0.02 mg/l, being recorded at all of the sampling sites to a maximum of 0.023 mg/l at KAW, AWW and WSW in the months of January, March and May. KAW, AWW and WSW however recorded the highest mean value of copper at 0.022 mg/l. While the other sampling sites recorded the lowest mean value at 0.021 mg/l. Table 6 below, depicts both January and March recorded the highest mean value of 0.022 mg/l each. The presence of copper in the water may be due to agricultural runoff, which contains both pesticides and fertilizer residues [29]. The water quality range for copper for which there are no health or aesthetic effects is 0-0.1 mg/l. All the sites fall within this range.

Table 6. Monthly mean copper values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	0.021	0.022	0.021	0.022	0.021	0.021

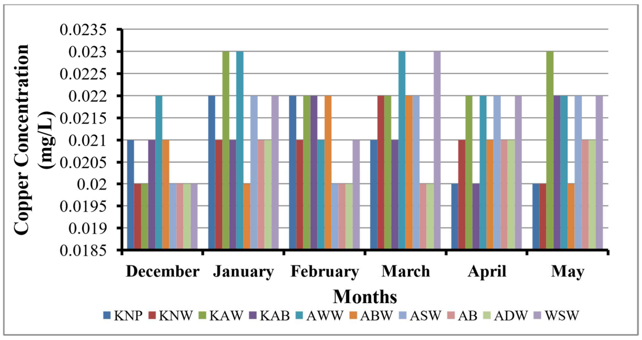

Figure 6. Monthly Variations in Copper at the Various Sites in the Study Area.

4.7. Iron

Silt and clay in suspension may contain acid-soluble iron. Sometimes iron oxide particles are collected with a water sample as a result of flaking of rust from pipes [22]. Iron is an essential micronutrient for plants (Laws, 1981). Figure 7 below has shown that, KNW recorded the lowest Iron value of 0.110 mg/l in January, while AWW recorded the highest value of 27.3 mg/l in December. Table 7 indicates mean values for the sites ranged from a minimum of 0.116 mg/l at KNW to a maximum of 8.943 mg/l at WSW. Mean monthly values ranged from 3.343 mg/l in February to 5.452 mg/l in April. Figure 7 has also shown the high values of Iron at KNP, KAB, ABW and AB could be attributed to flaking of iron rust from the pipes, leading to the collection of water samples with iron oxide. Samples collected from KNW, KAW, AWW and ADW may also be as a result of geological reasons and the containers used in drawing water from these sources. WSW and ASW may also be due to the discharge of effluents containing iron through runoffs. The range for iron for which there is no taste, aesthetic or health effects associated with water use and consumption is 0-0.1 mg/l and the recommended range for livestock watering is 0-10 mg/l. All the sites values fell within this range, except AWW and WSW which recorded significantly higher values.

Table 7. Monthly mean iron values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	3.669	3.898	3.343	4.662	5.452	4.581

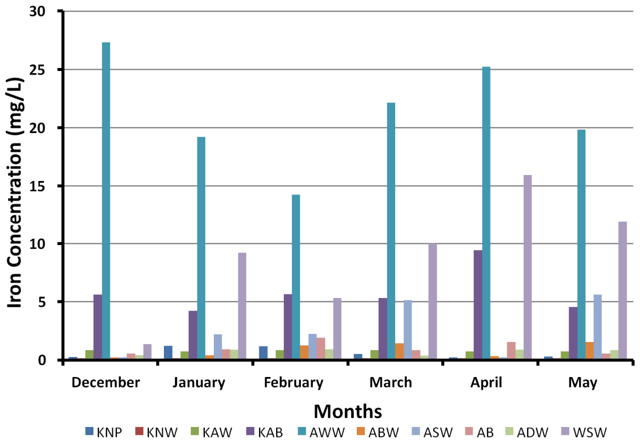

Figure 7. Monthly Variations in Iron at the Various Sites in the Study Area.

