SECOLOGICAL RISK OF HEAVY METALS IN SURFACE WATER, SEDIMENT AND DOMINANT FISH SPECIES FROM TUNGAN KAWO RESERVOIR, KONTAGORA, NIGER STATE, NIGERIA

BY

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(MTech/SLS/2017/7131)

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ABSTRACT

Developing countries like Nigeria are faced with increased in generation of domestic, industrial and agricultural wastes that found their way into the surrounding water bodies which are slowly contaminating the water. This study was aim to evaluate ecological risk of heavy metals in surface water, sediment and dominant fish species from Tungan Kawo Reservoir, Kontagora, Niger State, Nigeria. Physico-chemical parameters and heavy metals in surface water, sediment and three commercially important fishes were determined in the reservoir water using standard methods from July 2018 – February 2019 at four different sampling stations of human activities around the water. A total of five heavy metals were selected [lead (Pb), copper (Cu), manganese (Mn), iron (Fe) and chromium, (Cr)] in the surface water, sediment and fish species. The results from physio-chemical parameters showed that, nitrate (3.2 – 7.5 mg/L), temperature (27 – 32.4 ^{0}C), dissolved oxygen (2.4 – 5.2 mg/L), electrical conductivity (81 – 125 µS/cm), biochemical oxygen demand (1.9 – 4.4 mg/L), alkalinity (16 – 34 mg/L) and total dissolved solids (117 – 198 ppm) were within standard for drinking water and survival of fishes, however, the pH (6.3 – 9.8) and phosphate (0.4 – 2.5 mg/L) was above the standard for FEPA and NESREA for drinking water but can fairly support aquatic life. The results obtained from heavy metals showed that iron (Fe) and (Cr) had the highest concentration with mean of 6.18 mg/kg and 1.45 mg/kg in surface water and 7.08 mg/kg and 1.54 mg/kg in sediment respectively, followed by Mn with 1.36 mg/kg (sediment) and 0.09 mg/L (water) while Cu had the lowest concentration of 0.03 mg/kg in the Surface water and 0.99 mg/kg in the sediment respectively. Lead was detected in the sediment in low concentration with a mean value of 0.01 mg/kg in Stations 1, 2 and 4 respectively. However, Pb was not detected throughout the time of the study from surface water. In the three fish species examined, iron was the most highly concentrated value (0.64±0.072 mg/kg) in *Synodontis clarias* while lead (0.01±0.013 mg/kg) was the lowest found in *Oreochromis niloticus* and *Coptidon zillii (*formerly *Tilapia zillii)*. The bottom feeders were found to accumulate more of these heavy metals. This indicates the good health status of the reservoir for aquatic biota. The values obtained from risk indices were very low when compared with the background values and target for Hakanson risk index of a standard soil and have not constitute any risk to Tungan Kawo Reservoir. This current finding indicates that the water is safe for both aquatic life and domestic purpose but not suitable for direct human consumption without being properly treated. However, there is the need for regular monitoring of the heavy metals load in this water body and the aquatic organisms because of the long-term effects.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Ecological risk is the term used to describe a perceived threat posed by stressors (contaminants) to the survival and health of an aquatic ecosystem (MacFarlane, 2009). The pollution of the aquatic environment with heavy metals has become a world-wide problem during recent years, because they are indestructible and most of them have toxic effects on organisms (MacFarlane, 2009). This has long been recognized as a serious pollution problem (Farombi *et al.,* 2007). There are various sources of heavy metals in the ecosystem such as anthropogenic activities like draining of sewage, dumping of domestic wastes, recreational activities and storm water runoff thereby rendering it environmentally unstable (Malik *et al*., 2010). Heavy metals find their way into aquatic systems through Agricultural practices like the use of fertilizers, herbicides and pesticides for the control of pests in the cultivation of crops. Other activities such as mining industry as well as growth of the human population have increased the discharge of wastes into lakes and rivers rendering it environmentally unstable (Malik *et al*., 2010). It may also occur in small amounts naturally through the leaching of rocks, airborne dust, forest fires and deforestation.

Heavy metals are defined as metallic elements with a high relative density compared to water (Duffus, 2002). With the assumption that heaviness and toxicity are inter-related, they include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure. These heavy metals are categorized as potentially toxic agents such as cadmium, lead, and nickel even at low concentrations it can become harmful to human health when ingested over long period of time (Tuzen, 2009).

The toxicity of these chemicals is highly influenced by geochemical factors that influence their bioavailability (Fairbrother *et al*., 2007). Consequently, the discharge from slaughter houses near lakes as pointed out by Arimoro (2008), has the capacity to pose severe health risk to the populace, if not properly managed. However, World Health Organization, WHO (2008) investigation revealed that about 5 million people die every year from drinking contaminated water.

The family cyprinidae which has a widespread of distribution and widely consumed by human beings in the world today, due to their high protein supply and omega-3 fatty acids that help reduce the risk of certain types of cancer and cardiovascular diseases (Ayanwale *et al*., 2018). These fishes can as well accumulate heavy metals through the food chain (Mansour and Sidky, 2002).). Fishes are widely used as bio-indicators for the determination of heavy metal pollution in aquatic ecosystems (Alibabić, 2007; Ahmad and Shuhaimi, 2010). The concentrations of heavy metals in tissues and organs of fishes could indicate their concentrations in water (Ogbeibu *et al*., 2002). Fishes are notorious for their ability to concentrate heavy metals in their muscles and since they play important role in human nutrition, they need to be carefully screened to ensure that unnecessary high level of some toxic trace metals are not being transferred to man through fish consumption (Adeniyi and Yusuf, 2007).

Sediments are important sinks for heavy metals in aquatic ecosystem (WHO, 2008). These metals are non-biodegradable and once discharged into water bodies, they can either be adsorbed on sediment particles or accumulated in aquatic organisms. Sediment acts as both carrier and potential sources of contaminants in an aquatic environment (Iwegbue *et al.*, 2007). Contaminated sediments can cause lethal and sub-lethal effect in benthic and other sediment associated organisms (Arimoro, 2018). Thus, it tends to reduce ecological importance or eliminate the life of organisms either through direct effects or by affecting the food chain.

Heavy metals pollution may increase the susceptibility of aquatic animals to various diseases by interfering with the normal functioning of their immune, reproductive and developmental processes according to Environmental Protection Agency, EPA (2002). However, Kontagora Reservoir was constructed with major objective of providing good drinking water to it township and its environment; nevertheless, the reservoir has become an excellent source of fish apart from being use for domestic purposes and also for dry season farming (irrigation) which is a common practice around this Reservoir. Hence, there is urgent need to evaluate the level of heavy metal concentrations in surface water, sediment and dominant fishes from Tungan Kawo Reservoir, Kontagora.

1.2 Statement of Research Problem

Tungan Kawo Reservoir has witnessed constant discharge of domestic waste coupled with agricultural wastes which have led to contamination of the Reservoir thereby remains as an environmental threat (Abdullahi *et al*., 2015).

Farming activities along the shore area has haphazardly increased the nutrients of the water thereby causing algae bloom making it unfavourable and unfit to the aquatic organisms (fish) and humans (Paul *et al.*, 2014). Consumption of fish derived from contaminated bodies of water is the result of 90 percent of human health risks as attributed by Demirak *et al*. (2013). These heavy metals are considered as the most important pollutants present throughout the ecosystem and are detected in critical amounts which may increase the susceptibility of aquatic organisms (fish) to various diseases by weaken the immune system and induce pathological changes (Adebayo, 2017). Currently, little or no information is available on the health status of aquatic organism (fish) found in Tungan Kawo Reservoir this might be the first of its kind. Therefore, there is urgent need to look into all the problems in order to conserve its biota due to pollution problems and to provide a management plans in improving the reservoir productivity.

1.3 Justification for the Study

Tungan kawo is an important source of drinking water for humans and animals. Dry season farming is a common practise among the people of the community. The reservoir is rich in varieties of fish species for human consumption and commercial uses which generate income for fishermen in the area (Ibrahim *et al*., 2009).

Human activities around the riparian communities near the reservoir have contributed to alternation of water quality and reducing the productivity of the reservoir. Assessment of the physico-chemical parameters and heavy metals of the reservoir will provide a baseline data and reference point for assessing seasonal changes and environmental impact assessment for the water body caused by anthropogenic activities of man overtime.

Monitoring water safety of Tungan Kawo Reservoir will provide information about its richness, sustainability and improvement of the aquatic ecosystem in general. The communities around this reservoir will be more aware on the risk involved in farming with excess agrochemicals and the health implication feeding on crops grown with contaminated water. Although, some studies have reported different levels of heavy metals in soil and the health risk issues involved with the consuming vegetables harvested (Ibrahim *et al*., 2009). Thus, these current studies will specifically target on ecological risk of heavy metals associated with surface water, sediment and dominant fish species from Tungan Kawo Reservoir, Kontagora, Nigeria.

1.4 Aim of the study

The aim of this study is to evaluate the ecological risk of heavy metals in surface water, sediments and dominant fish species from Tungan Kawo Reservoir, Kontagora, Niger state, Nigeria.

1.5 Objectives of the study

The objectives of the study are:

(i) to determine some physico-chemical parameters of surface water in Tungan Kawo Reservoir.

(ii) to determine some heavy metals in the surface water, sediment and dominant fishes species in Tungan Kawo Reservoir.

(iii) to assess the ecological risk index of heavy metals concentration in sediment samples in Tungan Kawo Reservoir.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Physico-chemical Parameters of Water

Physico-chemical parameters is the sum total of the physical, biological and chemical uniqueness of water body (American Public Health Association, APHA, 2014). Water is precious liquid gold that exist on the earth, however, due to increasing in human activities and some natural processes the quality of the water is decreasing continuously and posing a great threat to all forms of life including man (Mahananda *et al.,* 2010). The functioning of an aquatic ecosystem and its stability to support life forms depends directly on the physico-chemical attributes of the water.

The introduction of pollutants into an aquatic system can set off a complicated series of biological and chemical reactions. In Nigeria, the freshwater is used for the disposal of refuse, human sewage, irrigation, abattoir, waste water etc. which has cause tremendous threat to the biota (Arimoro, 2007). Patrick *et al.* (2015) stated that physico-chemical parameters are one of the many routine practices of determining the health of the ecosystem and the survivability of the living biota within it. It is very essential and important to test the water before it is used for human purposes (Patil *et al.,* 2012). Selection of parameters for testing of water solely depends on the purposes, required quality and purity (Patil *et al.*, 2012).

Udoma *et al.* (2014) reported that water parameters such as temperature, turbidity, hardness, alkalinity, dissolved oxygen, conductivity, nutrients such as nitrate and potassium are some of the important factors that determine the growth of living organisms in the water body. Hence, water quality assessment involves the analysis of physico-chemical, biological and microbiological parameters that reflect the biotic and abiotic status of the ecosystem (Verma *et al.*, 2012). Important physic-chemical parameters influencing the aquatic environments are temperature, pH (Concentration of hydrogen ions), total dissolved solid (TDS) and turbidity while chemical tests should be conducted for biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), alkalinity and total hardiness (Sagar *et al.*, 2015). In addition, to understand how and why these reactions occur and to successfully manage any ecosystem, a sound knowledge of the structure and basic functioning of the system is vital. Below are various aspects of physico-chemical characteristics and impacts of pollution on water quality which have been reported by a number of researchers.

2.2 Factors Influencing the Water Quality

2.2.1 Temperature (^{0}C)

Temperature is a measure of the intensity (not the amount) of heat stored in a volume of water measured in calories and is the product of the weight of the substance (Wetzel, 2001). They also validate that water temperature is an important factor which influences the chemical, biochemical and biological characteristics of water body (Oso and Fagbuaro, 2008). Water temperature is of enormous significance as it regulates various abiotic characteristics and activities of an aquatic ecosystem (Kataria *et al.*, 1995). The temperature plays an important role for controlling the physico-chemical and biological parameters of water and considered as one among the most important factors in the aquatic environment particularly for freshwater (Singh, 2015). Aquatic plants (phytoplankton/zooplankton) increases, with increase in temperature, metabolic rates increase with increase in temperature and as temperature increases, the sensitivity of organisms to toxic wastes, parasites and diseases increases (Boulton, 2012). The author also reported that photosynthesis is temperature dependent. Temperature has been said to have the greatest influence on other water quality characteristics and aquatic lives (Olele and Ekelemu, 2008). Munday *et al*. (2008) noted that aquatic organisms tend to strongly adapt to wild range of environmental conditions that they experience throughout the year, thus any rapid increase in temperature above normal maximum temperatures are expected to have significant negative effects on over all viability of some fish population. George *et al.* (2012) worked on temperature variation in Tapi estuarine area of Gulf of Khambhat, India discovered a gradual fall of temperature in the rainy season and a rise in summer which range from 22 to 33 ^{0}C.

2.2.2 Dissolved Oxygen (DO)

Dissolved oxygen refers to the volume of oxygen that is contained in water. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface. Dissolved oxygen content of water body is commonly taken as indicators of potential primary and secondary productivity (Tanimu *et al.,* 2011). Dissolved oxygen (DO) play a significant role in the survival of organisms in any ecosystem that is. Its presence implies a positive sign and the absence implies a sign of severe pollution. DO is also the most important indicator of the health of water bodies and its capacity to support a balanced aquatic ecosystem of plants and animals (Adefemi, 2011). Waters with consistently high dissolved oxygen are considered to be stable aquatic systems capable of supporting many different kinds of aquatic life. Different organisms have different oxygen requirement range and outside such ranges, disease outbreak, abnormal behaviour and mortality may result (EPA, 2002; Eletta and Adekola, 2005). Ramchandra and Solanki, (2007) observed that dissolved oxygen is essential to the respiratory metabolism of most aquatic organisms (fishes) and it is needed for many chemical reactions that are important for lake functioning such as oxidation of metals, decomposition of dead and decaying matter etc. Olele and Ekelemu

(2008) and Sikoki and Anyanwu, (2012) also reported that oxygen has a moderate solubility in water and decrease with increase in temperature.

2.2.3 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand denotes the available oxygen in water that is used up by microscopic organisms during decomposition of organic matters by bacteria. BOD showed total degradable organic pollutants accessible to biochemical degradation in airy water body. Polluted water has greater dissolved oxygen demand (Mbalassa *et al.*, 2014). When BOD is high, the oxygen level may be low. Wakawa *et al.* (2008) reported that BOD of water increases with increasing chemical oxygen demand (COD) and that COD may be used to estimate BOD. Higher BOD value observed in the wet season than dry season might be due to inputs of decomposing organic matters through surface run-off (Usman *et al.*, 2014). Umunnakwe and Johnson (2013) also observed seasonal and spatial variations in BOD values in Imo River located in Ngor and Alau Lake in North East Nigeria.

2.2.4 Water pH

pH is the negative logarithm of hydrogen ion concentration, is one of the most important and frequently used tests in the water chemistry. The pH value of a water source is a measure of its acidity or alkalinity. It is a measurement of the activity of the hydrogen atom, because the hydrogen activity is a good representation of the acidity or alkalinity of water. For drinking water, the WHO guidelines set the pH in the range of 6.5-8.5 (WHO, 2008). Human activities like farming and toxic waste disposal have effect on the pH of water sources (Abdullahi *et al*., 2015). A change in the pH of water can have consequences on aquatic life which are extremely sensitive to changes in water temperature and composition. The pH of water determines the solubility and biological availability of certain chemical nutrients such as phosphorus, nitrogen, carbon as well as heavy metals like lead, copper, and cadmium. It indicates how much and what form of phosphorus is most abundant in water and whether aquatic life can use the form available. Metals tend to be more toxic at lower pH because they are more soluble in acidic water. Measured on a scale of 0-14, pH of natural water usually lies in the range of 4.4 to 8.5. The rise in pH parallels with the rise in carbonate alkalinity and percentage of Oxygen saturation. It is probably not affected by photosynthetic activity of a water body (Kobbia *et al.,* 1992; Kebede, 1996). pH has been considered to cause summer minima of total phytoplankton density (Hujare, 2008). Sharma *et al*. (2008) who describe the role of pH in formation of algal bloom too and the impact its plays in controlling biotic community structure of a water body.

2.2.5 Total hardness (TH)

According to Zoeteman (2000) on total hardness affirmed that streams and rivers throughout the world ranged between 1 and 1000 ppm as $CaCO_3$. Hardness reflects the composite measure of polyvalent cations whereas calcium (Ca) and magnesium (Mg) is the primary constituent of hardness. Hardness value above 500 mg/L is generally unacceptable, although this level is tolerable in some communities (Zoeteman, 2000). Total hardness is an important parameter in the detection of water pollution and causes various diseases**.** Hardness of water is mainly caused by calcium and magnesium in addition to water sulphates, nitrates, and silicates may also contribute to hardness (Sengupta *et al*., 2013). The author also added that temporary hardness is caused by carbonate and bicarbonate ions and they are removed by boiling of water on the other hand chlorides, sulphates and heavy metals are difficult to remove. Hardness has been evaluated and correlated by different workers for different purposes. Kudari *et al.,* (2006) classified water bodies based on the hardness as slightly hard, moderately hard and hard. While Moshood, (2008) stated that the utilization of calcium and magnesium ions by organisms probably causes decrease in the concentration of total hardness in the dry season, thus, hardness is an important parameter in decreasing the toxic effects of poisonous elements.

Table 2.1 classification of water hardness

Concentration $CaCO_3$ (mg/l)	**Description**
0-75	Soft
75-1500	moderately
150-300	Hard
300-up	very hard

Source: (Boyd, 1979)

2.2.6 Chlorides

The chloride concentration is one of the important indicators of water pollution (Khare *et al.*, 2007). The maximum permissible limit that is 500 mg/L for drinking water prescribed by WHO, (2008). Chlorides occur naturally in all types of waters; high concentrations of chlorides are considered to be the indicators of pollution due to organic wastes of animal or industrial origin and are troublesome in irrigation water and also harmful to aquatic life (Rajkumar *et al.*, 2004). The ionized form of chlorine is one of the most abundant inorganic ions in natural water and wastewater. Excess chloride in water leads to stomach discomfort and eye irritation (Sagar *et al.*, 2015).

