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Quality assessment of drinking water: A case study of selected rivers in Mubi North Local Government Adamawa State Nigeria

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Abstract

Present study aimed at investigating the qualities of water from selected rivers in Mubi North local government area for drinking. Water samples were taken from five Rivers (Yedzaram, Musera, Muchalla, Gova, and Kirya). The physico-chemical properties of the water samples were determined by chemical analysis (pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and NO_3). The result revealed that the values ranged from 6.52 - 8.01, 10.53 - 48.90 µS cm-1, 6.73 - 31.29 mg/l, 2.00 - 6.40 mg/l , 0.16 - 2.94 mg/l, 4.06 - 7.06 mg/l , 0.71 - 2.45 mg/l, 0, 0.55 - 1.55 mg/l, 8.20 - 9.60 mg/l, 10.31 - 18.11 mg/l and 0.92 - 1.15 mg/l for pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and NO_3 respectively. The results of all the physico-chemical parameters analyzed showed that the values were within the permissible limit of WHO and BIS standards. Therefore water from the rivers are safe for drinking purpose.

Key Words: Investigation; Drinking water; WHO; BIS, Physico-chemical; Mubi and Adamawa

Introduction

Water is another source of nutrient that is very importance for both human and animals and intimately involved in a wide array of bodily functions. It serves as the universal solvent in the extracellular and intracellular compartments, containing 99% of all molecules in the body (NRC, 2007). Water is necessary to sustain life, optimize growth, lactation and reproduction in animals. It aids digestion, metabolism of energy and nutrients, transport in circulation of nutrients and metabolites to and from tissues, excretion of waste products, maintenance of proper ion, fluid and cushioning environment for developing foetus (Murphy, 1992). Water covers about 78% of the earth's surface, yet water available for human use is limited. Being a basic need of human development, health and wellbeing, safe drinking water is an internationally accepted human right (WHO, 2001), which has been enlisted as one of the ten targets in the Millennium Development Goals (MDGs).

Drinking water quality is a relative term that relates the composition of water with effects of natural processes and human activities. Deterioration of drinking water quality arises from introduction of chemical compounds into the water supply system through leaks and cross connection. Rainfall is one of the factors affecting water quality as it can wash dissolved nutrients into the watershed and increase organic carbon level, and can also depress alkalinity levels and stimulate corrosion. The chemicals used for water treatment can also be a source of contamination of drinking water (Lohani, 1982).

Distance traveled, age of pipes and extent of internal deposition in mains and conduits are the key factors contributing towards drinking water contamination (Dusa *et al.*, 2017). However, during dry season, the absence of rain can result in proportionally high levels of dissolved minerals or nutrients in a particular water source.

Pollution is a major problem in urban areas of developing country such as Nigeria. Improper management of waste especially treatment and disposal of solid and liquid wastes are the major contributors to urban area pollution. The combined results of these problems lead to drinking water contamination, which is detrimental to human health. A quality standard sets the acceptability levels of concentration for pollutants in water to be used for various purposes, e.g., drinking, irrigation, aquaculture, etc.

Over 2 billion people of the world's population have suffered from diseases related to drinking polluted waters. More than 250 million new cases of waterborne diseases are reported each year, resulting in more than 10 million deaths and nearly 75% of these waterborne disease cases occur in tropical areas (McFeters, 1990, Napacho and Manyele, 2010). The relationship between water quality and health problems are complicated and include both negative and positive effects (Tebbut, 1983). The Bonn International Conference on Freshwater in 2001 revealed that half of the people in Africa suffer from water related diseases. (Dusa *et al.*, 2017)

The ground water quality, on the other hand, is relatively uniform throughout an aquifer. Changes in quality occur slowly due to the fact that it is not exposed to the air and is not as subject to direct pollution and contamination from runoff as surface water. Due to natural filtering action of the aquifer, the ground water is relatively free from microbes than surface water. In most cases contamination results either from improper well construction or poor waste disposal facilities (AWWA, 1971).

