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Seasonal Variation in Physicochemical Parameters on Fisheries of Ebonyi River System

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Abstract

The study analyzed the seasonal variation in physicochemical parameters on fisheries of Ebonyi river system. The objectives of the study were to analyze the physiochemical properties of Ebonyi river system and its correlation and to make necessary recommendations for the general improvement of fish management in the study area. Multimesh gillnets were used to monitor the abundance and structure of the fish fauna. Stratified random sampling was carried out in each water body. The fishes were caught, identified, counted, graded, measured and weighed according to species. The species for chemical and histological analysis were taken immediately after weighing to the laboratory. Concentration of metals were studied in fish blood, liver and in the tissue lying between the lateral lines and the fins, since high concentrations of metals do not imply that the metal have a toxic effect (-). Toxicity of metals is mostly associated with vital physiological functions, such as enzyme activity, modifications in membrane, lipid composition and changes in tissue structures. It was observed that in dry season, water temperature of Mkpuma river and pond water were statistically similar ($p > 0.05$). However, their values differed significantly of those of Ameka Dam, Enyigba River and Ebonyi river. The pH in dry season across study areas was similar for Ameka Dam and Enyigba River and these were significantly higher ($p < 0.05$) than those of other study areas, which did not differ significantly ($p > 0.05$) among themselves. Mkpume river, Ebonyi river and Ameka Dam had statistically similar DO values ($p > 0.05$) while Enyigba and pond water had insignificantly different DO concentration ($p > 0.05$). The CO_2 concentration in dry season was significantly higher in Mkpume river followed by Ameka dam but the CO_2 of Ameka dam was not significantly different ($p > 0.05$) from those of Ebonyi river and pond water. Enyigba River had the least CO_2 concentration. Water had it highest transparency in Enyigba river ($p < 0.05$) followed by those of Mkpume river, pond water, Ebonyi River and Ameka dam. It was also observed that during rainy season, water temperature in Mkpume river was significantly different ($p < 0.05$) from those of other study areas while the water temperature of Ameka Dam was the least. Mkpume river also had the highest pH value but it does not differ significantly ($p > 0.05$) from that of Ebonyi river. However, the pH of pond water was significantly low ($p<0.05$). There was no significant difference in the DO concentration of all study area during the rainy season. Based on the research findings, the following policy recommendations are therefore proffered. World health /bank should please assist the state Government in making available good quality refined urban tap water to the villages and subborbs so as to save the lives of both Urban and Rural dwellers. Safe disposal of domestic wastes and control of industrial effluents should be practical and where possible recycled to avoid these metals and other contaminants from going into the environment. There should be periodic monitoring of the heavy metals concentration in both the fishes and river system to ensure continuous safety of people in the area.

Keywords: Sub-borbs; Urban tap water; Heavy metals; Ecosystem; Tended solids; Inorganic pollutants

Introduction

Heavy metals are commonly found in natural waters and some are essential to living organisms, they may become highly toxic when present in certain concentrations. These metals also gain access into ecosystem through anthropogenic and get distributed in the water body, tended solids and sediments during the course of their mobility [1]. The rate of bioaccumulation of heavy metals in aquatic organisms depends on ability of the organisms to digest the metals in the river; it has to do with the concentration of the heavy metal in the surrounding soil sediments, and as well the feeding habits of the organism. Aquatic animals (including fish) bio-accumulate trace metals in considerable amounts and stay over a long period. Fishes have been recognized as a good accumulator of organic and inorganic pollutants [2]. Age of fish, lipid content in the tissue and mode of feeding are significant factors that affect the accumulation of heavy metals in fishes. Some heavy metals such as Zn and Fe are essential nutrients for animals and plants but are dangerous at high levels, whereas Pb have no well defined physiological functions but are detrimental at certain limits [3]. At such concentration, it may cause neurological impairment and central nervous system malfunctioning. Fish diagnoses are often used to detect and monitor these heavy metal contaminations in Aquatic ecosystem.

The surface drainage in the study area is irregular and consists of a number of small streams forming a dendritic pattern. The streams generally flow in different directions and empty into the Ebonyi River which is the main drainage channel serving the whole of Ebonyi State and it's environ.