2.2.7 Electrical conductivity (EC)

Electrical conductivity (EC) is a measure of water capability to transmit electric that solution carries and serves as tool to assess the purity of water (Murugesan *et al.,* 2006). It is used to estimate the ionic or soluble salt concentration in soils, water supplies, fertilizer solution and chemical solution (Sagar *et al.*, 2015) Conductivity depends on the presence of ions (cations and anions) in water, their total concentration and in groundwater monitoring as an indication of the presence of ions of chemical substances that might reflect the natural variation in water quality or the presence of contamination (Marandi *et al*., 2013).

2.2.8 Total alkalinity

Alkalinity is defined as the total carbonate of calcium and magnesium in a solvent. Total alkalinity is known to affect the toxicity of pollutants, especially metals to aquatic organisms (Wilson, 2010). Alkalinity affects fish production positively, directly or indirectly by affecting phytoplankton growth (Dokilil, 2003). The optimum values of alkalinity as is given at 20 mg/l to 40 mg/l or more as calcium carbonate (EPA, 2002; Wilson, 2010). Carbonates, bicarbonates, phosphates and hydroxides increase alkalinity in natural waters (EPA, 2002). Lower and less variable alkalinity in the wet season than in the dry season was observed in some Nigerian rivers. Tanimu *et al.* (2011) observed higher alkalinity during high water level in some lakes such as Galma in Zaria, while Ovie *et al.,* (1992) and Nsi, (2007) observed higher alkalinity during low water level in Kagera Pond, which was attributed to surface run-off into the lakes. Generally, the basic species responsible for alkalinity in water are bicarbonate ions, carbonate ions, hydroxide ions, alkalinity is a capacity and whereas pH is an intensity factor, alkalinity is a capacity (Manahan, 1993). For protection of aquatic life, the buffering capacity should be at least 20 mg/dm^3

2.2.9 Phosphates (PO_4^-P)

Phosphorus is necessary for the growth of biological organisms, including both their metabolic and photosynthetic processes, it occurs naturally in water bodies mainly in the form of phosphates a compound of phosphorus and oxygen (Malhotra *et al.*, 2018). Phosphorus is a nutrient essential for all organisms for the basic processes of life and natural element found in rocks, soils and organic material. Phosphorus clings tightly to soil particles and is used by plants, so its concentrations in clean waters are generally very low. However, Phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity (Malhotra *et al.*, 2018).

An investigation on the hydrological assessment and limonlogical parameterizations of aquatic communities by different researchers are reported. Keke *et al.* (2015) had studied on physicochemical parameters and heavy metals of surface water in downstream Kaduna River, at Zungeru, Niger State, Nigeria were evaluated to develop a baseline data on the pollution status of the water. The results showed the concentrations of the parameters ranged as follows: pH (5.90 – 6.80), air and water temperatures (25.00 – 31.00 ^{0}C), electrical conductivity (32.00 – 72.00 µS cm-1), dissolved oxygen (3.5 – 8.2 mg L^{-1}), biological oxygen demand (1.00 – 5.00 mg L^{-1}), phosphate (0.06 – 1.13 mg L^{-1}), nitrates (0.44 – 1.44 mg L^{-1}), alkalinity (8.00 – 16.00 mg L-1), transparency (36.00 – 40. 00 m), manganese (0.03 - 0.70 mg L^{-1}), Iron (2.00 – 3.80 mg L^{-1}), zinc (0.04 – 0.35 mg L^{-1}), and copper (0.01 - -0.07 mg L^{-1}).

Another study done by Ibrahim *et al.* (2009) focused on the seasonal variations in the physico-chemical parameters of water reservoir in Kontagora, Nigeria were studied from January to December 2007. They observed that the rainy season mean values for water temperature, depth, pH, nitrate-nitrogen, were significantly ($P<0.05$) higher than those for the dry season. However, for transparency, conductivity, dissolved oxygen, hardness, alkalinity, phosphate-phosphorus and total dissolved solid, the dry season mean value were significantly ($P<0.05$) higher than the rainy season mean value. As in most other African inland water bodies, there was seasonal variation in the physicochemical parameters evaluated (Ibrahim *et al.,* 2009).

Patrick *et al.* (2015) found out that fresh water bodies all over the world are constantly faced with pollution challenges most of which are anthropogenic in nature and physico-chemical parameters is one of the many routine practices of determining the health of the ecosystem and the survivability of the living biota within it. Their results indicate high significance difference ($P<0.05$) in biological oxygen demand, hardness, alkalinity, sulphate, nitrate, phosphate-phosphorus, total dissolved solids, electrical conductivity, and temperature of the sampling months with significance difference ($P<0.05$) in dissolved oxygen. The finding from the work indicated no significant ($P<0.05$) differences amongst the sites. The mean values of electrical conductivity ranged from 69.20±3.12 µs/cm (January) to 157.80±24.69 µs/cm (December), the dissolved oxygen: 3.05±0.22 mg/L (November) to 5.12±0.20 mg/L (January). Biological Oxygen Demand: 2.83±0.27 mg/L (December) to 6.37±0.24 mg/L (September). Hardness of water: 23.20±4.45 mg/L (December) to 177.60±19.71 mg/L (September), Alkalinity: 23.00±2.12 mg/L (August) to 48.80±1.66 mg/L (January). In similar study, Adedeji *et al*. (2019) evaluated the seasonal variation of the physico-chemical quality of Lake Ribadu, Adamawa State North eastern Nigeria. The results showed variation in the water parameters within the months. The mean water temperature varied from 22 ^{0}C in January to 28 ^{0}C in April while the mean pH varied between 6.89 in July and 8.08 in January. The mean dissolved oxygen varied between 4.23 mg/L in May and 6.89 mg/L in January while the biochemical oxygen demand varied between 2.17 mg/L in May and 3.91 mg/L in February. The lowest mean conductivity was observed in August (391 µmhos/cm) and the highest in April (480 µmhos/cm) while the total dissolved solid was lower in August with the mean value of 343.7 mg/L and highest in January (364.2 mg/L).

Omaka *et al.,* (2013) studied the physico-chemical parameters and nutrient loads of major rivers and streams in Abakaliki, Ebonyi State. The results obtained showed; temperature (28.60–30.00 ^{0}C), pH (6.80–7.93), DO (1.40–3.53 mg l^{-1}), turbidity (41.33–97.67 NTU) conductivity (19.00–613.30 µS cm^{-1}) total acidity (9.17–17.23 mg l^{-1}), total alkalinity (6.43–10.97 mg l^{-1}), BOD (1.20–7.03 mg l^{-1}), COD (16.200–53.533 mg l^{-1}), phosphate (0.11–1.17 mg l^{-1}) and nitrate (0.12–1.45 mg l^{-1}) ranges respectively. The turbidity and BOD were well above the prescribed standards. The results suggest that refuse disposal, fertilizer use and natural phenomena such as soil erosion; flooding, etc. might have contributed in various ways to the impairment of the water quality of the studied sites.

Aregbe *et al.* (2018) investigated on the temporal and spatial physico-chemical parameters of Kubanni dam, Galma dam and Shika Dam was carried out between (October 2016 to July 2017) for the determination of twelve physico-chemical parameters on monthly basis following standard method. The result indicated high significant difference ($p<0.05$) amongst most of parameters tested for the sampling locations except for hardness, biochemical oxygen demand and colour. The conductivity of water samples from the three dams ranged 133.97±30.33 (A.B.U dam) to 148.80±22.64 µS/cm (Shika dam) while pH ranged from 7.15±0.20 (Shika dam) to7.39±0.22 (Galma dam), Alkalinity ranged from 35.91±11.51 mg/L (Galma dam) to 41.83 mg/L (A.B.U dam). Turbidity ranged from 20.18±26.17 (Shika dam) to

37.39±35.69) NTU (Galma), Total dissolved solid ranged from 63.40±9.01) mg/L (Galma dam), to 70.64±6.99 (Shika dam), Chemical oxygen demand ranged from 238.80±48.95 mg/L, Galma to 274.25±97.90 mg/L A.B.U dam, dissolved oxygen ranges from 1.54±0.56mg/L, (Shika dam) to 1.81±0.42 (Galma dam), Chloride ranged from 12.62±2.35 (Galma dam) mg/L to 18.03±3.57 (Shika dam) and Temperature ranged from 26.05±1.41 ^{0}C (Galma) to 26.33±1.18 ^{0}C (Shika dam). Auta *et al.* (2016) had assessed the water variables and heavy metals concentration in fish Species collected from River Gurara at Izom, Niger State. The physico-chemical parameters determined were Dissolved oxygen (11.8-15.17 mg/L), biochemical oxygen demand (9-16 mg/L); pH (7.7-9.0); electrical conductivity (0.01-2.5 µs/cm); Total dissolved solid (67-133 ppm); temperature (24-27 ^{0}C); sodium (4.2-6.83 mg/L); chlorine (2.8-5.22 mg/L); potassium (1.43-6 mg/L); nitrate (0.5-1.5 mg/L) and phosphorus (0.11-3.5 mg/L). The results obtained revealed that pH was neutral in all stations; temperature was within the range of 24-27 ^{0}C. Dissolved oxygen and biochemical oxygen demand fluctuated slightly between (11.8-18.2 mg/L) and (9-16 mg/L) respectively. The author also indicated that the mean values were relatively moderate, there effects on most organic contaminants are weak organic acids and are more likely to enter organisms at low pH because they are un-ionized.

2.3 What are heavy metals?

The term "Heavy metals" is used to describe more than a dozen elements that are metals or metalloids such as chromium, arsenic, cadmium, lead, mercury, manganese (Perez *et al.*, (2001). Heavy metals have being defined by several researchers for instance Amo-Asare, (2012) defined heavy metals as any metallic chemical element that has a relatively high density (density higher than that of water) and is toxic or poisonous at low concentrations.

According to Kim *et al*. (2009) literatures has classified heavy metals into two types the essential (chromium, copper, iron, cobalt, manganese) and non-essential (lead, arsenic, mercury, cadmium). The essential heavy metals are less toxic at low concentrations and they act as co-enzyme in biological process. For example, haemoglobin and myoglobin consist of iron, vitamin b12 consist of cobalt. Non- essential heavy metals are highly toxic even at very low concentrations, they are no-biodegradable and cause severe toxic effects to living organisms by Kim *et al*. (2009).

Heavy metals are natural constituents of the earth's crust but indiscriminate human activities have drastically altered their geochemical cycles and biochemical balance (Singh *et al*., 2015). In small quantities, certain heavy metals are nutritionally essential for a healthy life especially elements like iron, copper, manganese, and zinc and some forms of them are commonly found in foodstuffs, fruits and vegetables, and in commercially available multi-vitamin products (Perez *et al.*, 2001). According to Edorh (2007) and Yahaya *et al.* (2009) the situation of heavy metal pollution is more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stakeholder. Industrial scale mining activity is comparatively low in Nigeria, yet at this level of mining, the nation is increasingly becoming exposed to the unwanted ecological effects of heavy metals (Olatunji and Osibanjo, 2012). The use of dumpsites as a farmland is a common practice in urban and sub-urban centres in Nigeria because of the decayed and composted wastes enhances soil fertility (Ogunyemi *et al.*, 2003). They added that when agricultural soils are contaminated, these toxins are taken up by plants and accumulate in their tissue, thus, animals that graze on such contaminated plants and drink from polluted waters as well as marine lives that breed in heavy metal polluted waters. In Nigeria, the situation is no better by the activities of most industries and populace towards waste disposal and management which usually lead to increasing levels of pollution of the environments. Many reports have showed that municipal refuse might increase heavy metal contamination in soil and underground water which may have effects on the host soils, crops and human health (Okoronkwo *et al.,* 2006). Thus, the environmental impacts of municipal refuse are greatly influenced by their heavy metal contents (Egila *et al.,* 2014). However, while total heavy metal contents are a critical measure in assessing risk of refuse dumpsite, total metal content alone does not provide predictive insight on mobility and fate of the heavy metal contaminants (Uba *et al.,* 2008). Thus, it is the chemical or species of the heavy metal that is an important factor in assessing their impacts on the environment.

2.4 Heavy Metals in Water

Heavy metals present in water are as a result of anthropogenic impacts which have caused serious ecological problems in many parts of the world (Sardar *et al*., 2013). This situation is provoked by the lack of natural elimination processes for metals (Ogunlana *et al*., 2015). The authors also added that heavy metals shift from one compartment within the aquatic environment to a great extent, including the biota, often with harmful effects. Perez *et al.* (2001) reported on heavy metal concentrations in water and bottom sediments of a Mexican reservoir. The finding showed that mercury, lead, chromium and iron were the main metal contamination problems. In the same study, spatial and temporal distributions of total metal levels had also been identified. The result from heavy metal concentrations showed evidence of the water self-cleaning capacity of the reservoir, despite high level metal contamination being determined (Perez *et al.,* 2001). Machado *et al.* (2002) also noted that water functions as a medium of transport for pollutants, heavy metal causing damaging effects on both living organisms and the environment have been observed. Ndeda and Manohar, (2014) documented that the heavy metal concentrations in Nairobi dam water in Kenya were analysed between the wet and dry seasons. They find out that during the dry vs. wet seasons were: 16.78 ± 0.21 versus 11.67 ± 0.21; 5.12 ± 0.18 versus 3.76 ± 0.15; 4.90± 0.25 versus 2.99 ± 0.05; 2.11 ± 0.12 versus 1.20 ± 0.13 mg/L respectively within water of Nairobi dam. The finding revealed that the water of this dam is not suitable for human consumption and even for agricultural activities (Ndeda and Manohar, 2014).

2.5 Heavy Metals in Sediment

Sediment represents an important sink for trace heavy metals in aquatic systems Edokpayi *et al*., 2016). Concentrations of heavy metals in sediment can be greater than the overlying water. More than 90% of the heavy metal load in aquatic systems is bound to the suspended particulate matter and sediments (Perez *et al.,* 2001). The accumulation of heavy metals in mangrove sediments has been reported for a number of countries including Hong Kong, Brazil and Nigeria (Machado *et al.,* 2002). Although there have been investigations on the levels of heavy metals in marine sediments of Malaysia (Yap *et al.,* 2002). A number of recent works have used sediment profiles to describe the contamination history. For example, Issa *et al*. (2011) worked on the sediment contamination by heavy metals in River Orogodo in Agbor, Delta State, Nigeria. The result of the analysis indicates significant difference ($p<0.05$) in pH, organic matters, Mn, Zn and Cr levels for the four-month variation. They observed the concentration ranges of metals (in mg/kg of dry sediment) measured were in order of Fe (339-925) > Mn (4.02 -0.50) > Zn (1.91 -1.11) > Cu (1.04-0.10) > Pb (0.96-0.30) > Ni (0.75-0.57) >Cd (0.43-0.09) > Cr (0.30-0.10).

Li *et al.,* (2007) reported that heavy metals in coastal wetland sediments of the Pearl River Estuary, China. The total concentrations of heavy metals such as Zn, Ni, Cr, Cu, Pb and Cd and their chemical speciation were investigated. The results showed that the sediments were significantly contaminated by Cd, Zn and Ni. Pb, Cd and Zn that was strongly associated with exchangeable fractions, while Cu, Ni and Cr were predominantly associated with organic fractions.

Adebayo (2017) worked on determination of heavy metals in water, fish and sediment from Ureje water reservoir. The results revealed a higher level of Zn (13.08 ± 0.45 mg/g) and Fe (2.10 ± 0.56 mg/g) in fish in comparison with other heavy metals examined. In the same study, Cadmium was not detected in soil, while other elements detected were in trace amount below the Environmental Protection Agency allowable limits in soil. In water, except for Fe (1.25 ± 0.02 mg/L), other metals were below allowable limit in water with reference to the World Health Organization's recommendation.

The heavy metals contents in sediment are often used to describe the contamination of metals in different environment, for instance, Bubu *et al.* (2018) worked on heavy metal concentrations in sediment of Bonny River, Nigeria. The total concentrations of heavy metals such as lead (Pb), copper (Cu), manganese (Mn) zinc (Zn) and iron (Fe) in sediments were investigated. The results showed that the sediments have low contamination level and are said to be unpolluted by all heavy metals.

Similarly, Jonathan *et al.* (2016) also investigated on the distribution of heavy metal pollution assessment in the sediments of Lake Chad, Nigeria. The results indicated that the sediments have been polluted with cadmium, chromium, iron, manganese, lead, Zinc and Arsenics. Abdullahi *et al*. (2015) evaluated the metal concentrations in bottom sediments from Tungan Kawo reservoir in Kontagora, Niger State. The results of sequential extractions of the metals showed all were more concentrated in the residual fraction during cool and dry season. They concluded that major proportions of most metals are associated with the inert fraction and could therefore be classified to be of geochemical origin. However, the distribution patterns in other seasons differs among the metals; cadmium, copper and lead were found to enriched in carbonate bound fractions while chromium, iron, manganese, nickel and zinc were found highest in residual, Fe-MnO and organic bound fractions.

2.6 Heavy Metals in Aquatic Organisms

Fish and marine products contain many elements which are essential for human life at low concentration. Heavy metals accumulation in seafood, water and fish products is a growing global concern that poses severe health risks to the public and ecosystem. This is because fish is known for its high levels of protein, low in saturated fats, and contains essential nutrients such as omega-3 fatty acids. Furthermore, Docosahexaenoic acid (DHA) is one of the vital fatty acids found in fish oil and is responsible for normal development, cerebral cortex, skin, retina and functioning of the human brain in infants (Sakamoto *et al*., 2015). Nevertheless, they can become toxic at high concentrations. However, certain heavy metals such as mercury, cadmium and lead do no show essential functions in life and are toxic even at low concentrations when ingested over long period.