The quality of surface water (rivers and streams) is dynamic and can change within the catchments area. Small streams may carry clear water for most part of the year (American Water Works Association, 1971). During the rainy seasons, however, the water may carry moderate amounts of dirt organic debris and suspended materials. As rivers move close to inhabited areas, water quality can deteriorate further, although, rivers have the tendency of natural self–purification. Chemical parameters of drinking water quality give an indication of water acceptability for human consumption, which can be domestic use, agricultural use and industrial use (Dusa *et al.*, 2017).

Water quality is the physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly related to the safety of the drinking water to human use. Water quality parameters provide important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose. In villages where water bone pipe and wells are not available the major sources of drinking water are rivers. Unfortunately the qualities of water from the rivers in this area is not known. Therefore, the objective of this study is to investigation the physico-chemical parameters of water in the rivers in order to ascertain their suitability for drinking purpose.

Materials and Methods

Study Area

The research was carried out in Mubi North Local Government Area Adamawa State, Nigeria located at latitude $9^0\ 26^1$ and $10^0 10^1$ N and longitudes $13^0 1^1$ and $13^0\ 44^1$ E. Five rivers within the Local Government area were randomly selected. The rivers are: River Yedzaram, River Musera, River Muchalla, River Gova, and River Kirya. Three water samples were taken from each river for analysis (Figure 1) following the procedure adopted by Dusa *et al. (*2017) and Alexander *et al*. (2018). All chemicals and reagents used in the study were of analytical grade (Merck/BDH). Distilled water was used throughout the study. The physico-chemical analysis was performed following the standard methods (AOAC, 2000; Jain *et al.*, 2012).