The river basin is a booming fish farming area during dry and rainy seasons. Most industrial activities in the area include: stone crushing, metal mining (Pb-Zn) and smelting. These are located less than 100 meters near the river and they discharge their wastes directly into the river. When fish bio-accumulates these pollutants, it becomes a threat to human health since consumers depend heavily in the fish for their dietary needs. In addition, the streams also which serves as both drinking and domestic water become undrinkable since it endangers human health directly or indirectly.

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Research Questions

The biodiversity of inland aquatic ecosystem is increasingly threatened by a variety of factors all of which are related to humans [4]. Available data suggest that 30% of fish species are threatened by human activities [5]. Metals such as mercury, cadmium, copper and zinc form major types of toxic compounds that are released into many water courses by the mining industry [2]. Both air emissions and wastewaters are sources of metal pollution.

Ebonyi State being naturally endowed with several mineral resources which range from lead, gypsum, calcium carbonate, copper, zinc, mercury, etc is seen to be blessed by nature. These resources have as well attracted several investors in the area of mining. These miners are sole business men who are interested in their product without giving cognizance to the effect of or the by-product of their activity on their surrounding environment.

The Ebonyi river system is an example of the beautiful but vulnerable natural river system of the Federal Republic of Nigeria. Lack of fundamental information on the factors determining effect of quarrying activity on surrounding waters has made it imperative for such work. The chemicals used in the mining processes often escape into the environment causing large scale air and water pollution. It is pertinent to consider how mining affects its environment especially, land, water and the biodiversity.

Looking at the vast deposit of mineral resources in the state, miners have been attracted to the different locations of the state for economic purpose without considering its side effects. Meanwhile, metal pollution of Ebonyi river system caused by mining has not received any serious attention and the heavy metal contamination of its fishes has not been studied. Thus, this study investigated the effects of heavy metals on the aquatic systems and fisheries of Ebonyi river system.

In order to achieve the objectives of this study, the following research questions were asked: What are the physiochemical properties of Ebonyi river system? What are the possible management practices to reduce this pollution of these rivers?

Objectives of the Study

The broad objective of the study is to determine the seasonal variation in physicochemical parameters on fisheries of Ebonyi river system

The specific objectives are to find out:

1. The physiochemical properties of Ebonyi river system and its correlation

2. Make necessary recommendations for the general improvement of fish management in the study area

Justification of the Study

Fish had long been regarded *as a* desirable and nutritional source of high quality protein with generous supply of minerals and vitamins. During the last few decades, great attention has been paid to the possible dangers of heavy metal poisoning in humans due to the consumption of contaminated fish. Industrial and agricultural discharges such as coal and oil combustion, phosphate fertilizers, plastics, pesticides and mining effluents are considered the major sources of heavy metal pollutants of water. Fishes that absorbed heavy metals are recognized for their detrimental effects on human health. Metals also, may act as allergens, mutagens or carcinogens [6]. Many investigators have studied the presence of heavy metals in surface waters and in fish. Some authors investigated the removal of heavy metals from water [7,8]. Up till now, methods of removal of heavy metals and other pollutant have not been well investigated. The detection of toxicity of these pollutants in the water body and the aquatic organisms (fish) within this vicinity in recent times necessitated the study and this will attract the attention of various non-governmental organizations, donor agencies and researchers for possible intervention.

This study tends to be of maximum benefit to the farmers, residents, NGOs, miners, environmental policy makers, Ebonyi State Government, Researchers and the general public. The residents who use the water for drinking and domestic purposes (cooking) should access if the water is not good for the health without passing through treatment processes. This knowledge will now spur them into calling for Government assistance and in the area of drinking and domestic water for public use. The outcome of the study will be useful as a guide for NGOs workers especially those working on environmental issues and human health to see how they will call for foreign donors and WHO intervention on the behalf of the residents if need be.

Researchers will benefit from the study through consultation based on the work which will enable them go into further research which would be beneficial to both government and the general public. The general public will benefit through awareness creation and as well have good health or long life when the recommendations are put in place.