In unpolluted areas, fish normally carry natural burden of heavy metal concentration. In heavily polluted areas, the heavy metal concentrations actually found are exceeding the natural concentration (Kalay and Canli, 2000). Abdullah (2013) found that mollusk has a potential to be used as bioindicator for the contamination of Cd and Zn in water and sediment of an estuarine environment, as indicated by its high concentration factors (HCFs). The species seemed to accumulate certain metals in its tissue and resisted the entry of others from its surrounding environment. Ahmad and Shuhaimi. (2010) reported that the level of heavy metals in ten species of marine prawns along the coastal areas of Peninsular Malaysia. It was found that the levels of trace metals in most of the samples studied were below the maximum permissible limit of the Food Regulations in Malaysia, with the exception of a few samples collected from the coasts of Melaka and Matang, which contained higher levels of Pb and Cd. However, there was no clear evidence on the relationships of heavy metals in sediments and prawns (Ismail *et al.*, 1995). The effect of sex and body length on metal accumulation in fish was also established by Ali *et al*. (2019). The results showed that the average metal concentration in liver, skin and muscle of the female fish were found to be higher than those found in the male fish. The accumulation of zinc, copper, manganese and cadmium in the liver tissues of *Lithrinus* l*entjan* was found high compared to skin and muscle tissues (Yousuf *et al*., 2019).

Ibrahim *et al.* (2018) did a work on determination of some heavy metal contents in tilapia and cat fish species in Lake Njuwa, Adamawa State, Nigeria. It was found that the heavy metals were more concentrated in the bones (2.30, 2.50, 1.37, and 1.40) mg/kg than the gills (2.17, 2.20, 1.19 and 1.23) mg/kg and the muscles (0.5, 0.7, 0.99 and 1.03) of both the Tilapia and catfish during the wet season than the dry season.

Adaka *et al.* (2017) have evaluated the heavy metals in fish tissues of some fish species from Oguta Lake, South-Eastern Nigeria. the levels of heavy metals copper (Cu), lead (Pb), cadmium (Cd), arsenic (As) were determined in three common edible fish species these include *Tilapia zillii*, *Citharinus citharus* and *Heterotis niloticus.* The results obtained showed that the values of all the heavy metals in the fish samples were lower than the values recommended by World Health Organisation and the Food and Agricultural Organization of the United Nations, however, the dishes found in the lake are suitable for human consumption as noted by Adaka *et al.*, (2017). Adeosun *et al*. (2011) had studied the effect of heavy metals concentration in commercially important fish species in Ogun River. The results showed that copper and zinc were observed to be present in the entire specimen with concentration of 0.09 and 0.25 mg/L respectively in fish flesh samples, 0.17 and 0.22 mg/L respectively in fish bone samples. However, the level of heavy metal in the fish from Ogun River is less than the optimal range recommended by WHO which signifies the suitability of the fish species and water for consumption (Adeosun *et al*., 2011).

2.7 Human Exposure and Health Hazards Associated with Heavy metals

Humans are always exposed to the natural levels of trace elements. Under normal circumstances, the body is able to control some of these amounts (Doyi *et al*., 2018). However, continuous exposure to elevated levels of metals could cause serious illness or death (Okonkwo, 2005). Increased exposure may occur through inhalation of airborne particles or through ingestion of contaminated soil by children or by absorption through the skin (WHO, 2008). Metals and their compounds can accumulate in the body's tissues, such as bones or nerves. The health hazards presented by heavy metals depend on the level and the length of exposure and situations the health effects are immediately apparent; in others, the effects are delayed (Doyi *et al*., 2018).

2.7.1 Chromium (Cr) content

Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Low-level exposure to Cr can irritate the skin and cause ulceration.

Long-term exposure can cause kidney and liver damage and also circulatory and nerve tissues (Agency for Toxic Substance and Disease Registry, ATSDR, 2004). Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium. In drinking water, the level of chromium is usually low as well, but contaminated well water may contain the dangerous chromium (IV). Chromium (VI) is very toxic and is the real danger to human health, mainly for people who work in the steel and textile industry. People who smoke tobacco also have a higher chance of exposure to chromium (Katz and Salem, 1994). Other health problems that are caused by chromium (VI) are: skin rashes, upset stomachs and ulcers, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material and lung cancer (Doyi *et al*., 2018).

2.7.2 Copper (Cu) content

Presence of Cu in water imparts taste and colour (Cuppett *et al*., 2006). Cu content of soil ranges from 10-80 ppm, depending upon the nature of the parent material and the pedologic processes. Copper is strongly adsorbed to many solids (Clays, aluminium, iron hydrous oxides -and manganese oxides). Copper, generally forms stronger bonds with organic ligands than most other metal ions. Copper is an essential element for human life, but excessive intake results in its accumulation in the liver and produces gastrointestinal problems such as anaemia, liver and kidney damage (Nuhoglu and Oguz, 2003). Continued inhalation of copper-containing sprays is linked with an increase in lung cancer (Yu *et al.,* 2000). People with Wilson's disease are at greater risk for health effects from overexposure to copper (ATSDR, 2004). Copper can be released into the environment by both natural sources (e.g. wind-blown dust, decaying vegetation, forest fires, sea spray and human activities (mining, metal production, wood production and phosphate fertilizer production). This copper is released both naturally and through human activities, it is very widespread in the environment. Copper is often found near mines, industrial settings, landfills and waste disposals.

2.7.3 Iron (Fe) content

Most of the rocks contain iron as one of the common elements and it is also an important component of many soils especially clay soil where it is usually a major constituent (Gupta, 2016). Yu *et al.* (2003) observed that iron can cause undesirable problems in industrial processes or ecosystems if its concentration in water is not managed properly. Thus, excessive iron in water limits the usage of water for drinking or industrial processes. WHO has recommended a value of 0.3 mg/L as permissible limit for drinking water, for fresh water aquatic life, the limit is 1 mg/L. Chronic excessive intake of iron may lead to hemochromatosis.

2.7.4 Lead (Pb) content

Lead is not essential as trace elements to nutrition in human or animals. It can poison organisms including human even in low concentration as it bio-accumulates and biomagnifies in the food chain. Contaminated food, water, air, soil and consumer products result in the absorption of lead into human body (ATSDR, 2004). Ferner (2001) noted that individuals living in the vicinity of dangerous waste can be exposed to the leads of air, water, food or dust or dirt that contain plant. The author also concluded that the effects of lead exposure are the same whether it is breathed or swallowed. To support the above submission Zheng (2006), noted that child who swallows large amounts of lead may develop blood anaemia, kidney damage, severe stomach-ache, muscle weakness and brain damage. The concentrations of lead and exposure time are key factor in lead toxicity measurement. Acute poisoning occurs when one is exposed to high concentration of lead for a short duration and the adverse effects is high and severe, thus capable of disrupting metabolic processes and threaten lives (Zheng, 2006).

2.7.5 Manganese (Mn) content

Manganese is considered an essential trace element for plants and animals. Mn concentration amounts to approximately 0.1% in the earth's crust. Organic matter decomposition aids manganese solubility. Toxic concentration of manganese is more likely than that for zinc, iron or copper. Toxic levels occur only in strongly acidic soils. Prolonged inhalation of high levels of manganese negatively affects the central nervous system, visual reaction time, hand steadiness and eye-hand coordination (EPA, 2002).

2.8 Ecological Risk Index

The potential ecological Risk Index (RI), proposed by Hakanson, (1980) was used to evaluate the potential risk of one or multiple elements to the ecology. The sensitivity of the biological community can be reflected by RI when it takes the potential ecological risk factor and the toxicity response coefficient into accounted. The method of potential ecological risk index is the only method that considers both concentrations and toxic response factors of heavy metals and has been commonly employed due to the following advantages:

(i) Ri-value will increase when sediment contamination increases

(ii) a lake polluted by numerous substances will have a higher Ri-value than an area contaminated by only a few substances

(iii) various elements have different toxicological effects, among which some are highly toxic and others slightly toxic (Sun *et al*., 2010)

Ecological risk management provides policy makers and resource managers as well as the public with systematic methods that can inform decision making. A number of studies have applied this method for instance, Lin *et al.* (2017), reported that the contamination, ecological risk and source apportionment of heavy metals in sediments and water of a contaminated river in Taiwan. Analysis of Contamination factor (Cf_i) and potential Ecological risk factor (Ef_i) of heavy metals in water showed that there were low grades of contamination and potential ecological risk for all heavy metals, suggesting that heavy metals in water were less likely to pose risks to the ecosystem. However, sentiment samples were found to have severe contamination levels based on ranges found in sediment quality guidelines

Pollution load are often used to describe the contamination of metals in different environment. For instance, Wang *et al.* (2012), worked on metals pollution and ecological risk assessment of sediments in the Poyang Lake, China. The total concentrations of heavy metals such as Cd, Pb, Zn, Fe, Mn, Cr, Zn, Cu and Ni, and their chemical speciation were investigated. The results showed that the concentrations of Cu (28.1–213 mg/kg), Zn (82.6–257 mg/kg), Pb (49.8–81.4 mg/kg) and Ni (33.5–56.0 mg/kg) were higher than the background values, while Cd (0.15–0.81 mg/kg) was lower. Zn, Cu and Ni were predominately bound to residual fraction. The content of Pb in the Fe–Mn oxides fractions was considerable (Wang *et al.,* 2019). Fractionation of heavy metals in sediments can help in understanding potential ecological risk hazards of heavy metals. Fatoba and Ogunkunle (2012) evaluate pollution loads and the ecological risk assessment of soil heavy metals around a mega cement factory in Southwest, Nigeria. The results showed that the mean concentrations of Pb, Cu, Cd, and Cr (666.1, 613.4, 47.9 and 188.5 mg/kg, respectively) were above the international standard limits. Nemerow pollution indices, according to the axes, indicated serious pollution with heavy metals. The Single Potential Ecological Risk Index (PERI) showed that soil contamination from Cd in the 3 axes had very high potential ecological risk, which translated into the high value of comprehensive potential ecological Risk Index (RI) value (11,488) for the entire study area. This study suggests that the bioremediation of the soil around the cement factory, especially for Cd, is needed to avert a potential environmental disaster (Ogunkunle and Fatoba, 2012).

Ntakirutiman *et al*. (2013), have documented a finding focused on various heavy metals found in sediments taken from Donghu Lake, China. Six High Metals: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn) were determined. Potential ecological risk indices showed that the lake was polluted by heavy metals. Cd had moderate potential ecological risk to the ecological environment and was the main contributor to potential toxicity response indices for various heavy metals in Lake Donghu (Ntakirutimana *et al*., 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

Tungan Kawo Reservoir is located in Kontagora, Niger State and it was officially commissioned in May 1991 by Niger State Water Corporation (NSWC). The Reservoir lies between latitude 10˚21"58.51˚N and 10˚23"28.50˚N of the equator and between longitude 5˚19"29.23˚E and 5˚20"59.23˚E in Tungan Kawo village, northwest of Kontagora (Figure 1). The main objective of the Reservoir is to provide water for domestic use to Kontagora Township, with a total storage capacity of 17.7 million cubic metres by Aquaculture and Inland Fisheries Project, AIFP (2004) and a surface area of 143 square kilometres. The Reservoir has its source from Kontagora River, a seasonal river (Ibrahim *et al*., 2009). The people residing close to the Reservoir and its environs are predominantly farmers and have remained so for years (Abdullahi *et al*. 2015).

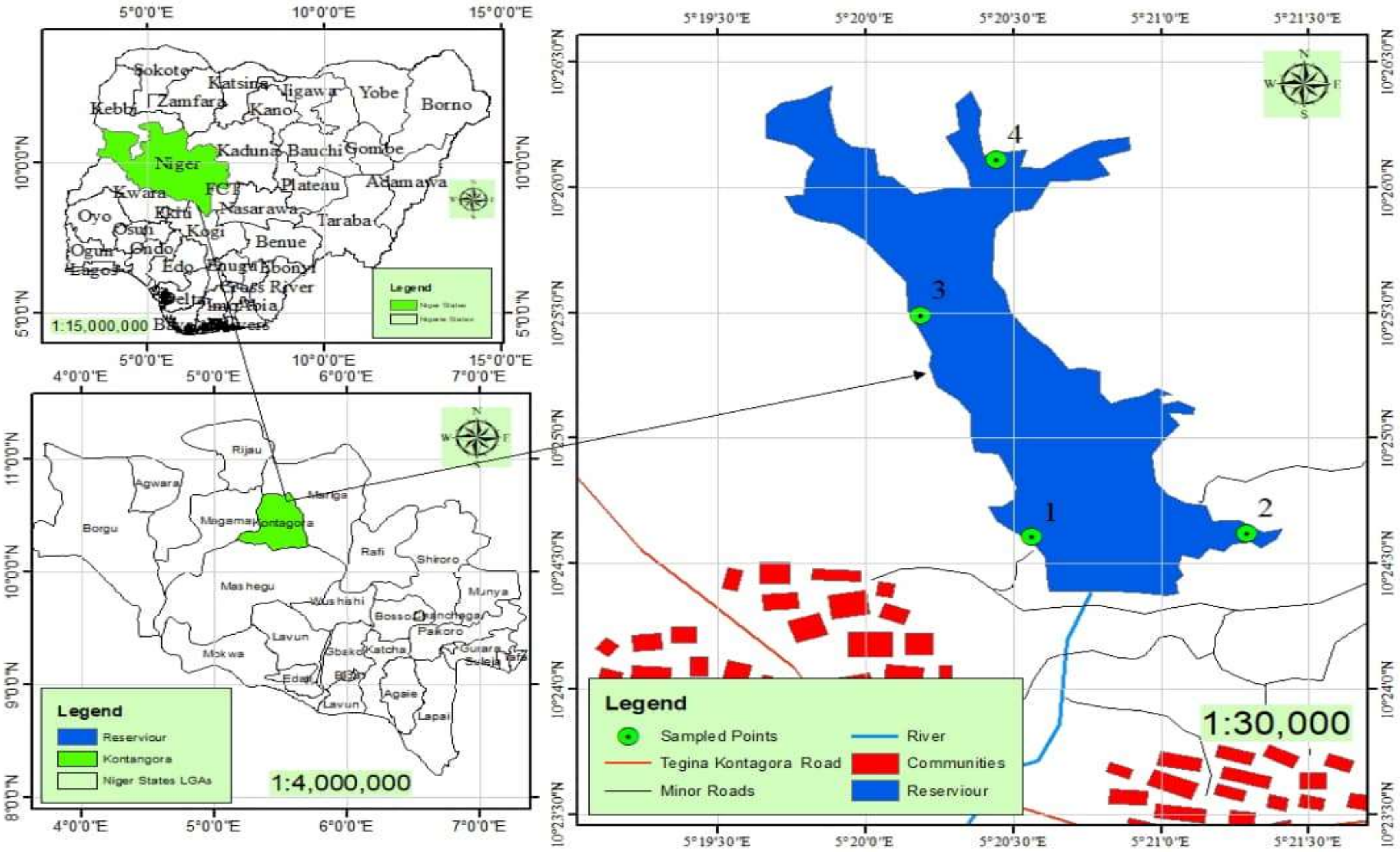

Figure 1: Hydrological Map of Tungan Kawo Reservoir showing the sampling sites
Source: Remote Sensing/ Geographical information system (GIS) laboratory, Geography department, FUTMINNA (2019).

3.2 Description of sampling stations

3.2.1 Station 1

Kwatan Mustafa: It is located upstream of the Reservoir between latitude 10^0 24’42.36” N and longitude 5^0 20’30.36” E. Farming of vegetables, banana, okro are being done around the shore area of the Reservoir. The area is surrounded with hip of mud stand.

3.2.2 Station 2

Babban Kwatan: This is market depot of fishes in that Reservoir. A lot of domestic waste and agricultural waste are discharge into the reservoir. The common crops plants in this site are mostly grains. The station is located at the upstream on the latitude 10^0 24’.36.19” N and longitude 5^0 21’7.51” E.

3.2.3 Station 3

Kwatan Abdullahi: It is located closed to the pumping discharge of the Reservoir. Farming activities like grains cultivation, some boats, and fishing equipment are abandoned there. The reservoir is located in latitude 10^0 25’25.67” N and longitude 5^0 20’12.26” E. The vegetation is mainly shrubs, few tall trees, and dead fishes, leaves, shrimps are observed at the shore area of the reservoir.

3.2.4 Station 4

Gonna Hajiya: It is located around middle side of the Reservoir. Cultivation of crops is highly down in this region. It’s observed that all the fishermen park their boats, take their baths, and even wash their dirty cloths. It’s located in between latitude 10^0 26’1.70” N and longitude 5^0 20’27.83” E.

3.3 Sample Collection and Identification

3.3.1 Collection of fish samples

Fish samples were identified and purchased from the lake on monthly basis for a period of 8 months. At each sampling station, the fish were sampled with gill nets from the lake. Adult individuals of similar size were selected from the reservoir and two of the same fish species were brought to the laboratory using cold box and stored in refrigerator until analysis.

3.3.2 Identification of fish samples

Samples of all available fish species were collected for identification. The species were identified by the used of monographs and texts of Olaosebikan and Raji (1998), Idodo-Umeh (2003) and Adesulu and Sydenham (2007).

3.3.3 Collection of water samples

Water sample were taken from different stations of the reservoir using sterilized two litre capacity bottles. Water and fish samples were brought to the laboratory using cold box and stored in refrigerator until analysis following the method of American Public Health Association (2014).

3.3.4 Collection of sediment

The sediment samples were collected from four points in the lake using Ekman grab. This was done using the instrument as shown below in Plate 1. The grab has a rope that is dip into each station and allowed to reach the floor bed of the reservoir and closed immediately after collecting the sediment by pulling the rope on the grab to close the two arms. The grab was now finally pull out from the water with the muddy sediment and discharge on a container, then 1 sterile container of the sediment was stored in a pre-cleaned polythene bag and later spread on a flat tray inside the laboratory to be air dried for two days at room temperature after which it was pounded and sieved for further digestion process according to APHA (2014).

Plate 1: Collection of sediment.

Source: Field photograph (2018).

3.4 Determination of Physico-chemical Parameters

3.4.1 Temperature

Air and water temperatures were measured at each station in degree centigrade using mercury in glass bulb thermometer (0 – 110 ^{0}C). Readings were taken at level of the eye meniscus. Air temperature was determined by holding the thermometer above water for about 2 minutes until it stabilized before reading according to Environmental Protection Agency (2002). The water temperature was determined by lowering the thermometer into the water and reading was taken when established following the method of EPA, (2002).