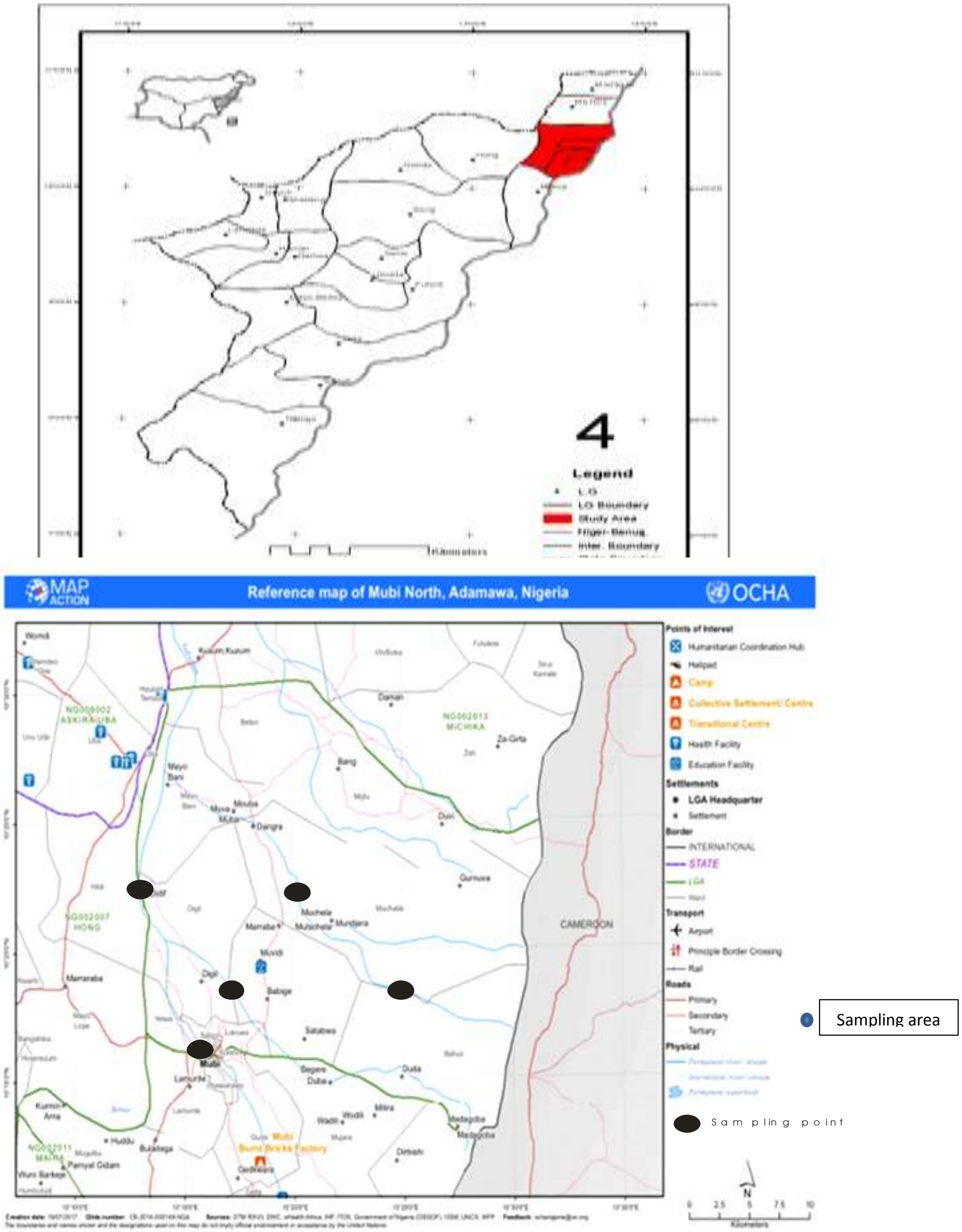

Figure 1: Map of the study area showing the sampling points

Results and Discussion

The results of the chemical analysis of the water samples taken from the five rivers are presented in Table 1 while Table 2 shows the comparison of water quality parameters with drinking water quality standard (Indian and WHO).

Table 1: Concentration of various parameters in the water samples from the rivers (All units are in mg/l except EC (μS cm^{-1}), and pH)

River	SO_4^{2-}	NO_3	CO_3^{2-}	HCO_3^-	Cl^-	EC	TDS	pH	Mg^{2+}	Na^{2+}	Ca^+	K^+
Yadzram	18.11 ±0.20	1.09 ±0.02	ND	1.55 ±0.03	9.60 ± 0.30	48.90 ±0.40	31.29 ±0.30	7.68 ±0.20	2.94 ±0.02	5.04 ±0.02	6.40 ±0.03	1.42 ±0.01
Musra	10.31 ±0.15	1.15 ±0.02	ND	0.70 ±0.02	8.20 ±0.04	12.68 ±0.23	8.06 ±0.20	6.80 ±0.03	0.54 ±0.01	4.06 ±0.20	2.18 ±0.02	0.71 ±0.02
Muchalla	13.02 ±0.13	1.00 ±0.01	ND	0.55 ±0.01	8.31 ±0.06	10.53 ±0.21	6.73 ±0.10	6.52 ±0.11	0.75 ±0.03	7.04 ±0.04	2.00 ±0.01	0.71 ±0.03
Gova	12.44 ±0.12	1.13 ±0.01	ND	0.70 ±0.01	9.25 ±0.20	10.67 ±0.11	6.82 ±0.02	6.71 ±0.20	0.16 ±0.02	5.06 ±0.02	2.27 ±0.04	2.45 ±0.02
Kirya	14.00 ±0.18	0.92 ±0.01	ND	0.75 ±0.02	8.40 ±0.07	13.68 ±0.11	8.75 ±0.13	8.01 ±0.03	0.45 ±0.10	7.06 ±0.10	4.98 ±0.02	1.42 ±0.02

All values represent mean ± SD (Standard Deviation). ND (Not Detected)

Table 2: Comparison of the results of water quality parameters from the study with drinking water quality standards (Indian and WHO)

	Range		BIS Standards		
Parameters	Minimum	Maximum	Acceptable limit	Maximum limit	WHO Limit
pH	6.52	8.01	6.5-8.5	6.5-9.2	6.5-8.5
EC	10.53	48.90	300	-	300
TDS	6.73	31.29	500	2000	500
Na^+	4.06	7.06	50	-	200
K^+	0.71	2.45	-	-	12
Ca^{2+}	2.00	6.40	75	200	75
Mg^{2+}	0.16	2.94	30	100	150
CO_3^{2-}	0.00	0.00	75	200	75
HCO_3^-	0.55	1.55	30	-	150
Cl^-	8.20	9.60	200	1000	200
SO_4^{2-}	10.31	18.11	200	400	200
NO_3	0.92	1.15	-	-	10