Literature Review

Effects of various heavy metals on the biochemical parameters of fishes

Various organic and inorganic wastes in industrial and domestic effluents are responsible for pollution. Non-degradable heavy metals are regarded as hazardous to aquatic ecosystems because of their environmental persistence and their tendency for bioaccumulation [9]. As heavy metals are immutable, their bio-magnification has been reported in aquatic ecosystems. Heavy metals may affect aquatic organisms if the organisms are sub-lethally exposed to them for a long time. It has been reported that heavy metals affect biochemical parameters of the fish liver [8]. Arsenic contamination is mainly caused by the use of the arsenic pesticides, industrial activities and mining operations [10]. Due to increasing levels of arsenic in the ground water in Bangladesh and West Bengal, considerable attention was given to the study of the effect of arsenic on human beings and selected mammals [11]. However, there were only a few reports on the physiological and biochemical responses of fish to arsenic [1]. Enzymes are biochemical macromolecules that control metabolic processes of organisms. Thus a slightly variation in enzyme activities would affect the organism [12]. By estimating the enzyme activities in an organism, we can easily identify disturbances in its metabolism. Roy [12], we monitored the disturbance of metabolism in *Labeo rohita* by exposing them to two concentrations of arsenic.

The variation in enzyme activities in the freshwater fishes exposed to various pollutants and heavy metals, in particular have been reported [13]. However, there was very little data on the effect of arsenic toxicity to enzymes in fishes. It has been reported that the variation in enzyme activities in heavy metal treated fish is due to increased permeability of the cell as well as the direct effect of the heavy metal on the tissues [14]. Therefore, significant depletion of enzymes in the fishes exposed to arsenic observed in the present study can be attributed to increased arsenic levels in the tissues. Furthermore, accumulation of arsenic in liver and muscles could be the possible reason for variation of enzyme

activities. Such correlation between accumulation of heavy metals in fish tissues and abnormal enzyme activities has been reported in the exposure of the freshwater fish *Clianna punciatus* to cadmium [4].

Arsenic, in the form of arsenate, can also resemble phosphate which is used by cells for energy and signaling. By displacing phosphate in enzymes or signaling proteins, arsenic can block, energy production and normal cell signaling Decreases in phosphatase activity levels shown in this 2005 study might be due to the increased arsenic level in the water and its accumulation in the tissues of the fishes. As arsenic toxicity induces oxidative stress, the antioxidant enzymes (especially the glutathione-dependent enzymes), react to defend against arsenic toxicity [9]. In reference [15] showed that activities of glutathione-S-transferase, glutathione peroxides, glutathione reductase and caused, decreased in the liver and kidney as a result of arsenic in the liver and kidney. This can be correlated with the decrease in GOT and GPT activities in the fishes exposed to arsenic in this study.

Few comparative data were available from the areas but it seems that our waterways are less concentrated than industrialized country waterways. The contents of toxic metals in Persian Gulf canned tuna fish are below the permissible levels listed by the joint Food and Agriculture Organization/World Health Organization Expert Committee on food additives [16]. Of course, more studies are needed to properly assess other sources and to compare with tolerable weekly intakes.

From this study, it can be clearly seen that the concentrations were varied among the metals and trips of sample collection. The differences in concentration in each sample were depending on species, sex, biological cycle and the portion of sample being analyzed [17]. Furthermore, ecological factors such as season, place of development, nutrient availability, temperature and salinity of the water also may contribute to the inconsistency of metals concentration in fish tissue [2]. Moreover, some marine organisms have the ability to concentrate heavy metals in their tissue in several orders of magnitude higher than those in water and sediment [18].

The deteriorating conditions of surface water resources by heavy metal pollution have led to the study of Ivo River in Ishiagu area of Ebonyi State Nigeria. Most pollutions result from uncontrolled discharge of untreated effluent from mining companies and industries in the area. Rashid [19] reported that metal pollutants in water are not degraded, rather they are deposited, and some of them are assimilated by the aquatic animals posing serious threats to human health when they are consumed. Some heavy metals such as Zn and Fe are essential micronutrients for animals and plants but are dangerous at high levels, whereas Pb have no well defined physiological functions but are detrimental at certain limits [3]. The concentration of Pb may cause neurological impairment and central nervous system malfunctioning. The detection of toxic level of these pollutants in the aquatic organisms observed in this vicinity in recent times necessitated this study and this has attracted the attention of various non-governmental organizations and researchers. Fish diagnoses are often used to detect and monitor these heavy metal contaminations in aquatic ecosystem. This study was embarked upon to determine the levels of heavy metals in fish samples from Ivo River in Ishiagu Ebonyi State, Nigeria. Most inhabitants in Ishiagu depend on the fish for consumption, rearing and trading due to the fact that they are abundant and affordable. Water pollution has been observed for Alayi-Ovim area a nearby area and this was attributed to proximity to lead (Pb)-zinc (Zn) and Chloride (Cl) formations of the Turanian Eze-Aku and the Albian Asu River group [5]. This study was very important since the Ivo River in this study area is underlain by the Ezeaku Formation [4]. The surface drainage in the study area was irregular and consisted of a number of small streams forming a dendritic pattern. The streams generally flowed in the north-south direction into the Ivo River. Ivo River is the main drainage channel in Ishiagu area and environs. The river basin is a booming fish farming area during dry and rainy seasons. Most industrial activities in the area include: stone crushing, metal mining (Pb-Zn) and smelting. These are located near the river and they discharge their wastes directly into the river. When fish bio-accumulates these pollutants, it becomes a threat to human health since consumers depend heavily in the fish for their dietary. In addition, the streams also become undrinkable since it endangers human health.