3.4.2 Electrical conductivity (EC)

Two separate beakers were poured into a 100 mL of distilled water and 100 mL of water sample. The conductance meter has been activated and its sensor rod has been tipped into the beaker that contains distilled water to standardize it, and then it has been plunged into the second beaker that contains water sample (APHA, 2014).

3.4.3 Total dissolved solid (TDS)

This parameter was determined by pouring 100 mL of water sample through a pre-weighted filter (glass fibre) of specific pore size, the filter was weighed again after the drying process that removed all the water from the filter. The gain in weight is a dry weight measure of the particulates present in the water samples. Results were reported in milligrams of solids per liter of water mg/L (APHA, 2014).

3.4.4 Water pH

To collect a water sample for pH determination, a washed bottle rinsed with water was used. The pH meter was battery operated (model ETh 3055, Tecpet China) standardized with the pH 4-8 buffer and taped, labelled and brought to the laboratory for analysis. Before it was switched to "on position," the sensor was immersed into the water for pH measurement and was recorded at the nearest 0.1 pH unit (APHA, 2014).

3.4.5 Dissolved oxygen (DO)

The determination of dissolved Oxygen (DO) was done in situ using a portable dissolved oxygen analyser (model JPB – 607, Yokogawa China) following (APHA, 2010) method; Procedure: DO meter was standardized by distilled water and buffer solution. Then drop inside the water and wait for at least 1 minute, after which reading was recorded from DO meter and written down into the notebook. In the same way, the procedure was repeated in all the sampling sites but before every measurement DO meter was sink into distilled water.

3.4.6 Biological oxygen demand (BOD)

This was determined according to APHA (2014) method. At the field, the reagent bottles set aside for BOD was filled with water samples and wrapped with black polythene bags to avoid any form of light penetration. The samples were then transported to laboratory and kept in a dark cupboard. After five (5) days, the procedure for carrying out dissolved oxygen was repeated to check the amount of oxygen that has been used up by microorganisms.

Calculation: BOD1=DO1-DO5

DO1=initial dissolved oxygen at the first day

DO5=Dissolved oxygen reading after 5 days

Result expressed in milligram per litre (mg/L)

3.4.7 Total alkalinity

This was determined by titration methods following the method of APHA (2014). The collected water was measured to 50 mL and poured into a clean 150 mL conical flask, and then three drops of phenolphthalein indicator was added. The sample was titrated with 0.05 mL of sulphuric acid (H_2SO_4), until the colour disappeared. To the colourless solution, three drops of methyl orange indicator was added and titrated further until the colour change from yellow to permanent reddish or orange red colour and the titre values were recorded and used to compute the alkalinity.

3.4.8 Total hardness

The water samples were thoroughly shaken and 25 mL was taken and diluted to 50 mL with distilled water. Two ml of phosphate buffer solution was added to bring the pH of the water sample to 10. Three drops of ferrochrome black indicator were also added. This was titrated with 0.01 Mol/L EDTA to a blue colour end point. Hardness was then calculated in line with APHA (2014) method.

3.4.9 Phosphate – phosphorus (PO_4-P)

This was determined by colorimetric method. To two mL aliquot of the water sample in a 25 ml volumetric flask was added and one drop of phenolphthalein indicator followed by two mL of ammonium molybdate also one ml of freshly diluted stannous chloride solution. These were made up to 25 mL volume with distilled water and mixed thoroughly. After 5 - 6 minutes and before 20 minutes, the colour intensity (absorbance) will be measured at a wavelength of 660 nm in a Spectrophotometer (OPTIMA SP 300, Optimas U.K.) following the method of APHA (2014).

3.4.10 Nitrate –nitrogen (NO_3-N)

The reaction with the nitrate and brucine produces yellow colour that can be used for the colorimetric estimation of nitrate. The intensity of colour was measured at 410 nm. The method is recommended only for concentration of 0.10 – 2 mg/L. All strong oxidizing and reducing agent interfere. Sodium arsenide was used to eliminate interference by residual chlorine; sulphanilic acid eliminates the interferences and chloride interference was masked by addition of excess sodium chloride. High concentration of organic matter also might interfere in the determination.

3.5 Acid Digestion

3.5.1 Digestion of water sample

Ten (10) ml of water sample was measured with a measuring cylinder and 10 mL of concentrated nitric acid (HNO_3) was added to the sample in the beaker. The solution was then transferred to a water bath digestion at 150 ^{0}C until chucking odour is clear. After which the sample was then removed and allowed to cool for about 25 minutes under room temperature. The cooled sample was then filtered into 100 cm^3 volumetric flask and the filtrate was made up with distilled (Olafisoye *et al.,* 2013). The prepared sample solution was then transferred into the pre-cleaned labelled sample bottles in readiness for lead, copper, manganese, iron, and chromium using Atomic Adsorption Spectrophotometer (AAS) analysis (model: wfx-110A, Rayleigh China).

3.5.2 Digestion of sediment samples

The sediment sample was air dried for 3 days and ground into smaller particles. It was sieved and went through digestion process: One gramme (1g) of the sediment sample was weighed and poured into a beaker, thus, 10ml of nitric acid (HNO_3) and 10 mL hydrochloric acid (HCl) which was be heated for 75 minutes on a water bath at 150 ^{0}C until chucking odour was clear. Sample was then removed and allowed to cool for about 25 minutes under room temperature. The cooled sample was then filtered into 100 cm^3 volumetric flask and the filtrate was made up with distilled (Olafisoye *et al.,* 2013). The prepared sample solution was then transferred into the pre-cleaned labelled sample bottles in readiness for lead, copper, manganese, iron and chromium using Atomic Adsorption Spectrophotometer (AAS) analysis (model: wfx-110A, Rayleigh China).

3.5.3 Digestion of fish samples

The fish samples were dried in an oven at 105 ^{0}C for six hours. After drying the fish sample in the oven, the bones and scales of the dried fish samples were removed, then only the tissue muscle was used. The tissue muscle of the fish sample was milled with a mortar and pestle. Then transferred into dry labelled polythene bag and stored until digestion. This involved digesting one gramme (1g) of the grounded sample which was weighed and poured into a beaker, 10 mL of nitric acid (HNO_3) and 10 mL hydrochloric acid (HCl) was added together that was heated for 75 minutes on a water bath at 150 ^{0}C until chucking odour was clear. The fish samples were then removed and allowed to cool for about 25 minutes under room temperature. The cooled sample was then filtered into 100 cm^3 volumetric flask and the filtrate was made up with distilled (Olafisoye *et al.*, 2013). The prepared sample solution was then transferred into the pre-cleaned labelled sample bottles in readiness for lead, copper, manganese, iron and chromium using Atomic Adsorption Spectrophotometer (AAS) analysis (model: wfx-110A, Rayleigh China).

3.6 Determination of heavy metals in water, sediment and fish samples

Heavy metals (copper, cadmium, iron, zinc, chromium and lead) in water, fish and sediment samples were determined using Atomic Absorption Spectrophotometer (model: wfx-110A, Rayleigh China).

3.6.1 Lead

A calibration curve for determination of lead in natural water by flame atomic absorption spectroscopy (FAAS) method was established by using the following procedure. First, an appropriate amount of working standard solutions of lead was transferred to an extraction tube, then, 1 mL of 0.005% dithizone was added and the obtained solutions were extracted for 120 seconds with carbon tetrachloride. Finally, after removing the organic solvent by slow evaporation, the residue was dissolved in 10 ml of NH_3 (1:1) while for sediment and fish (3:1), transferred to 100 mL volumetric flask and filled to the mark with deionized water

3.6.2 Chromium

Colour development and measurement: Ninety-five ml of the extract tube tested to a 100mL volumetric flask. Add 2.0 mL diphenylcarbazide solution and mix. Add H_2SO_4 solution to give a pH of 2 ± 0.5, dilute to 100 mL with reagent water and stand 5 to 10 minutes for full colour development. Transfer an appropriate portion of the solution to a 1cm absorption cell and measure its absorbance at 540 nm. Use reagent water as a reference. Correct the absorbance reading of the sample by subtracting the absorbance of a blank carried through the method. An aliquot of the sample containing all reagents except diphenylcarbazide should be prepared and used to correct the sample for turbidity (i.e., turbidity blank). From the corrected absorbance, determine the mg/L of chromium present by reference to the calibration curve as clearly stated by (APHA, 2014).

3.6.3 Copper

A copper sulphate solution was prepared so as to contain 0.1 mg of copper in solution, by dissolving 0.3928 gm. of pure copper sulphate ($CuSO_4$+$5H_2O$) in water and diluting to 1 litre. Clear crystals of copper sulphate that showed no sign of efflorescence are used. Then 0.5, 1 and 2 cubic centimetres (cc) of this standard solution was treated with acetic acid, potassium thiocyanate, pyridine, and chloroform in exactly the same manner as the sample solution and made-up to 25 cc. The standard which had approximately the same intensity of colour as the sample is selected, and the standard prism was usually set at 20 mm. When necessary the length of the standard column was varied in accordance with standard procedures (APHA, 2014).

3.6.4 Iron

The Standard Iron solution contained 0.2500 g/L of pure iron. Pipet 25.00 mL of this standard iron solution into a 500 mL volumetric flask and dilute up to the mark with distilled water. Pipet 10.00 mL of each sample solution (record the number) into a 250 mL volumetric flask and dilute to the mark with distilled water. Invert and shake the flask several times to mix the solution. Pipet two 25.00 mL aliquots of this solution into two 50 mL volumetric flasks labelled sample. Using a 10 ml graduated cylinder add 4.0 ml of 10 % hydroxylamine hydrochloride solution and 4.0 ml of 0.3% o- phenanthroline solution to each volumetric flask. Swirl and allow the mixture to stand for 10 minutes. Dilute each flask to the mark with distilled water and mix well by inverting and shaking the capped volumetric flasks several times.

3.6.5 Manganese

A portion (4.144g) of potassium tetraoxomanganate (VII) KMnO4 was dissolved in water and made up to 1000 cm^3 to obtain a concentration of 0.03 M. Working solutions of 0.25, 0.50, 1.0 and 2.0 mg/L were prepared by diluting 0.25, 0.50, 1.0 and 2.0 cm^3 respectively to 1000 cm^3 marks in a volumetric flask (APHA 2014).

3.7 **Ecological risk index**

The potential ecological risk index (RI) was calculated as follow:

$$RI = \sum_{i=1}^{n} E_f^i \; ; where \; E_f^i = C_f^i \times T_f^i$$

(Hakanson, 1980)

Where

C_f^i Is the contamination factor

T_f^i Is the toxicity response coefficient of each element

E_f^i Is the potential ecological risk factor of each element,

T_f^i the toxicity response coefficient of each element (Cu =5, Pb = 5, Mn = 1, Cr = 2 and Fe = Not Available (Hakanson, 1980) while the indices Criteria for degrees of ecological risk caused by heavy metals in sediments (Hakanson, 1980). $E^i r$ or Ri (Ecological pollution degree); $E^i r < 40$ or Ri < 150 (Low ecological risk); $E^i r < 80$ or Ri < 300 (Moderate ecological risk) and $E^i r < 160$ or Ri <600 (Very high ecological risk).

3.8 Data Analysis

Statistical analysis was conducted using computer programme software known as Statistical Package for Social Science (SPSS) Version 21. The Mean, standard error of means and range of values for each physiochemical parameters and heavy metals in water, sediment and fish were calculated and compared. One-way Analysis of variance (ANOVA) was employed to analyse the difference in each of the physico-chemical parameters and heavy metal concentration in surface water, sediment and dominant fish species while Durcan Multiple Range Test (DMRT) was used to separate the means at

$p<0.05$. Tables were used for data presentation. In addition, to ascertain the safety and the degree of health risks associated with consuming contaminated fish caught from

0Tungan Kawo Reservoir and its catchment areas. Results were compared with the permissible limits as set by the Federal Environmental Protection Agency (FEPA), National Environmental Standards and Regulations Enforcement Agency (NESREA) and Food and Agriculture Organization (FAO). Furthermore, sediment samples were subjected to Hakanson (1980) indices criteria for degrees of ecological risk.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Physico-chemical Parameters

The mean, standard error and range of physico-chemical parameters measured during the study period in Tungan Kawo Reservoir, Kontagora, between July 2018 and February 2019 is summarized in Table 4.1. Water temperatures fluctuated between 27 and 32.4 ^{0}C in Station 4. However, indicated no significant difference (P>0.05) cross all the sampling Stations. The pH values ranged from (6.6 and 9.8) mg/l in Station one. Electrical conductivity (µS/cm) revealed no significant difference (P>0.05) with a highest mean value (105 ± 5.28) in station 4 while the least was recorded in Station 2 with the mean of (96.4 ± 3.92) mg/L. The mean value for total dissolved solids (ppm), alkalinity, hardness and phosphate ranged from 115 ppm to 198 ppm, 16 mg/L to 34 mg/L, 20 mg/L to 54 mg/L and 0.35 mg/L to 2.5 mg/L respectively and were also not significantly different (P>0.05) in all stations sampled. The biological oxygen demand (BOD) level ranged from 1.9 mg/L to 4.4 mg/L while high levels of nitrate were recorded in the 4 Stations at some points (ranged between 3.6 mg/L and 7.5 mg/L. However, while dissolved oxygen, BOD and nitrates were significantly different (P <0.05) along the Stations but did not show wide variation.

Table 4.1: Mean and range values of physico-chemical parameters of Tungan Kawo Reservoir, from July 2018 to February 2019.

Environmental Variable	Station 1	Station 2	Station 3	Station 4	** FEPA	** * NESREA
Water Temperature (^{0}C)	29.70±0.51[a*] (27.2-32.1)	30.39±0.46[a] (28-31.8)	30.4±0.48[a] (27.9-32.1)	30.65±0.63[a] (27-32.4)	–	30
pH	8.4±0.46[a] (6.6 – 9.8)	8.11±0.50[a] (6.3 – 9.5)	8.3±0.48[a] (6.5 – 9.6)	8.3±0.44[a] (6.4 – 9.7)	6–9	6.5-8.5
Electrical Conductivity (µS/cm)	104±5.09[a] (87 – 122)	96.4±3.92[a] (84 – 115)	104.3±5.40[a] (81 – 124)	105±5.28[a] (88 – 125)	1000	240
Total Dissolved Solids (ppm)	151.48±8.42[a] (117 – 198)	144.73±5.61[a] (120 – 165)	143.88±5.59[a] (118 – 168)	147.64±4.13[a] (126 – 163)	2000	200
Alkalinity (mg/L)	24±0.73[a] (22 – 28)	23±1.11[a] (20 – 29)	25±1.24[a] (18 – 30)	23.4±2.09[a] (16 – 34)	100	-
Dissolved Oxygen (mg/L)	4.0±0.33[a] (2.6 – 5.2)	3.89±0.28[a] (2.5 – 5.1)	3.6±0.29[b] (2.4 – 4.8)	3.78±0.29[b] (2.6 – 4.9)	7.5	10
BOD (mg/L)	3.25±0.30[a] (2.0 – 4.4)	2.83±0.26[b] (2.0 – 3.8)	2.63±0.26[b] (1.9 – 3.8)	2.83±0.26[b] (2.0 – 3.8)	30	10
Hardness (mg/L)	33.5±2.25[a] (25 – 46)	35.75±3.06[a] (26 – 52)	34.75±3.02[a] (28 – 54)	33.38±3.49[a] (20 – 51)	150	150
Nitrate (NO_3) (mg/L)	4.48±0.57[a] (3.2 – 7.5)	4.90±0.58[b] (3.5 – 7.5)	4.55±0.40[a] (3.4 – 6.5)	5.24±0.44[b] (3.6 – 7.5)	20	0.2
Phosphate (mg/L)	0.89±0.14[a] (0.6-1.5)	1.15±0.24[a] (0.4-2.5)	1.36±1.1[a] (0.4-2.0)	0.96±0.11[a] (0.5-1.5)	5	0.1

***** Values followed by the same superscript alphabets in the row are not significantly different at ($P > 0.05$) tested by Durcan Multiple Range Test. **

Federal Environmental Protection Agency, FEPA (1991), *** National Environmental Standards and Regulations Enforcement Agency NESREA (2007)

4.1.2 Spatio-Temporal Variation in Physico-chemical Parameters

4.1.2.1 Temperature (^{0}C):

Temperature revealed insignificant difference (P>0.05) among the sampled Stations. The mean values ranged between 29.70±0.51 at Station 1 during the month of August and 30.65 ± 0.63 ^{0}C at Stations 4 during the month of December (Figure 4.1a). Stations 2 and 3 showed wider variations in the water temperature levels than Station 1, however, Station 4 showed the highest mean value (30.65 ± 0.63 ^{0}C) while Station 1showed the lowest mean value (29.70 ± 0.51 ^{0}C).

4.1.2.2 pH (Hydrogen ion Concentration):

There was no significant difference (P>0.05) in the values recorded among the Stations. The lowest mean value for the pH (8.11±0.50) was recorded in Station 2 in January, Station 4 in December and Station 3 in February (Figure 4.1b). The highest value (8.4±0.46) was recorded in Station 1 in the month of October. Station 1 was characterized by very wide fluctuations in pH from 6.63 in December to 9.8 in November.