*Units of all the parameter are in mg/l except EC (μS cm-1) and pH.

pH

pH is a term used to express the intensity of acidic or alkaline conditions. It is the expression of hydrogen ion concentration, more precisely, the hydrogen ion activity. pH is an important parameter in assessing the water quality. In general, water with a pH of 7 is considered neutral while pH less than 7 is acidic and greater than 7 is basic. It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste (Napacho and Manyele 2010; Chadetrik and Arabinda 2011). Exposure to extreme pH value results in irritation to the eyes, skin and mucous membrane. Eye irritation and exacerbation of skin disorders have been associated with pH greater than 11. Also solutions of pH 10 – 12.5 have been reported to cause hair fibers to swell, pH below 12.5 damage epithelium (WHO, 1986; Fasae and Omolaja 2014). According to WHO standards pH of water should be 6.5 to 8.5 and BIS limit for drinking water is also 6.5-8.5 as shown in Table 2 (WHO, 1996). The pH values analyzed in the water samples varied from 6.52 to 8.01. The low pH does not cause any harmful effect. The results show that all the water samples were within permissible limits.

Electrical Conductivity (EC)

The ability of a solution to conduct an electrical current is governed by the migration of solutions and is dependent on the nature and numbers of the ionic species in that solution. This property is called electrical conductivity. It is a useful tool to assess the purity of water (Chadetrik and Arabinda 2011; Alexander *et al*., 2018). According to WHO and BIS standards EC value for drinking water should not exceed 300µS/cm (Table 2). In this study, EC value ranged from 10.53 to 48.90 µS cm^{-1}.which fall within the WHO accepted limit and BIS standard.

Total Dissolved Solids (TDS)

The electrical conductivity of water correlates with the concentration of dissolved minerals or with what is commonly known as the total dissolved salts in water (Fasae and Omolaja 2014). Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, magnesium, sodium, bicarbonates, sulfates chlorides, etc. These minerals produce un-wanted taste and diluted color in appearance of water. Total dissolved solids (TDS) in drinking water could originate from sewage, industrial wastewater etc. Therefore, TDS is a parameter considered in determining the general quality of drinking water (Chadetrik and Arabinda 2011). According to WHO and BIS standards the acceptable limit of TDS is 500 mg/l. The values of TDS obtained from the water samples varied between 6.73 to 31.29 mg/l as shown in Table 2. The highest TDS value was observed in the water sample from river Yadzram (Table 1). Since these ranges were within the WHO acceptable limit and BIS standard, the water from the rivers are safe for drinking from TDS point of view.

Calcium (Ca^{2+})

Calcium is 5th most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. Calcium may dissolve readily from carbonate rocks and lime stones or be leached from soils. Other sources include industrial and municipal discharges. Calcium is an essential nutritional element for human being and aids in maintaining the structure of plant cells and soils. Its deficiency may lead to protein energy malnutrition. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases (Chadetrik and Arabinda 2011). According to WHO and BIS standards, its permissible limit in drinking water is 75 mg/l. The results of the study show that the concentration of calcium ranges from 2.00 to 6.40 mg/l (Table 2). The high and the low values were observed in Muchalla and Yadzram rivers respectively (Table 1). However, an adult requires 1,000 mg/ day to work properly.

Magnesium (Mg^{2+})

Magnesium is the 8th most abundant element on earth crust and natural constituent of water. It is essential for proper functioning of living organisms and found in minerals like dolomite, magnesite etc. Human body contains about 25g of magnesium 60% in bones and 40% in muscles and tissues (Timothy, 2018; Williams *et al.,* 2018). According to WHO standards the permissible limit of magnesium in drinking water should be 150 mg/l, and that of BIS standard is 30 mg/l. In this study magnesium concentration ranges from 0.16 to 2.94 mg/l (Table 2). The high and the low values were observed in river Gova and Yadzram respectively (Table 1). The concentration of magnesium in all the water samples from the study area is significantly low. Such a low concentration can affect the health of residents as it is essential for human body.