4.8. Zinc

Zinc on the other hand is an abundant element in rocks and ores but present in natural water only as a minor constituent because of the lack of solubility of the free metal and its oxides. It is present only in trace quantities in most alkaline surface and ground waters, but more may be present in acid waters. The main industrial use of zinc is in galvanizing and it may enter drinking water from galvanized pipes. Another important use of zinc is in the preparation of alloys, including brass and bronze. Average zinc concentration in surface water is about 10 mg/l, with a range from 0.2 mg/l to 1 mg/l. [18]. From figure 8 below the values obtained for zinc during the study period ranged between a minimum of 0.006 mg/l to a maximum of 0.110mg/l. AB recorded the lowest mean value of 0.007 mg/l while KAB recorded the highest mean value of 0.036 mg/l. Table 8 documented the month of May recorded the maximum mean value of 0.035 mg/l while the month of April recorded the least mean value of 0.015 mg/l.

Table 8. Monthly mean zinc values recorded in mg/L at the sampling sites.

Months	December	January	February	March	April	May
Mean	0.016	0.018	0.016	0.019	0.015	0.035

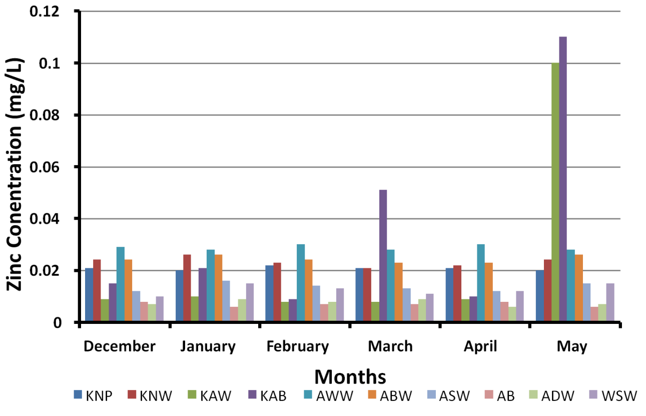

Figure 8. Monthly Variations in Zinc at the Various Sites in the Study Area.

Water containing zinc at concentrations in excess of 5.0 mg/litre has an undesirable astringent taste and may be opalescent, developing a greasy film on boiling. Although drinking-water seldom has a zinc concentration greater than 0.1 mg/l, levels in tap-water can be considerably higher because of the zinc used in plumbing materials. The World Health Organization has proposed that the guideline value for zinc in drinking water should be 5.0 mg/l, based on taste considerations. Zinc may be toxic to aquatic organisms but the degree of toxicity varies greatly, depending on water quality characteristics as well as the species being considered

4.9. Arsenic

Soil arsenic levels are normally elevated near arseniferous deposits, and in mineralized zones containing gold, silver, and sulphides of lead and zinc. Natural weathering of rocks and soils adds about 40,000 tons of arsenic to the oceans annually, accounting for <0.01 mg/l input to water on a global basis [21]. As natural components of underground rocks and soils, arsenic works its way into the underground water sources. Arsenic is introduced into the aquatic environment through atmospheric deposition of combustion products and through runoff from fly-ash storage areas near power plants and nonferrous smelters [15]. Anthropogenically, arsenic gets into water bodies from sources such as mining, manufacturing and use of or disposal of pesticides in the environment. From both figure 9 and table 9 below the arsenic concentrations recorded throughout the study period was 0.001 mg/l at all the sampling sites. The low concentration of arsenic as recorded in the water samples in this study is due to the absence of or low pesticides disposal, industrial and mining activities in the area.

Table 9. Monthly Mean Arsenic values Recorded in mg/L at the Sampling Sites.

Months	December	January	February	March	April	May
Mean	0.001	0.001	0.001	0.001	0.001	0.001

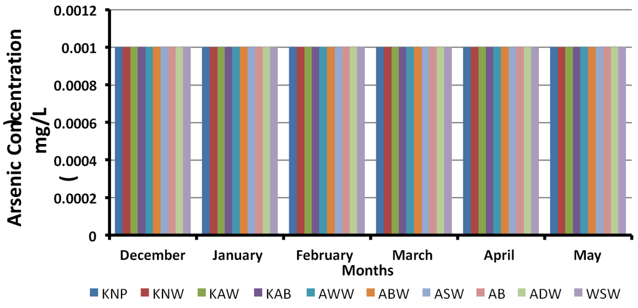

Figure 9. Monthly Variations in Arsenic at the Various Sites in the Study Area.