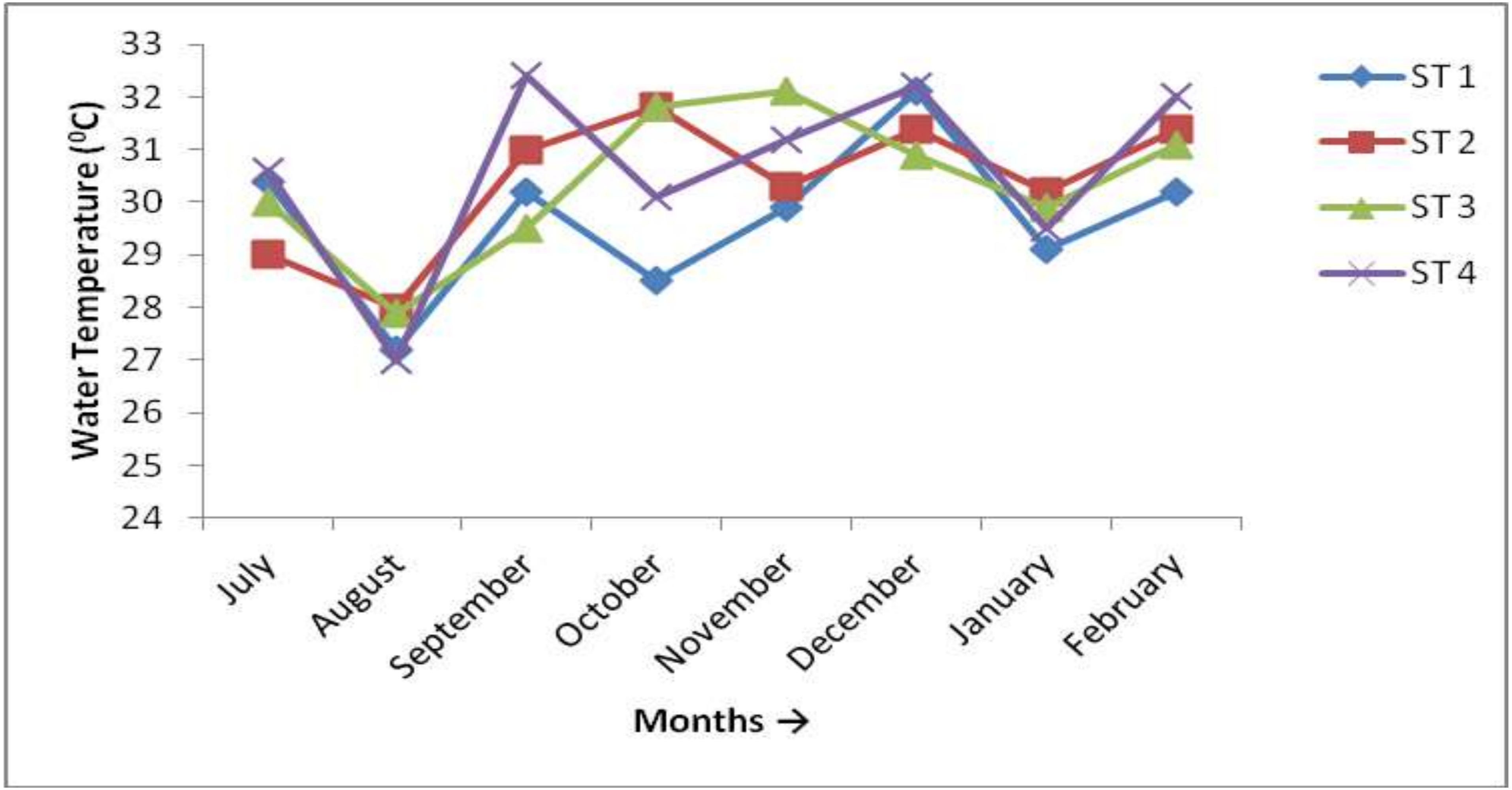

Figure 4.1a Spatio-temporal variations in the water temperature of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

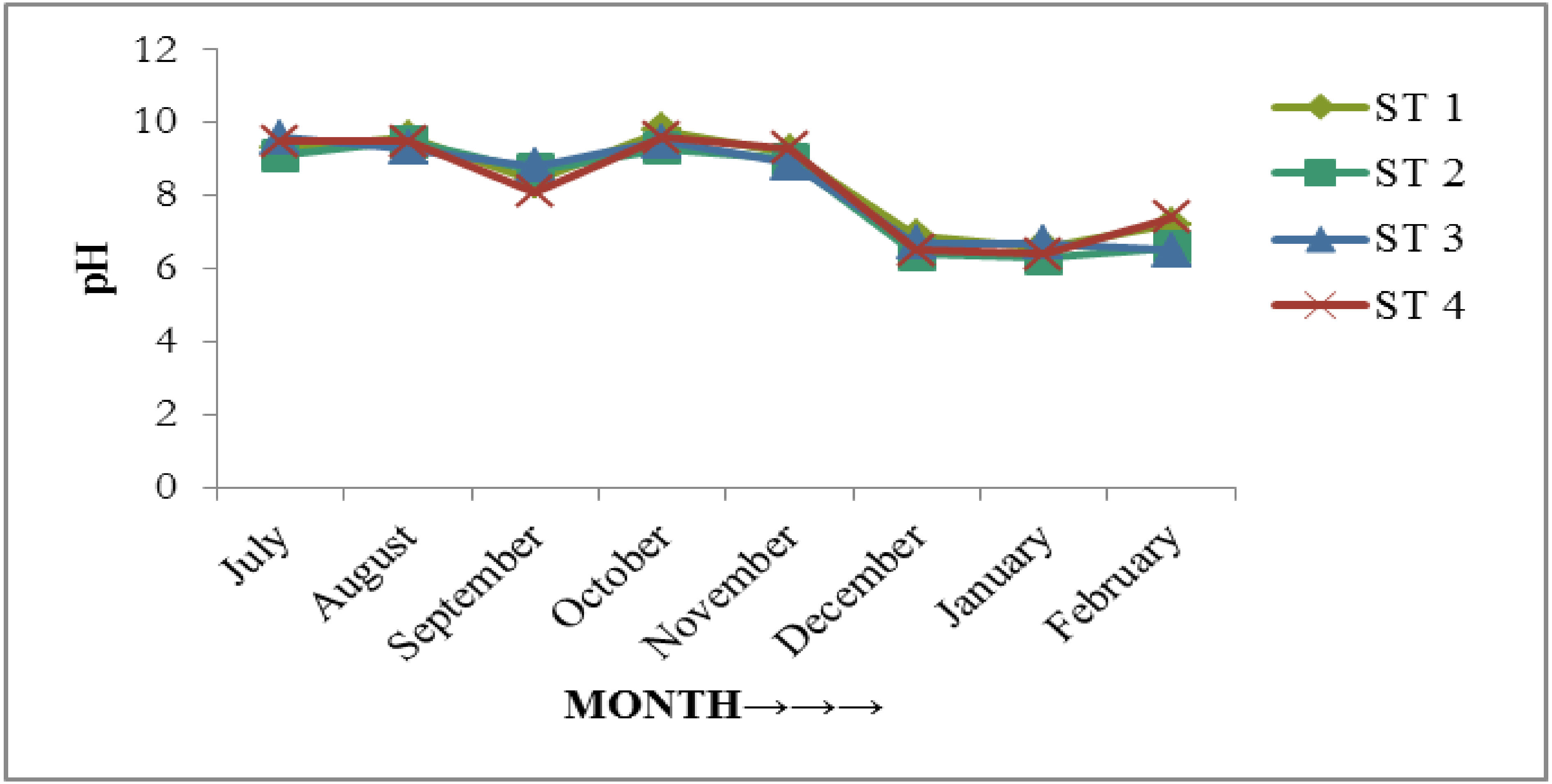

Figure 4.1b Spatio-temporal variations in the pH of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

4.1.2.3 Electrical conductivity (EC)

Electrical conductivity did not show any significant difference (P>0.05) among the Stations sampled. All the stations recorded slight high values of conductivity, especially in the wet seasons of October (Figure 4.1c). The lowest value of concentration was recorded in the month of August for Station 2. The overall highest (105±5.28 µs/cm) in station 4 and lowest (96.4±3.92 µs/cm) values of conductivity was recorded in Station 2 respectively. There was a gradual increase in the conductivity levels in all the Stations from November to February after that there was a drop in the conductivity in the month of August

4.1.2.4 Total dissolved solids (TDS)

Total dissolved solids did not show any significant difference (P>0.05) among the sampled stations. The values ranged between 96.4±3.92 mg/L and 105±5.28 mg/L for Stations 2 and 4 respectively (Figure 4.1d). The lowest value was recorded in the month of August whereas the highest value was obtained during the month of September. There were fluctuations in all the TDS levels of all the stations.

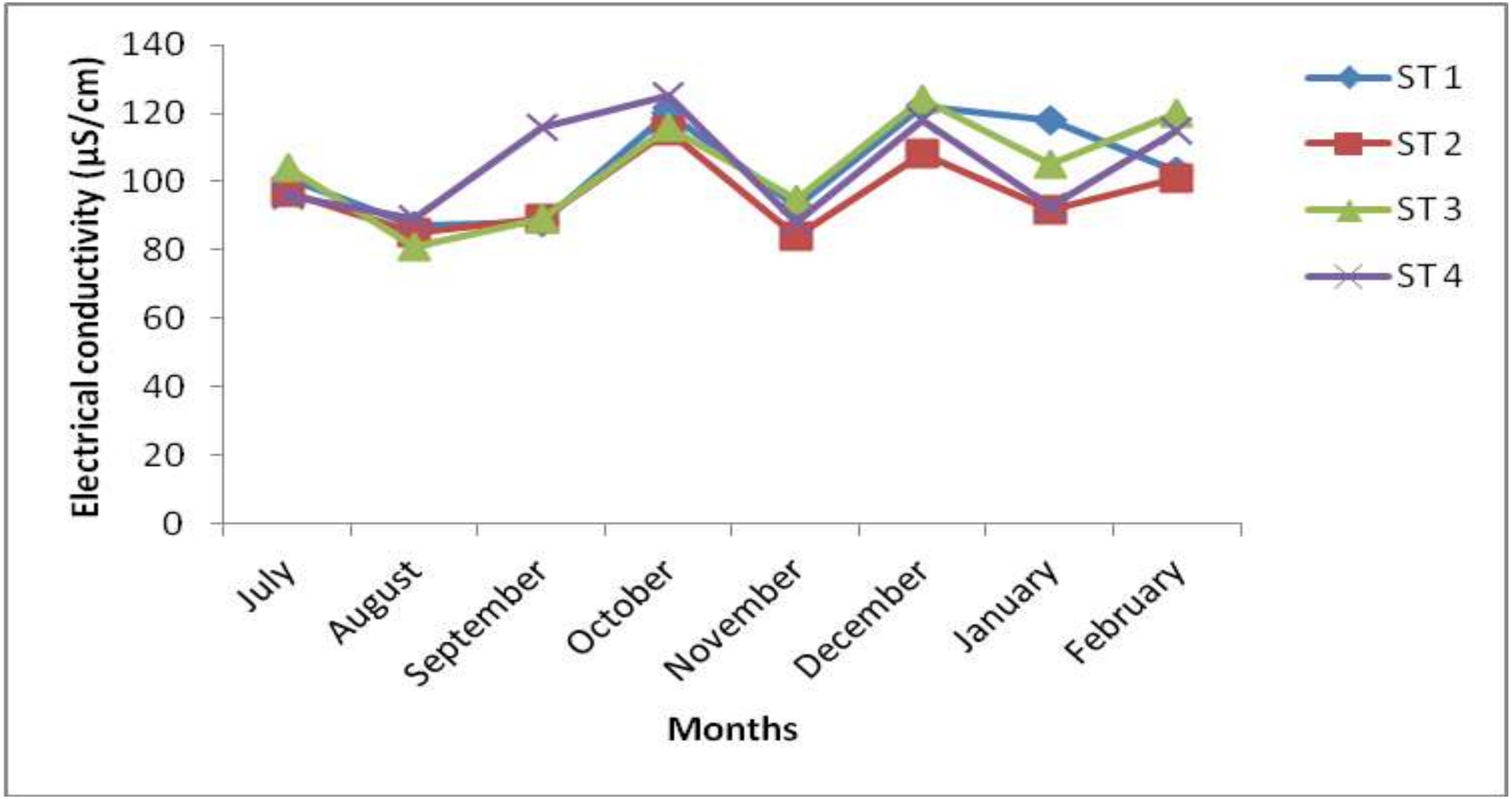

Figure 4.1c Spatio-temporal variations in the electrical conductivity of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

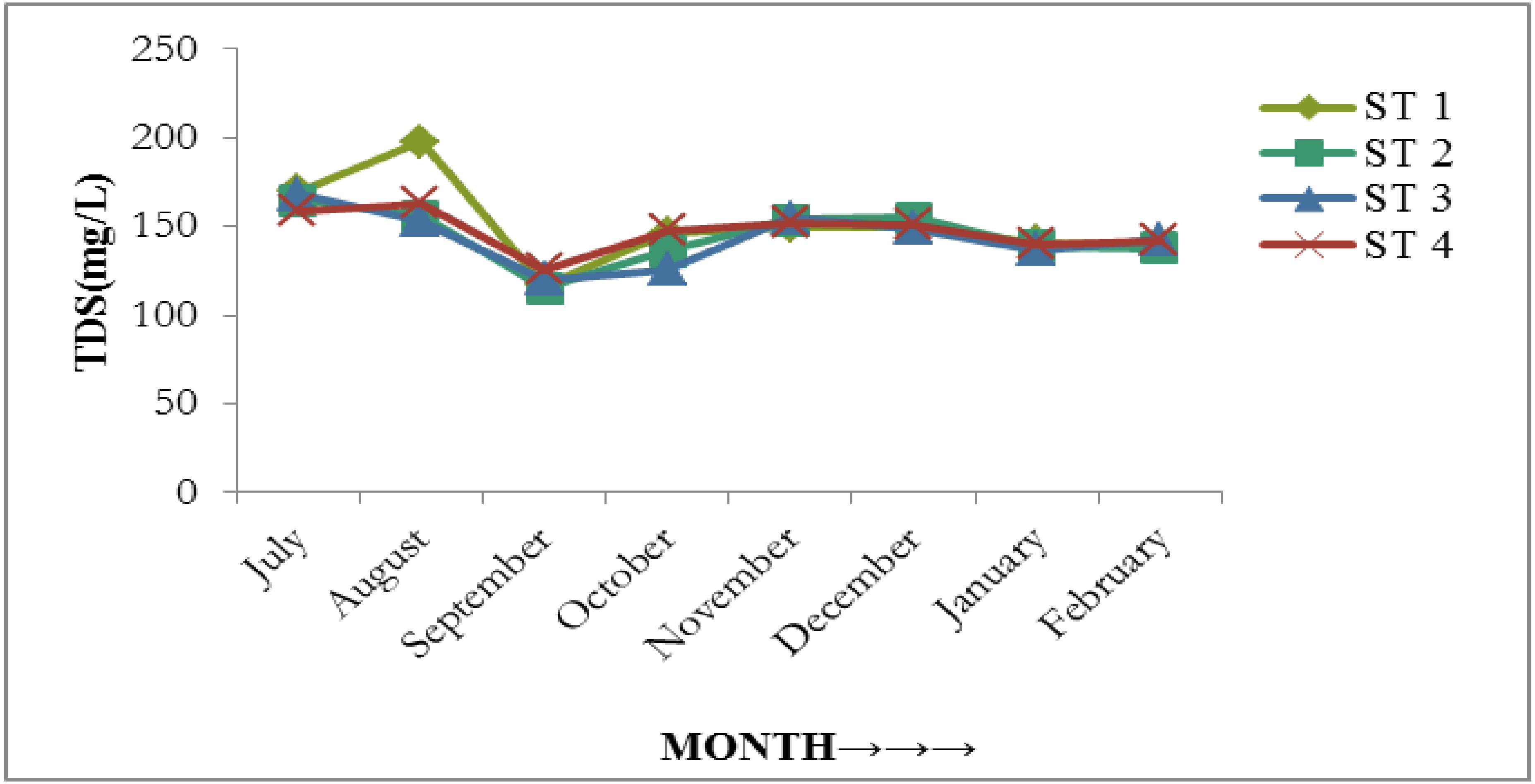

Figure 4.1d Spatio-temporal variations in the Total Dissolved Solids (TDS) of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

4.1.2.5 Alkalinity

The monthly Alkalinity (mg/L) values varied among the sampling Stations (Figure 4.1e). The Alkalinity (mg/L) mean value ranged from 16.00 mg/L to 34.00 mg/L. The overall highest value of nitrate 34.00 mg/L was recorded in August at Station 4 while the overall lowest value of nitrate 16.00 mg/L was observed in August at station 4 also. There was no steady trend of increase or decrease in alkalinity levels in all the stations, rather all sampled stations were characterized by series of fluctuations. There was significant difference ($p>0.05$) in the values recorded among the Stations, according to repeated measures ANOVA.

4.1.2.6 Hardness

Repeated ANOVA for hardness did not show any significant difference ($P>0.05$) among the Stations sampled. The four stations were parameterized for series of monthly variations (Figure 1f). Station 2, with hardness of 52.00 mg/L, in the month of September, showed the highest value while Station 4, with hardness of 20.00 mg/L, in the month of August, was observed to have the lowest value. Station 2 showed the highest mean value (35.75±3.06 mg/L) while Station 4 showed the lowest mean value (33.38 ± 3.49 mg/L).