Sodium (Na^{+})

Sodium is a silver white metallic element and found in less quantity in water. Water in contact with igneous rocks will dissolve sodium from its natural source. Higher concentration of Na^{+} ion in drinking water may cause heart problems. Excessive amount of Na^{+} ion in water normally affects the palatability of the water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc (Dusa *et al.*, 2017). In most of the countries in the world majority of water supply bears less than 20 mg/l while in few countries the concentration of sodium in water exceed 250 mg/l (WHO, 1984). According to WHO standards, concentration of sodium in drinking water is 200 mg/1. The permissible limit of sodium in drinking water as prescribed by BIS is 50 mg/l. The range of Na^+ ions in the water samples varied from 4.06 to 7.06 mg/l (Table 2). The high and the low values were recorded in samples from river Mudsra and river Kirya respectively (Table 1). All the values were within the permissible limit of WHO and BIS standard.

Potassium (k^+)

Potassium is a silver white alkali which is highly reactive with water. It is an important cation and plays a vital role in intermediate metabolism. K^+ is an essential nutrient for both plant and human life. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total amount of potassium in human body lies between 110 to 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium deficiency is rare but may led to muscle weakness, depression, heart rhythm disorder etc (Khalaf & Hassan, 2013; Bhat, *et al.*, 2018). According to WHO standards the permissible limit of potassium is 12 mg/1. The value of K^+ concentration in the water samples varied from 0.71 to 2.45 mg/l (Table 2). The high and the low values were recorded in river Mudsra as well as river Muchalla and Gova respectively (Table 1). These results were within WHO standards. Therefore the people drinking water from these rivers are safe from diseases associated with extreme potassium.

Carbonate (CO_3^{2-})

Carbonates in water are mainly in association with Ca^{2+} and Mg^{2+}. Both WHO and BIS acceptable limit of CO_3^{2-} is 75 mg/l (Table 2). The carbonate content of the water samples from the study area was not detected.

Bicarbonates (HCO_3^-)

Bicarbonates in water are present mainly in association with Ca^{2+} and Mg^{2+}. Bicarbonates concentration in water relies on pH. The weathering of rocks adds to bicarbonate content in water. Mostly bicarbonates are soluble in water i.e. bicarbonate of magnesium and calcium is the main causes of hardness of water. It is the standard alkaline constituent found in almost all surface and ground water bodies and therefore affects alkalinity and hardness of water (Timothy, 2019). The hard water is not suitable for drinking purpose and causes the gastro diseases. (Chadetrik and Arabinda 2011). According to WHO standards, concentration of Bicarbonates in drinking water is 150 mg/1. The permissible limit of Bicarbonates in drinking water as prescribed by BIS is 30 mg/l. The results of the study revealed that the concentration of Bicarbonates in the water samples ranges from 0.55 to 1.55 mg/1 (Table 2). The high and the low values were observed in rivers Muchalla and Yadzram respectively (Table 1). All the values were within the permissible limit of WHO and BIS standard.

Chloride (Cl^-)

Chloride is an anion found in variable amount in river water. It is widely distributed in nature as salts of sodium chloride (NaCl), potassium chloride (KCl) and calcium chloride (CaCl2). Chloride may be present naturally in water and may also originate from diverse sources such as weathering, leaching of sedimentary rocks dissolution of salts deposits, effluents from chemical industries (Bhatacharya, 1988), oil well operations (Pettyjohn, 1971), sewage (Pettyjohn, 1972), irrigation drainage (Bond and Straub, 1973), refuse leachates (Schneider, 1970), sea spray and seawater intrusion in coastal areas like Temeke (NRCC, 1977) etc.

Each of these sources may result in local contamination of surface water and groundwater. The chloride ion is highly mobile and is eventually transported into closed basins or to the oceans (NRCC, 1977). Surface water bodies often have low concentration of chlorides as compare to ground water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harms growing plants (Pettyjohn, 1972; Khalaf & Hassan, 2013; Bhat, *et al.*, 2018). Excess concentrations of chloride to about 250 mg/l can give rise to detectable taste in water, depending on associated cations. Chlorides are found in water as mineral solvents. It is said that huge ingestion of chlorides may results in several health effects including tooth decay (Napacho and Manyele 2010). According to WHO and BIS standards concentration of chloride should not exceed 200 mg/l as shown in Table 2. Because chloride is soluble in water, it is not easily removed, and conventional water treatment processes are generally ineffective (WHO, 1984).