4.10. Manganese

Manganese is a relatively common element in rocks and soils where it exists as oxides or hydroxides in the (II), (III) or (IV) oxidation state. These compounds strongly absorb other metallic cations and, along with iron oxides, are of great importance in controlling the concentrations of various trace metals present in natural water systems. Manganese dissolved in natural water is in the divalent state. The solubility of manganese in natural water is largely a function of pH and the oxidation-reduction potential. In relatively anoxic systems of near neutral pH, considerable concentrations of dissolved manganese may develop, but oxidation and precipitation may result from slight shifts in pH and potential. Average concentrations of manganese in rivers are around 12 mg/l, with a range of less than 1 mg/l to 130 mg/l.

Figure 10 below the values of manganese recorded at the sampling sites ranged between a minimum of 0.06 mg/l at KNW in April to a maximum of 9.62 mg/l at AWW in December. The mean monthly values were between a minimum of 1.56 mg/l in April and May to a maximum value of 1.77 mg/l in February. Table 10 has also shown below the mean values recorded at the sampling sites also were between 0.07mg/l at KNW and 6.75 mg/l at AWW. At levels exceeding 0.15 mg/l, manganese in water supplies stains plumbing fixtures and laundry. At higher concentrations, it causes an undesirable taste in beverages. In common with iron, its presence in drinking-water may lead to the accumulation of deposits in the distribution system. Even at a concentration of 0.05 mg/l, manganese will often form a coating on pipes which may slough off as a black precipitate.

In addition, the presence of even low levels of manganese renders a water supply unsuitable in certain industrial applications such as those for the textile dyeing, food processing, distilling and brewing, paper, plastics, and photographic industries. The World Health Organization recommended guideline of manganese in water intended for domestic use value is 0.4 mg/l.

Table 10. Monthly mean manganese values recorded in mg/l at the sampling sites.

Months	December	January	February	March	April	May
Mean	1.70	1.65	1.77	1.73	1.56	1.56

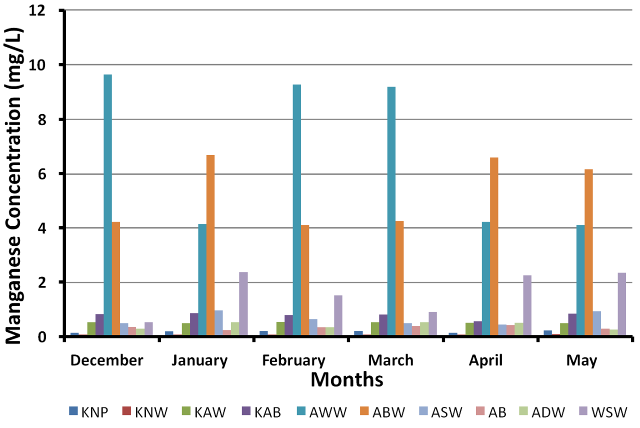

Figure 10. Monthly Variations in Manganese at the Various Sites in the Study Area.

5. Conclusions and Recommendations

Results obtained from the study suggest that except for turbidity values at some locations, many chemical parameters in drinking water (e.g. temperature, colour, TDS, pH, conductivity and suspended solids) were within the WHO permissible guideline range. This was due to the frequency of water fetching throughout the day. High TDS values recorded in well water at Agavenya and Akyekyeso especially in the dry season probably reflect excessive withdrawal or demand of water for domestic use.

The levels of chemical parameters analyzed from all the sampling sites were found to be within the WHO permissible limit except for manganese, iron and zinc which were extremely above this limit. The sources of water that serve the communities under study with drinking water therefore, need to be checked since this and further increase will have health implications to the users.

It is recommended that, there should be regular monitoring, treatment and testing of the water quality of the sources of drinking water as well the maintenance of the existing boreholes, pipes and wells in the study communities by GWCL and WATSAN officials to minimize the level of microbial and chemical contamination so that water related diseases could be prevented in this area. Also, source of pipe-borne water is lacking and so should be improved or the coverage should be increased.

Increased accumulation of lead, iron, manganese and arsenic concentration may have adverse effects surfacing. The once again recommended that, there is therefore the need to check the concentration in further research to observe the future trends and the necessary action taken.

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