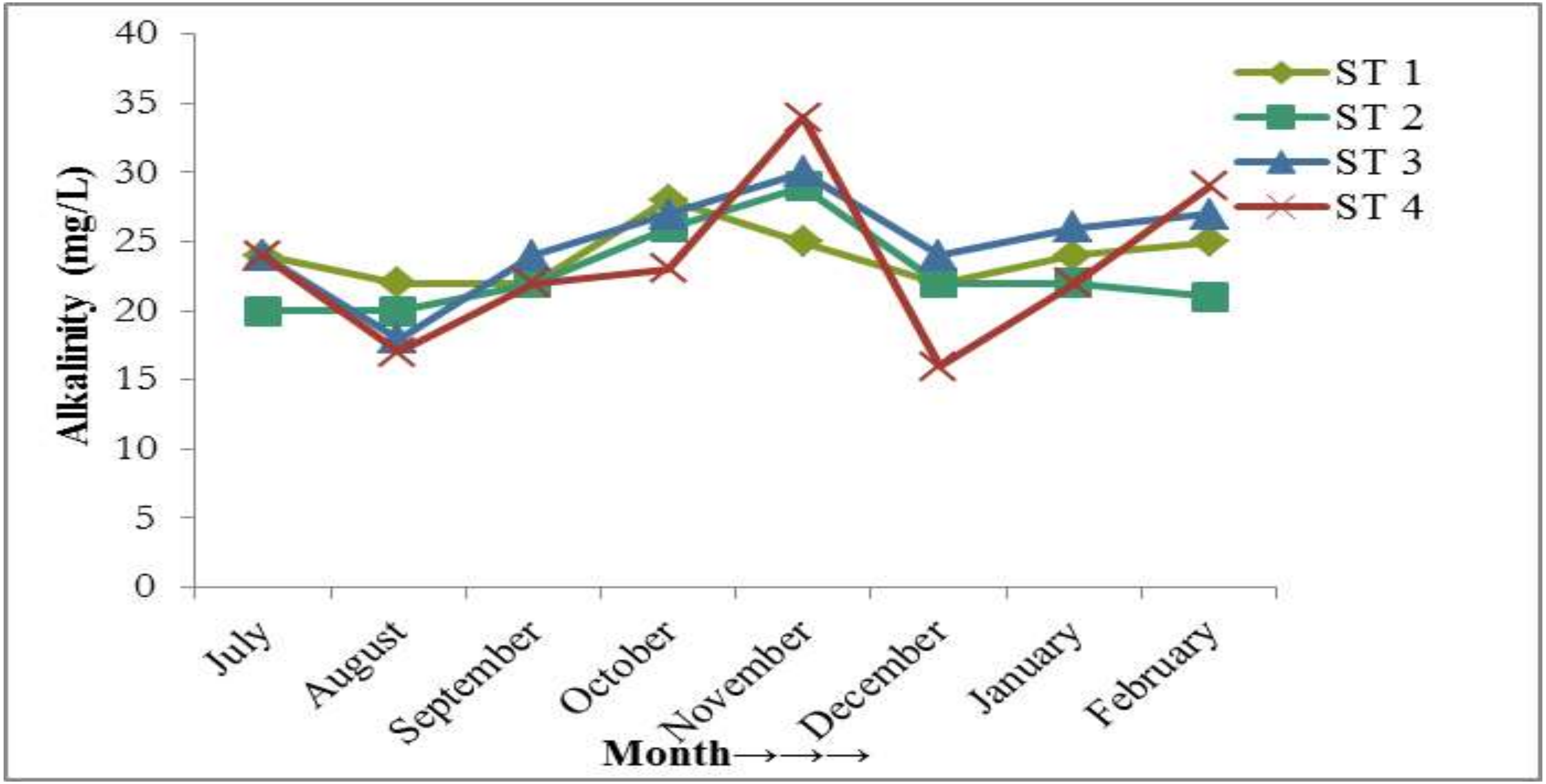

Figure 4.1e Monthly variations in the Alkalinity of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019)

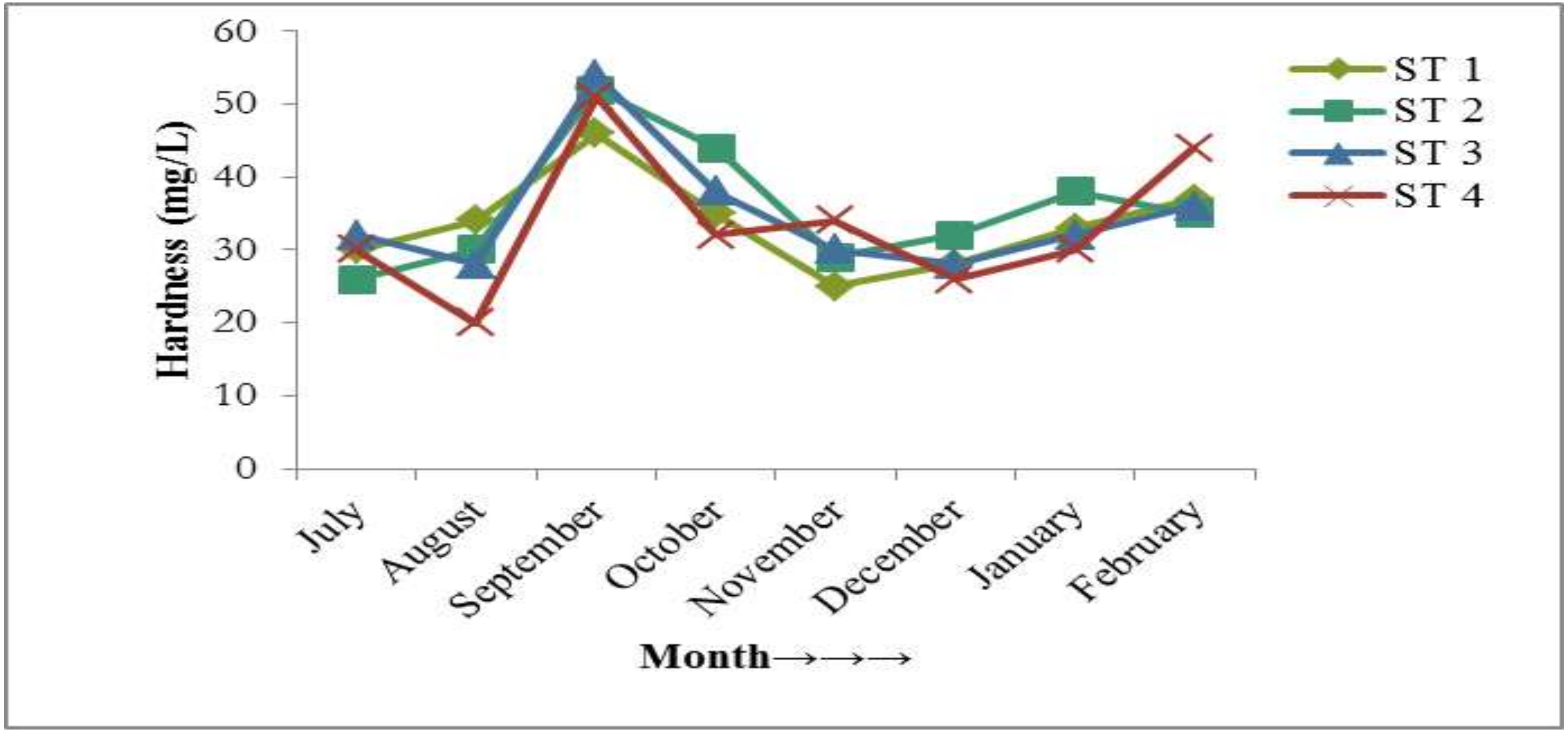

Figure 4.1f Spatio-temporal variations in the Hardness of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019)

4.1.1.7 Dissolved oxygen (DO)

The monthly DO varied among the stations. Stations 1 and 2 revealed higher DO values than other stations (Figure 4.1g). The DO values ranged from 2.40 mg/L (station 3 in the month of July to 5.20 mg/l (station 1 in the month of February). There was a slight fluctuation throughout the months in all the stations sampled. Station 1 showed the highest mean value (4.00 ± 0.33 mg/L) while station 3 showed the lowest mean value (3.6 ± 0.29 mg/L). There was significant difference ($P<0.05$) in the values recorded among the stations.

4.1.1.8 Biological oxygen demand (BOD)

The variation in BOD among the stations showed in Figure 4.1h. The overall BOD values ranged from 1.90 mg/L (station 3) to 4.40 mg/l (stations 1). The highest value of BOD (4.40 mg/L) in was recorded in February in station 1 as a result of low dissolved oxygen value. Meanwhile, the overall lowest value of BOD (1.90 mg/L) stations was observed in July in station 1. There was significant difference ($P<0.05$) in the values recorded among the stations.

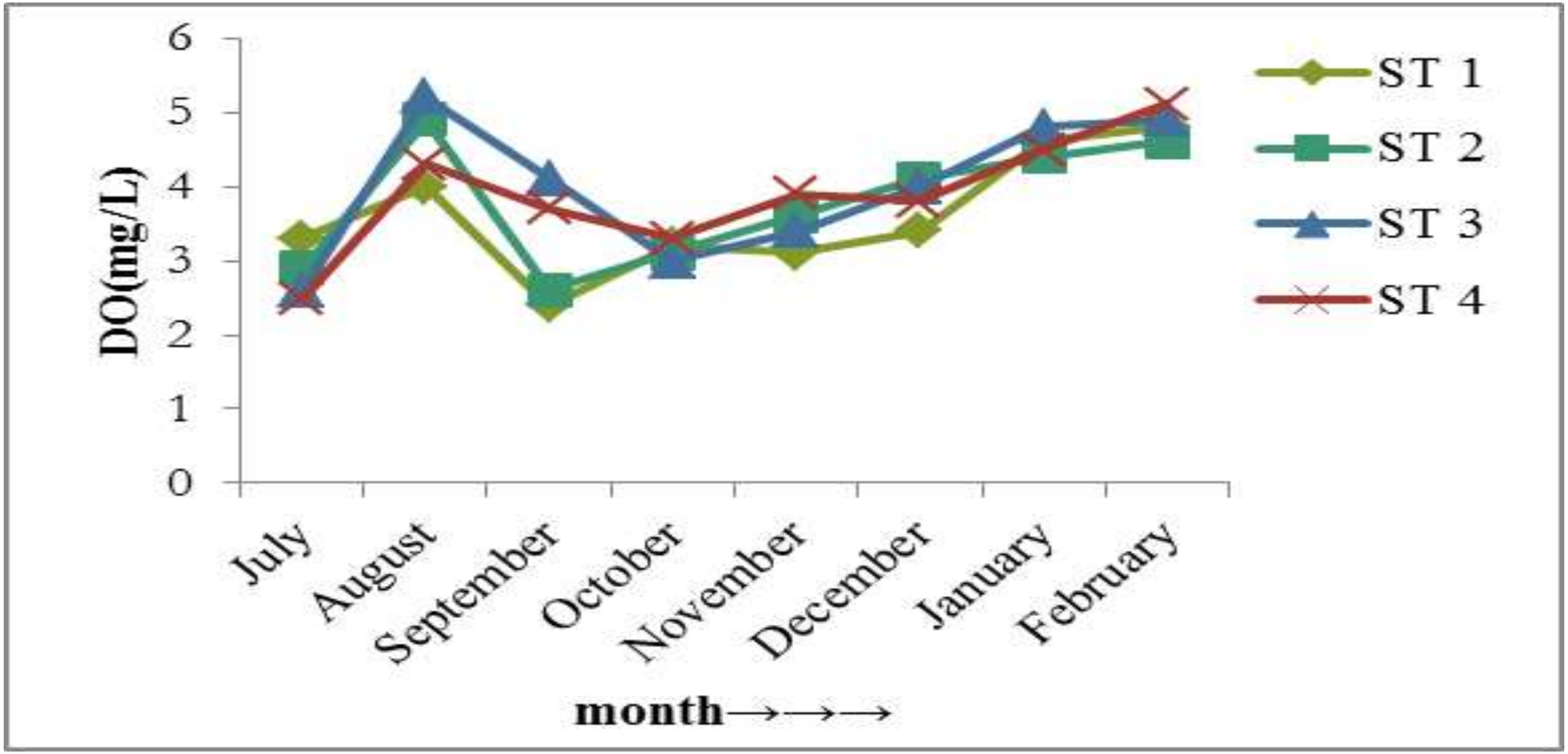

Figure 4.1g Spatio-temporal variations in the Dissolved Oxygen (DO) of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

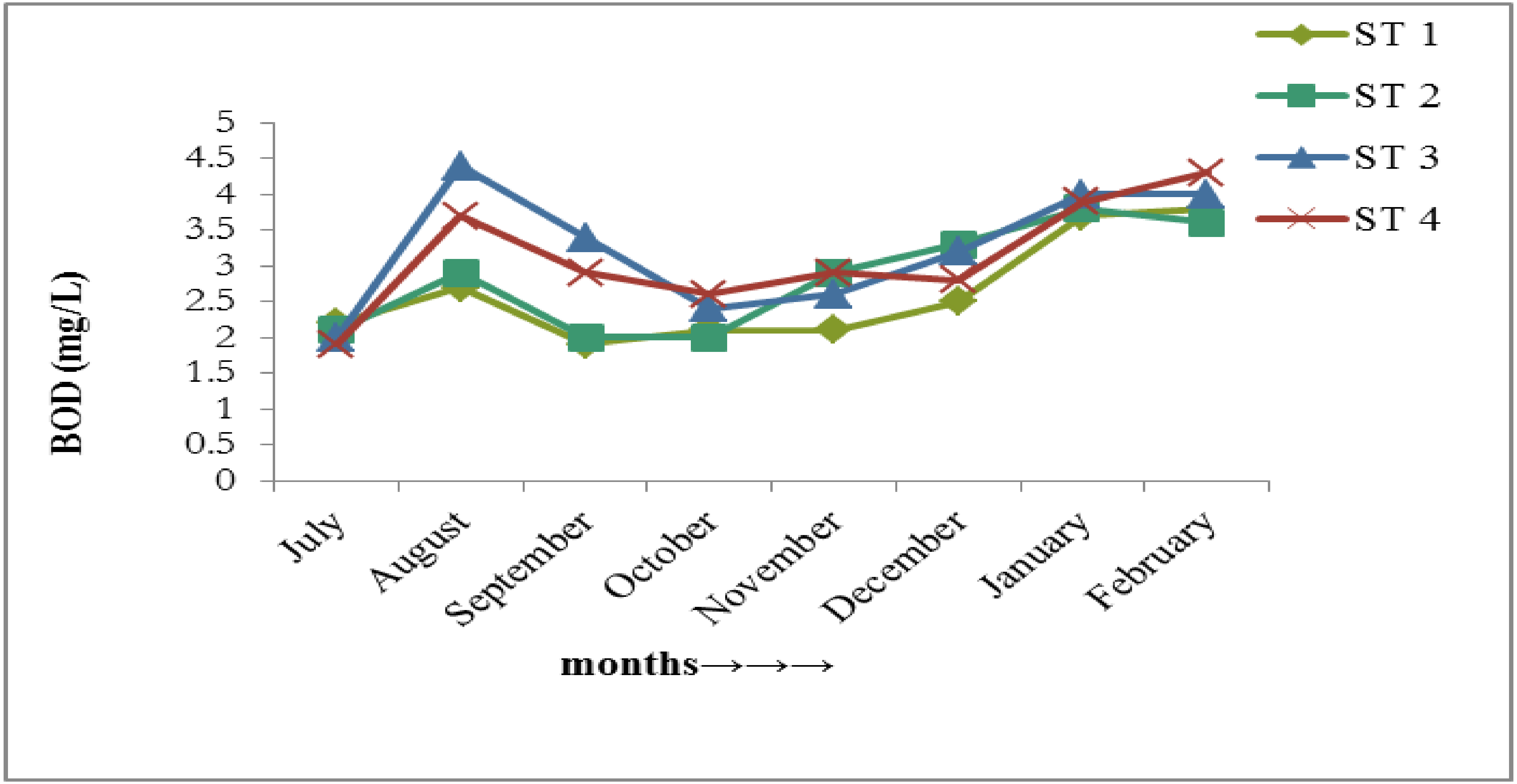

Figure 4.1h Spatio-temporal variations in the BOD of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019)

4.1.1.9 Nitrate (mg/L)

The monthly nitrate values varied among the Stations (Figure 4.1i). The nitrate value ranged from 3.20 mg/l to 7.50 mg/L. The overall highest value of nitrate (7.50 mg/L) was recorded in February at station 4 while the overall lowest value of nitrate (3.20 mg/l) was observed in July at station 1. There was no steady rise or drop in nitrate levels in all the stations. However, it showed a series of fluctuations. Station 4 also showed the highest mean value (5.24±0.44 mg/L) while Station 1 showed the lowest mean value (4.48 ± 0.57 mg/L). There was significant difference ($p<0.05$) in the values recorded among the Stations, as tested by ANOVA.