A removal of 87% has been reported using a point-of-use treatment device employing granular activated carbon adsorption and reverse osmosis (Regumathan *et al.,* 1983). Chloride concentrations in water may increase if aluminum or iron chloride is used for flocculation purposes as well as during the treatment process if chlorine is used for disinfection purposes (WHO, 1979). Current study revealed the concentration of Chloride ranges from 8.20 to 9.60 mg/l (Table 2). The high and the low values were observed in rivers Musra and Yadzram respectively (Table 1). Hence these values were within the standard limit of WHO and BIS as well.

Sulfate (SO_4^{2-})

Sulfate is abundantly found in almost all water bodies. It is mainly derived from the dissolution of salts of sulfuric acid. Sulfate concentration in natural water ranges from a few to a several hundred mg per liter but no major negative impact of sulfate on human health is reported. High concentration of sulfate may be due to oxidation of pyrite and mine drainage etc (Mohsin *et al*., 2013). The WHO and BIS standard limit of sulfate in drinking water is 200 mg/l. The concentration of Sulfate in this study ranges from 10.31 to 18.11 mg/l (Table 2). The high and the low values were recorded in river Musra and river Yadzram respectively (Table 1). All the values were within the permissible limit of WHO and BIS standard.

Nitrate (NO_3)

Nitrate is a compound that occurs naturally and is an important component of vegetables because of its potential to accumulate. It is naturally formed in living and decaying plants and animals, including humans (Lundberg *et al.,* 2008; Camargo and Alonso, 2006). The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. Additionally nitrate biotransformation is complex and involves nitrate reduction, nitrite formation, nitrite reoxidation to nitrate, and resulting methaemoglobin in a dynamic equilibrium (WHO, 1996; Lundberg *et al.,* 2004, 2008).Nitrate is also used in agriculture as a fertilizer to replace the traditional use of livestock manure and in food processing as an approved food additive. Nitrate is relatively nontoxic, but its metabolites, nitrite, nitric oxide and Nnitroso compounds, its conversion to nitrite plays an important antimicrobial role in the stomach, whereas other nitrate metabolites also have important physiological and pharmacological roles (Gupta *et al.,* 2000; Lundberg *et al.,* 2004; Bryan *et al.,* 2005). Nitrate is one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. Because nitrate is tasteless and odorless, water must be chemically tested to determine contamination. If water contains greater than 10 mg/l NO_3-N, the options for reducing health risks are either in-home treatment or source elimination (Mohsin *et al*., 2013). Relatively inexpensive means of reducing nitrate intake is by substitution of bottle water for drinking. Nitrate is easily dissolved in water; hence it is difficult to remove. The technology for removal of nitrate from drinking water does exist. Three water treatment systems that remove nitrate are reverse osmosis, ion exchange and distillation. Reverse osmosis forces water under pressure through a membrane to filter out contaminants. Ion exchange introduces another substance, normally chloride, to "trade places" with nitrate in water. Distillation boils water, then catches and condenses the steam while nitrate and other minerals remain in the boiling tank (Gupta *et al.,* 2000). Treatment of drinking water to remove nitrate is expensive. Since simple household treatment procedures such as boiling, filtration, disinfection, and water softening do not remove nitrate from water (Napacho and Manyele 2010; Mohsin *et al*., 2013). The WHO allows maximum permissible limit of nitrate in drinking water is 10 mg/l. The concentration of nitrate in this study ranges from 0.92 to 1.15 mg/l (Table 2). The high and the low values were recorded in river Kirya and river Mudsra respectively (Table 1). All the values are within the permissible limit of WHO and BIS standard.

Conclusion

The physico chemical parameters of water samples from five rivers (Yedzaram, Musera, Muchalla, Gova and Kirya) in Mubi North Local Government area were investigated. To assess the water quality, the result of each parameter was compared with the standard desirable limits prescribed by World health organization (WHO) and Bureau of Indian Standard

(BIS). The study revealed that water from the rivers are safe for drinking purposes from the point of view of the investigated parameters

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