4.1.1.10 Phosphate (mg/L)

There was no significant difference ($P>0.05$) in the values recorded among the Stations. The Post-hoc tests conducted using Durcan Multiple Range Test showed that all sampling stations were similar to each other. The lowest ranged value for phosphate (0.35 mg/L) was recorded in stations 2 while station 2 also had the highest (2.5 mg/L) value (Figure 4.1j). The lowest and highest values were recorded in the months of December and October, respectively. There was a steady fluctuation in phosphate levels in all the stations and in the months. Station 3 showed the highest mean value (1.36 ± 1.10 mg/L) while station 1 showed the lowest mean value (0.89 ± 0.14 mg/L)

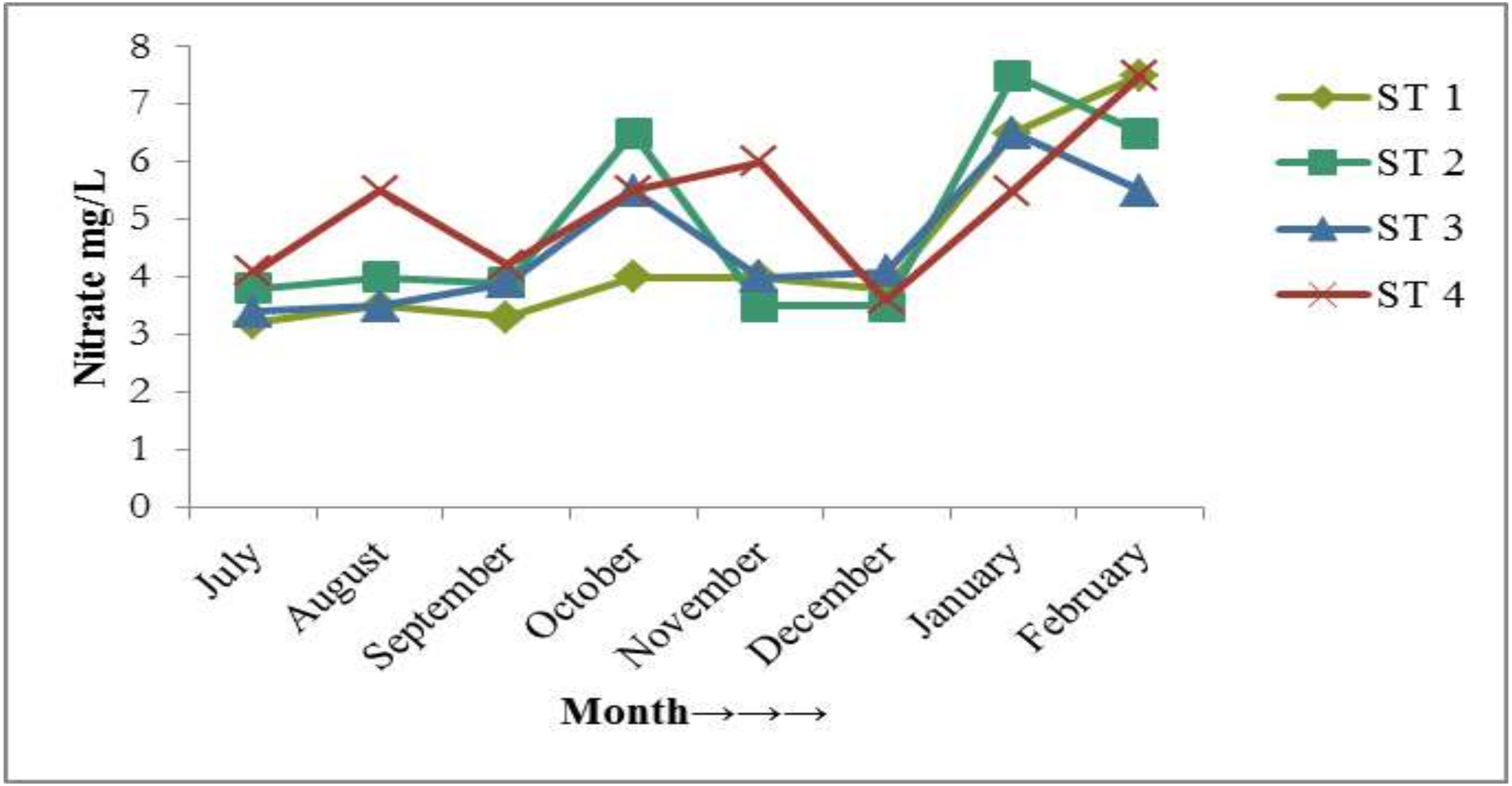

Figure 4.1i Spatio-temporal variations in the nitrate (NO_3) of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019)

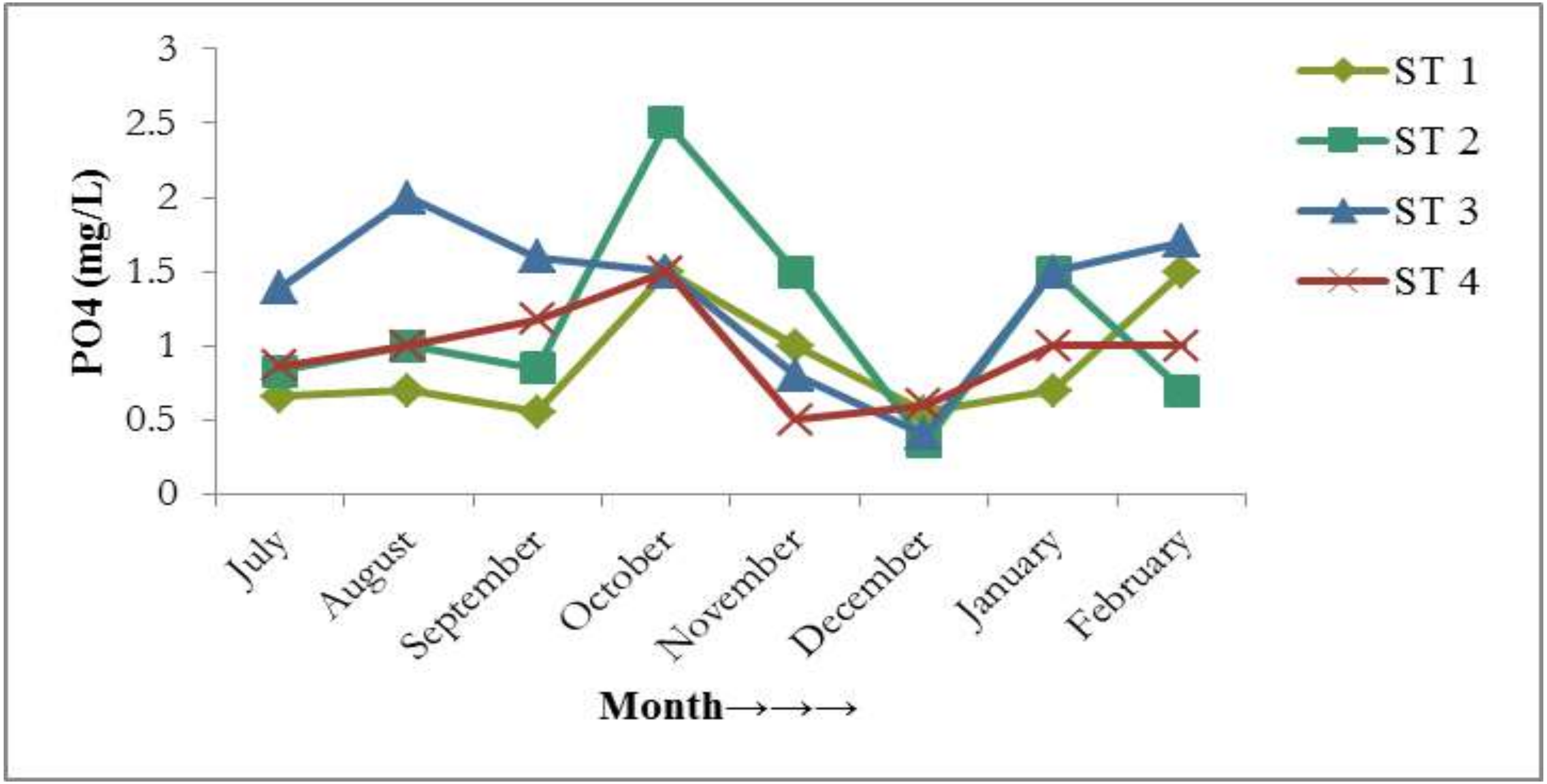

Figure 4.1j Spatio-temporal variations in the phosphate (PO_4) of Tungan Kawo Reservoir, Kontagora (July 2018-December 2019).

4.1.3 Concentration of heavy metals in surface water

The result of lead, copper, manganese, iron and chromium in surface water measured from four different stations of Tungan Kawo Reservoir, is presented in Table 4.2. The result showed that lead was not detected in all the sampling stations. The highest mean value of copper (0.04 mg/L) was recorded at station 4 while the least concentration of Cu^{+} mean value (0.03 mg/L) was observed in station 1, 2 and 3 respectively. Copper was not significantly different (P>0.05) between stations. The lowest mean value of manganese (0.07 mg/L) was recorded from station 1 while the highest Mn mean value of (0.09 mg/L) was obtained in station 2. There was no any significant different (P>0.05) in Mn between the sampling stations. The lowest iron (Fe) mean value of 5.02 mg/l was recorded in station 1 while the highest Iron mean value of 6.18 mg/L was observed in station 4. Iron was not significantly different (P>0.05) between stations. The highest mean value of chromium (1.45mg/L) was recorded in station 4 while the least mean value of Cr (1.03mg/L) was recorded in station 3. However, chromium shows a slight significant difference (P<0.05) between the sample stations.

Table 4.2: Heavy metals concentration (mg/L) in Surface water from Tunga Kawo Reservoir, Kontagora from July 2018 to February 2019

Heavy metals	Station 1	Station 2	Station 3	Station 4	NIS**	WHO***
Pb	0.00±0.00[a*]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.01	0.1
Cu	0.03±0.01[a]	0.03±0.01[a]	0.03±0.01[a]	0.04±0.11[a]	1.0	1.3
Mn	0.07±0.01[a]	0.09±0.01[b]	0.08±0.00[a]	0.08±0.00[a]	0.2	0.4
Fe	5.02±0.42[b]	5.04±0.21[b]	5.11±0.19[b]	6.18±0.43[b]	0.3	1.3
Cr	1.34±0.22[c]	1.10±0.08[b]	1.03±0.19[b]	1.45±0.04[c]	0.05	0.15

*Values followed by the same superscripts alphabets in the row are not significantly different at (p > 0.05) tested by DMRT *** World Health Organisation, (2011), **Nigerian Industrial Standard, (2015).

4.1.4 Concentration of heavy metals in sediment

The concentration of lead, copper, manganese, iron, and chromium in sediment measured from four different Stations of Tungan Kawo Reservoir is presented in Table 4.3. The result obtained showed that lead (Pb) was detected with a mean value of (0.01 ± 0.002) mg/kg within three sampling stations. Pb was not significantly different ($P>0.05$) between Station. The lowest mean value of copper (0.79 mg/kg) was recorded in Stations 1 while the largest mean value of Cu^{+} (0.99 ± 0.11 mg/kg) was recorded in Stations 4. Copper was not significantly different ($P>0.05$) between stations. The lowest Manganese mean value of 1.05 mg/kg was recorded in station 1 while the highest manganese mean value of 1.36 mg/kg was reported from Stations 3. Manganese was not significantly different ($P>0.05$) between Stations 1 and 2 also 3 and 4. However, manganese showed a significant different ($P<0.05$) between Stations 1 and 3; also, in station 2 and 4 respectively. The highest Iron mean value of 7.08 mg/kg was recorded in Stations 3 while the lowest Iron mean value of 5.08 mg/kg was reported from Stations 2. Iron was not significantly different ($P>0.05$) between Stations 1 and 2 also 3 and 4. Similarly, Iron showed a significant different ($P<0.05$) between Stations 1 and 3; also, in station 2 and 4 respectively. The highest mean value of Chromium (1.54 mg/kg) was recorded in station 1 while the least mean value of Cr (1.06 mg/kg) was recorded in station 3. However, chromium revealed a slight significant difference ($P<0.05$) between the sample stations.

Table 4.3 Heavy metals concentration in (mg/kg) in Sediment from Tunga Kawo Reservoir, Kontagora from July 2018 to February 2019

Heavy metals	Station 1	Station 2	Station 3	Station 4	NIS**	WHO***
Lead	$0.01\pm0.00^{a*}$	0.01 ± 0.00^{a}	0.00 ± 0.00^{a}	0.01 ± 0.00^{a}	0.01	0.10
Copper	0.79 ± 0.03^{b}	0.82 ± 0.11^{b}	0.88 ± 0.08^{b}	0.99 ± 0.11^{b}	1.0	1.30
Manganese	1.05 ± 0.10^{bc}	1.15 ± 0.16^{bc}	1.36 ± 0.15^{b}	1.23 ± 0.10^{b}	0.2	0.40
Iron	5.52 ± 0.42^{c}	5.08 ± 0.21^{c}	7.08 ± 0.43^{b}	5.55 ± 0.19^{b}	0.3	1.30
Chromium	1.54 ± 0.22^{d}	1.33 ± 0.08^{d}	1.40 ± 0.04^{c}	1.06 ± 0.19^{c}	0.05	0.15

*Values followed by the same superscripts alphabets in the row are not significantly different at (p>0.05) tested by DMRT ***World Health Organisation, (2011), **Nigerian Industrial Standard, (2015).

4.1.4 Concentration of heavy metals in fish species.

The concentrations of lead, copper, manganese, iron and chromium in dominant fishes measured from four different station of Tungan Kawo Reservoir were presented in Table 4.4. The result obtained for lead showed a gradual increase in the concentration of lead ions from the three selected fishes with a mean value of 0.01 to 0.02 mg/kg. Lead concentrations were not significantly different (P>0.05) between the species fish. The lowest copper concentration (0.10 mg/kg) was recorded in *Coptidon zillii* while the highest value of 0.13 mg/kg was recorded in *Oreochromis niloticus*. Copper was significantly different (P>0.05) between the species of fishes. The lowest manganese mean value of 0.19 mg/kg was recorded in *Oreochromis niloticus* while the highest Manganese mean value of 0.22 mg/kg was observed in *Coptidon zillii* and *Synodontis clarias*. Manganese was not significantly different (P>0.05) between the fishes. The highest iron means value of 0.64 mg/kg was recorded in *Synodontis clarias* while the lowest iron mean value of 0.54 mg/kg was reported in *Coptidon zillii*. Iron was not significantly different (P>0.05) between the fish's tissues. Chromium was detected in the fish tissue from the lake. It fluctuated between 0.15 to 0.22 mg/kg. The lowest value of 0.15 mg/kg was observed *Oreochromis niloticus*, while the highest value of 0.22 mg/kg was recorded in *Synodontis clarias*. Chromium was not significantly different (P>0.05) between the selected fishes.

Table 4.4. Heavy metals concentration in (mg/kg) of dominant fish species from Tungan Kawo Reservoir, Kontagora from July 2018 to February 2019

Fish species	Lead	Copper	Manganese	Iron	Chromium
F1	0.01±0.013[a*]	0.13±0.015[b]	0.19±0.024[a]	0.62±0.044[a]	0.15±0.019[a]
F2	0.01±0.013[a]	0.10±0.007[ab]	0.22±0.021[a]	0.54±0.031[a]	0.19±0.153[a]
F3	0.02±0.018[a]	0.08±0.012[a]	0.22±0.018[a]	0.64±0.072[a]	0.22±0.065[a]
WHO**	0.10	1.30	0.40	1-3	0.05-0.15
FAO***	0.50	2.00	5.00	1.00	0.05

*Values followed by the same superscripts alphabets in the column are not significantly different at (p>0.05) tested by DMRT, **F1**- *Oreochromis niloticus*., **F2**- *Coptidon zillii*., **F3**- *Synodontis clarias*., * World Health Organisation (2011), ** Food and Agriculture Organization (2015).

4.1.5 The ecological risk of heavy metals in the sediment

The ecological risk of heavy metals in the sediment of the study was presented in Table 4.5. The mean concentrations of lead, copper, manganese, iron and chromium were 0.25, 4.35, 1.20, 5.81 and 2.67 mg/kg respectively. The highest concentration ecological risk was found in Fe with mean value (5.81 mg/kg) while the least risk was found to be Pb with the mean value (0.25 mg/kg). However, station 3 has the highest risk concentration (7.08 mg/kg) of iron whereas station 1 recorded the least concentration 0.00 mg/kg (lead) of risk in the sediment accumulation. The extensive ecological Risk Index (RI) of the 4 sampling stations increased from 13.14 to 16.29 as shown in the Table, which also indicated that each sampling stations has a low risk accumulation.

Table 4.5: Single (Er) and comprehensive (RI) ecological risk factors of heavy metals in the sediment from July 2018 to February 2019

STATION	Lead	Copper	Manganese	Iron	Chromium	RI
Station 1	0.00	3.95	1.05	5.52	3.08	14.32
Station 2	0.15	4.10	1.15	5.08	2.66	13.14
Station 3	0.65	4.40	1.36	7.08	2.80	16.29
Station 4	0.2	4.95	1.23	5.55	2.12	14.05
Calculated mean ecological Index	0.25	4.35	1.20	5.81	2.67	-

Keys: Station 1=Kwata Mustafa; Station 2=Baban Kwata; Station 3= Kwata Abdullahi; Station 4=Gonna Hajiya

4.2 Discussion

4.2.1 Physico-chemical Analysis of Water

The uniqueness of any aquatic environment is controlled by its physical, chemical and biological components, which directly or indirectly influence its productivity (Marshall, 2007; Edokpay *et al*., 2015). The findings of this work revealed that the water in Tungan Kawo Reservoir is alkaline in nature due to landscape runoff in the area tends to pick up toxic chemicals like calcium carbonate into the reservoir. The pH range of 6.50 to 9.55 obtained from this study fall outside the normal limits. The reservoir is surrounded with rocks such as limestone the runoff pickup chemicals which rises the pH. Similarly, the work agrees with the finding of Auta *et al*. (2016) in River Gurara at Izom, Niger state, Nigeria documented a higher mean range (6.8 –9.7) during the study period. Thus, the pH range obtained in this study is above the acceptable level of 6.5 to 8.5 for the recommended levels for drinking water (WHO, 2011; NIS, 2015). The temperatures documented in this present study were within the optimal range which influences the quality of aquatic life. This report is similar to the work of Keke *et al*. (2015) recorded (27 – 32.4 ^{0}C) and Masese *et al*. (2009) who reported that the mean air and surface water temperatures obtained are typical of African tropical rivers and aquatic organism (fish) grow best at 25 to and 32 ^{0}C. In the same view, the data obtained followed the work of Okunlola *et al.* (2014) and Oyakhilome *et al*. (2012) who documented a temperature mean value (27.53 and 31.65 ^{0}C) within the optimal range revealed that aquatic life survives rapidly. However, the finding contradicted the work of Adama (2016) in Kainji lake reported a higher mean of 36.23 ± 0.8 ^{0}C of water temperature. In view of the fact that changes in geographical characterizations might cause the high increase of water temperature. DO levels of 2.82 to 4.85 mg/L in this study indicated the reservoir experience inflow of fertilizers and excessive growth of plants around the shore areas which tends to reduce the oxygen level. However, the DO documented in these studies was within the permissible limits (10 mg/L) of drinking water (NESREA, 2007). The work is in agreement with Ayoade *et al*. (2007) and Abubakar *et al.* (2015) who worked on Dadin-kowa reservoir recorded a DO (2.73 to 4.92 mg/L) which indicated a thriving basis for aquatic organisms.

The observed mean range values of (BOD) were within permissible level (2.05 mg/L and 3.93mg/L) for drinking water and fish production. The low values of BOD in this current study indicate a low volume of decomposed organic matter at high temperatures which are difficult to breakdown. This work was similar to the report of Lewis (2002) and Idowu *et al*. (2013) from Ado Ekiti reservoir who documented that tropical water with higher temperature poses poor ability to hold oxygen compared to water with lower temperature as well as high rates of microbial metabolism at higher temperature. However, this study contradicts the findings of Keke *et al.* (2015) work in downstream Kaduna River at Zungeru, recorded a higher BOD of 1.00 – 5.00 mg/L which indicated a high content of easily degradable and organic matters which find their way into the river.

The electrical conductivity in this study showed gradual increase due to runoffs from farmland, bedrocks runoff which enter into the reservoir. Similarly, this is in agreement with the finding of Idowu *et al*. (2013) and Abubakar *et al.* (2015) who recorded a mean value of (432 ± 8.64 µS/cm) respectively due to constant discharge into the reservoir.

The recorded the mean value of the total alkalinity in this study favoured well with the range given for lakes and reservoir by FEPA (1991) and NESREA (2007) thus, this implies an indicator of a good quality of the reservoir water. This agrees with the work of Suguna (1995) who reported that total alkalinity above 40 mg/L suggest high productivity of a reservoir.

The water hardness in this study was low and this could be as a result of low water levels and the concentration of ions. However, this report contradicted the work of Kolo and Oladimeji (2004) who recorded (41.6 and 54.4 mg/L) in they work in Shiroro Lake and Ufodike *et al*. (2001) for Dokowa Mine Lake recorded (422.67 and 23.79 mg/L) a higher mean value during the dry season as compared to the wet season. Total dissolve solids (TDS) values in this study to be in the range of 117 to 198 ppm this implied that dissolved salts coupled with uptake of ions as shown to lower the TDS values in the dry season. Similarly, Uddin *et al*. (2014) recorded the mean value of 129 to 131 ppm in dry season and 106 to 111 ppm in wet season in Jamuna River, in Bangladesh since runoff from roads that have been salted during the wet season settled in the river.

The high concentration of nitrate and phosphate documented in this study indicated evidence of leaching and run-off of fertilizers from nearby farmlands, washing with detergents and soaps into the lake could have also caused the high concentration of phosphate ions. This process may lead to eutrophication of the lake with seasonal algal bloom and changes the uniqueness of water properties. This was in line with the findings of Mustapha *et al.* (2008) in Oyun Reservoir who reported that human activities are the chief leading factor of any lake excess enrichment. Similarly, also agreed with the findings of Akponine and Ugwumba (2014) works on Ibuya River in old National Park, Sepeteri, Oyo State, Nigeria. The overall mean values of phosphates recorded were generally high when compared to the standard of 3.2 to 630 mg/L. However, this study, recorded a slightly higher mean values which were within acceptable limits recommended by FEPA 1991 and NESREA limit (2007) respectively. However, this contradicted the work documented by Yakubu *et al*, (2014) who work on Agaie/Lapai dam in Niger State, Nigeria; observed low nitrates level which might be attributed to high photosynthetic activities by aquatic plants since the vegetation of the study sites vegetation reflected that of savannah zone, dominated by grass but with scattered trees.

4.2.2 Concentration of heavy metals in surface water

The lead was not detected in all the sampling points. This is due to absence of direct waste emission from industrial source during mining. This report conformed to the work of Keke *et al*. (2015) in Kaduna River at Zungeru, Nigeria, whose finding revealed the absence of lead. However, this disagreed with the result of Amoo *et al.* (2005) who recorded a higher mean value of Pb^{+} in Lake Kainji, Nigeria. The implication was due to mining high treatment plant area the area. The mean concentration of copper in this study was very low in all the sampled station. Lower concentrations of copper were reported in water of Lake Manzala, Egypt (Bahnasawy *et al.,* 2011). These might be attributed to the different anthropogenic activities that supply the water bodies. The mean concentration of Mn in this present study clearly revealed extremely high concentration of Mn^{+} in all the sample stations than the 0.02 mg/L recommended limit for Mn^{+} in drinking water reported by NESREA 2007). Therefore, the implication is that Tunga Kawo Reservoir is being contaminated by runoffs from uplands thereby making the water unfit for human consumption as this would result to Mn related health. The high concentrations of Fe in the surface water in this study might be linked to the fact that the reservoir is dominated by farming activities and other human activities around the lake. Similarly, this study agrees with the work of Yacoub and Gad (2012) who works on River Nile in Upper Egypt observed higher concentration of iron as a result of different anthropogenic activities. This finding also attested to the research work of Keke *et al.* (2015) whose results revealed high concentrations of iron in the sediment and the surface water. The implication is that River Kaduna and its tributaries which are surrounded by industries like petrochemical plants, battery factory. However, the concentration of iron in this study is totally above the values reported for heavy metals concentrations in water by WHO (2011).

In this study, the concentrations of Chromium were high due to inflow of nearby wastes and runoff of wastes from farmland. This report agreed with the work of Sanyal *et al*., (2015) who obtained high concentration of chromium in the sediments of sections of the river Churni receiving effluents from handloom textile factories. However, the values of chromium fell outside the limits of FEPA (1991) and NESREA (2007) respectively.

4.2.3 Concentration of heavy metals in sediment

In this study, higher mean concentration was observed with manganese, iron and chromium due to constant domestic waste, runoff from agricultural lands which enter the reservoir. A similar observation was reported by Fernandes *et al*. (2007) in Portugal Lagoon obtained high concentration of manganese, iron and chromium due to constant pollutant into reservoir. This finding was compatible with the result obtained in Dandaru Lake, recorded higher mean value which exceeded the probable effect level of the guidelines (Ayoade *et al*., 2018). The values recorded for lead and copper in this study did not exceed permissible limit of FEPA (1991) and NESREA (2007) in all the stations. It follows the work of Abiona *et al*., (2012) who obtained lower concentration of copper, zinc in Dandaru Reservoir in Ibadan, Nigeria. A similar observation was reported by Adekanmbi *et al*., (2015) who recorded a high concentration of manganese, iron and chromium and iron, lead and zinc. However, this study, recorded mean values which were below the probable effect level of sediment quality guidelines FEPA (1991) and NESREA (2007) respectively.

4.2.4 Concentration of heavy metals in Fish species

In this study, high concentration of lead was recorded in *Synodontis clarias* when compared to *Oreochromis niloticus* and *Coptidon zillii*, the implication could be attributed to the fact that *Synodontis clarias* is typical bottom dwellers while *Oreochromis niloticus* and *Coptidon zillii* are mostly found at the surface (pelagic) area of lake. This was line with the report of

Okoye *et al*. (1991) who noted that bottom feeders are known to pick up particulate matter more than the surface feeders. Similar observation was reported by Adefemi *et al.* (2004) on two species of fish, *Oreochromis niloticus and Clarias gariepinus* sampled from Ureje dam in Ado Ekiti, Ekiti State. Moreover, *Oreochromis niloticus* and *Coptidon zillii* tend to accumulate copper in flesh as observed by Akan *et al*. (2012) from River Benue, Nigeria. According to the analysis of this current study the results of heavy metal concentrations in fish tissue showed that Fe, Cr and Mn had the highest in *Synodontis clarias* and *Oreochromis niloticus* had the lowest concentrations. Similar results were reported by Öztürk *et al.*, (2009) from Avsar Dam Lake recorded a higher concentration of Fe, Mn and Pb accumulation in the muscle of *Cyprinus carpio* samples. This finding affirmed with the report of Mshana, (2015) who examined the concentrations of heavy metals in *C. gariepinus*, *O. esculentus* and *O. rukwaensis* samples in Lake Luika and Songwe River in Tanzania. Lead (Pb) mean of 0.55±0.018 µg/g during dry season in C. *gariepinus* and mean of 0.17±0.003 µg/g. during the rainy season in *O. esculentus* and *O. rukwaensis* fish sample. The higher levels of lead in Lake Luika and Songwe Rivers indicate that gold mining in the catchment area may contribute to the higher concentration of heavy metals in fish muscles.

This was also in conformity with the work of Oyakhilome *et al.* (2009) on three species of fish, *Clarias gariepinus*, *Clarias anguillaris* and *Oreochromis niloticus* sampled from Owena Multi-Purpose Dam, Ondo State. The result obtained showed *Clarias gariepinus* and *Clarias anguillaris* have more of heavy metals than *Oreochromis niloticus* in spite of their large weight. However, when in excessively high concentration, it might be due to bioactive metals which pose serious threats to normal metabolic processes. Similarly, the report from Oguzie, (2003) who recorded higher concentrations of heavy metals in the water during the wet season due to increased surface runoff and agricultural pollution, especially chemical fertilisers containing Ni and Pb. Heavy rainfall leads to farm draining. Large amounts of pesticides containing metal compounds are brought to the surface via runoff from the farms to the river and highly contribute to agricultural pollution, especially chemical fertilisers containing Ni and Pb. However, several reports found that mean heavy metal concentrations in fish were higher in the dry season (Idodo-Umeh, 2000; Oguzie, 2003). This is because higher concentrations of metals in fish during the dry season were due to high temperatures, which increased the activity, ventilation, metabolic rate and feeding sessions (Nussey *et al*., 2000). Lead causes renal failure and liver damage in humans. This result was lower compare to the findings of Doherty *et al*. (2010) (0.395 – 0.62 ppm) and Okoye *et al*. (1991) (9 ppm) of lead from some fishes in Lagos Lagoon. Farombi *et al*. (2007) reported 0.73 - 4.12 ppm in *Clarias gariepinus* from Ogun River, which are higher. The reason for this extremity in values is might be due to the addition of civic wastes and industrial effluents as the sewage of the city is directly discharged into the river along with the industries which are also discharging their effluents directly into the river. This was in agreement with the studies of Akan *et al*. (2012) who reported that the level of heavy metals increasing in the rivers due to discharge of industrial effluents and civic pollution of various kinds. This is in turn deteriorating the water quality making it unsuitable for both aquatic and human life.

In this current study, iron was the dominant heavy metal measured during the study. This observation was similar to the observation of Okoye (1991). It has also been observed that iron is the dominant metal in the muscle of *Clarias gariepinus* (Farombi *et al*. 2007). This contradicted with the report of Adaka *et al*., (2017) who observed lower concentration Of Cu, Fe, Pb, Cd and As, respectively in three common edible fish species these included *Tilapia zillii*, *Citharinus citharus* and *Heterotis niloticus*. These study heavy metal concentrations in fish tissue samples were slightly below but Fe and Cr exceeded the limits of NESREA (2007) and FAO (2015) respectively.

4.2.5 The ecological risk of heavy metals in the sediment

In a nutshell, the high concentration of iron and copper in this current study on the sediments could be attributed to the geological environment surrounding the Reservoir, fishing activities and irrigated farming, civic wastes discharge into the Reservoir. This agreed with the report of Dalman *et al*. (2006) who explains that high metal concentrations could be attributed to the augmentation of industrial waste and other human activities such as agriculture and fishing. Their difference in heavy metal concentrations are attributed to the different loading in different locations. Cao *et al.* (2009) concluded that metals in polluted soils have the potential to affect crops, and the effects could be observed directly or indirectly in humans that consume the crops. The tendency of these heavy metals to accumulate in crops planted around the shore area of any water bodies. Similarly, Yisa *et al*. (2012) reported with great affinity that heavy metals deposited on sediments accumulate in crops and being trans-located to the above-ground parts, making them available for transfer up the food chain. In general, this current study, the toxic level in sediments confirmed a low element of potential ecological risk as indicated in Hakanson Index.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The limnological uniqueness of water quality in ecosystems has usually arrows toward evaluating the physico-chemical parameters; but such evaluation alone cannot provide ecological information and integrity of any water bodies. The chemical and physical analysis of sediment and aquatic organisms' tests give information on the status of any water bodies. The result of the physico-chemical parameters showed that water temperature (27-32.4 ^{0}C), conductivity (88 – 125 µS/cm), total dissolved solids (117 – 198 ppm), alkalinity (16 – 34 mg/L), dissolved oxygen (2.6 – 5.2 mg/L), BOD (1.9- 4.4 mg/L), total hardness (20-54 mg/L), nitrate (3.2 – 7.5 mg/L), pH (6.6 – 9.8) all the values recorded were within the guideline limit with the exception of phosphate (0.4-2.0 mg/L) which was above the standard for FEPA (1991) and NESREA (2007) drinking water but can support aquatic life

The iron, chromium, manganese, copper and lead in the surface water clearly indicated that Iron (Fe) concentration (6.18±0.43) mg/L and Cr (1.34±0.22) mg/L, were abundant in the water and were above the guideline limit with the exception of that Mn (0.09±0.01) mg/L, Cu (0.04±0.11) mg/L and Pb (0.00±0.00) mg/L, that were within safety limit for aqua dwellers.

The iron (6.18±0.43 mg/L), Cr (1.54 ± 0.22 mg/L), Mn (1.36 ± 0.15 mg/L) concentrations in the sediments were all above the guideline limits with the exception of Cu^{+} (0.99 ± 0.11 mg/L) and Pb (0.01 ± 0.00 mg/L) that were within safe for bottom dwellers and other planktonic organisms. The results obtained from dominant fishes documented revealed a low heavy metal concentration, Pb (0.02±0.018 mg/kg), Cu (0.13±0.015 mg/kg), Mn (0.22±0.018 mg/kg), Fe (0.64±0.072 mg/kg) and Cr (0.22±0.065 mg/kg) respectively. Pb, Fe, Mn and Cr concentration were high in *Synodontis clarias* when compared to *Oreochromis niloticus* and *Coptidon zillii* whereas *Oreochromis niloticus* accumulate more of copper compared to *Synodontis clarias* and *Coptidon zillii*. The difference noticed in the levels of accumulation in the fish tissues could be attributed to the differences in their physiological roles toward maintaining homeostasis, feeding habits, regulatory ability and behaviour of each fish.

The calculated potential ecological risk indices showed that the lake was not polluted by heavy metals. The value obtained from risk indices for heavy metals were: Pb (0.25), Cu (4.35), Mn (1.20), Fe (5.81) and Cr (2.67) were very low when compared with the background value and target for Hakanson risk index of a standard soil and have not constitute any risk to the ecosystem in general.

5.2 Recommendations

i. Regular monitoring and sensitizing should be encouraged so as to enlighten the community on the side effects of channeling their wastes into the water of Tungan Kawo Reservoir.

ii. Research findings should be carried out on the accumulation of heavy metals in cultivated farm produces which are irrigated and also to check effect on the people feeding on such crops that uses the water of Tungan Kawo Reservoir.

iii. Government should pay attention to improve water quality of Tungan Kawo Reservoir which should also consider heavy metals accumulation into the sediment to it minimum concentration.

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APPENDICES

Appendix A

Location: Map of Tunga Kawo Reservoir Kontagora, Nigeria
Source: Google earth, (2018).

Appendix B

Comprehensive data for physicochemical parameters

	TEMPT	pH	EC	ALK	DO	BOD	HDNESS	TDS	Po4	NO
1	30.4	9.3	101	24	3.3	2.2	30	170	0.66	3.2
1	27.2	9.6	87	22	4	2.7	34	198	0.7	3.5
1	30.2	8.4	88	22	2.4	1.9	46	117	0.55	3.3
1	28.5	9.8	120	28	3.2	2.1	35	146	1.5	4
1	29.9	9.2	93	25	3.1	2.1	25	149.8	1	4
1	32.1	6.9	122	22	3.4	2.5	28	150	0.55	3.8
1	29.1	6.6	118	24	4.6	3.7	33	141	0.7	6.5
1	30.2	7.2	103	25	4.8	3.8	37	140	1.5	7.5
2	29	9.1	97	20	2.9	2.1	26	165	0.83	3.8
2	28	9.5	85	20	4.9	2.9	30	156	1	4
2	31	8.7	89	22	2.6	2	52	115	0.85	3.9
2	31.8	9.3	115	26	3.1	2	44	136	2.5	6.5
2	30.3	9	84	29	3.6	2.9	29	153.8	1.5	3.5
2	31.4	6.4	108	22	4.1	3.3	32	155	0.35	3.5
2	30.2	6.3	92	22	4.4	3.8	38	139	1.5	7.5
2	31.4	6.6	101	21	4.6	3.6	35	138	0.7	6.5
3	30	9.6	104	24	2.6	2.6	32	168	1.39	3.4
3	27.9	9.3	81	18	5.2	5.2	28	153	2	3.5
3	29.5	8.8	89	24	4.1	4.1	54	120	1.6	3.9
3	31.8	9.5	116	27	3	3	38	126	1.5	5.5
3	32.1	8.9	95	30	3.4	3.4	30	155	0.8	4
3	30.9	6.7	124	24	4	4	28	149	0.4	4.1
3	29.9	6.7	105	26	4.8	4.8	32	137	1.5	6.5
3	31.1	6.5	120	27	4.9	4.9	36	143	1.7	5.5
4	30.6	9.5	96	24	2.5	2.5	30	159	0.86	4.1
4	27	9.5	89	17	4.3	4.3	20	163	1	5.5
4	31.4	8.1	116	22	3.7	3.7	51	126	1.18	4.2
4	30.1	9.6	125	23	3.3	3.3	32	148	1.5	5.5
4	31.2	9.3	88	34	3.9	3.9	34	152.1	0.5	6
4	32.2	6.5	118	16	3.8	3.8	26	151	0.6	3.6
4	29.5	6.4	93	22	4.5	4.5	30	140	1	5.5
4	32	7.4	115	29	5.1	5.1	44	142	1	7.5

Appendix C

Comprehensive data for species of fish

species		Pb	Cu	Mn	Fe	Cr
O. niloticus	1	0.1	0.18	0.21	0.48	0.62
	1	0	0.1	0.28	0.46	0.36
	1	0	0.1	0.24	0.62	0.16
	1	0	0.06	0.22	0.84	0.1
	1	0	0.11	0.18	0.68	0.13
	1	0	0.13	0.15	0.65	0.15
	1	0	0.18	0.13	0.72	0.1
	1	0	0.15	0.07	0.69	0.1
T. zillii	2	0.1	0.1	0.21	0.48	0.35
	2	0	0.1	0.3	0.62	0.48
	2	0	0.1	0.26	0.56	0.14
	2	0	0.06	0.26	0.58	0.06
	2	0	0.09	0.25	0.45	0.15
	2	0	0.1	0.21	0.42	0.12
	2	0	0.12	0.16	0.68	0.12
	2	0	0.12	0.12	0.55	0.08
S. clarias	3	0.14	0.13	0.24	0.35	0.22
	3	0	0.06	0.22	0.34	0.22
	3	0	0.06	0.3	0.48	0.16
	3	0	0.08	0.24	0.65	0.18
	3	0	0.06	0.28	0.8	0.12
	3	0	0.06	0.18	0.88	0.12
	3	0	0.14	0.18	0.75	0.06
	3	0	0.07	0.15	0.67	0.14