Materials and Methods

The study area

The study area is Ebony State of Nigeria. The State lies approximately 7°3' N and longitudes 5°4' E and 6°45' W. It is located in the Eastern part of Nigeria. The state is made up of thirteen (13) local government areas, which are divided into three (3) agricultural zones, namely: Ebonyi North, Ebonyi Central and Ebonyi South. It has a landmass of approximately 5,932 square kilometers. It is bounded in the East by Cross River State, in the North by Benue State, in the West by Enugu State, and in the South by Abia State (15).

Ebonyi State has a population of 2.1 million people [20]. The vegetation of the state is a mixture of savanna and semi-tropical forest with agriculture and mining as the mainstay of the economy. It lies in an area of moderate relief of between 125 metres and 245 metres above sea level. The soil is texturally clay loam, fairly to poorly drained, with gravely subsoil in some locations especially the upland adjacent to lowland areas [11]. Crops grown in the area include; rice, yam, cassava, cocoyam, groundnut, cowpea and vegetables. Livestock farming, especially the extensive system of rearing sheep, goats and native cattle, is also practiced by the people. Fishing activities are predominant in all the zones of the state.[11] noted that three main seasons prevail in the area - the rainy (wet) season, which spans from early April to early November, the harmattan period which lasts between mid-November to late January and the dry season, which lasts from late January to early April. However, a short dry spell is usually experienced during the month of August, and this is termed the August break. Lowland areas popularly called, FADAMA are largely available and serve as good sites for rice and fish farming during the rain and dry season vegetable farming. Some non-farm activities prevalent in the State include: quarrying, petty trading, pottery, weaving etc. Medium to large-scale industries also exist in the state. Notable among them are the Abakaliki rice milling industry, the fertilizer blending plant and the building materials industry. Large deposits of solid mineral resources such as lead, gold, gellena, zinc, iron, oxide, quartz, grease, gypsum, limestone, marble stone, common salt and others are found in Ebonyi State.

Field Sampling

Three locations within the river systems in Ebonyi State, lying close to mine sites were sampled on monthly bases for two years beginning from March 2011 to February 2013. Then a river system which does not lay close to any mining site was used to serve as control 1. Then culture pond water using urban tap water to culture *Clarias albopunctatus* was used as control 2. Specimen of *Clarias albopunctatus* were collected from the Ebonyi state university earthen pond and acclimatized to

the laboratory conditions for fifteen days. The fishes were fed with industrial coup hen industrial feed at the 3% body weight twice daily. The fishes, measuring 4 to 6 cm in length and weighing 8 to 10 gm were selected for the experimental purpose. The physiochemical parameters of the water were estimated according to [9]. The test specimen was stocked in a concrete pond supplied with urban tap water. The water was changed bimonthly. The experiment was sampled monthly, for onward processing and preservation for analytical purpose. Samples for water quality were taken and analyzed in IITA according to Fishers Standard Methods (FSM standards) for sediments samples.

Multi-mesh gillnets were used to monitor the abundance and structure of the fish fauna [6]. Stratified random sampling was carried out in each water body. The fishes were caught, identified, counted, graded, measured and weighed according to species. The species for chemical and histological analysis were taken immediately after weighing to the laboratory.

Concentration of metals were studied in fish blood, liver and in the tissue lying between the lateral lines and the fins, since high concentrations of metals do not imply that the metal have a toxic effect (-). Toxicity of metals is mostly associated with vital physiological functions, such as enzyme activity, modifications in membrane, lipid composition and changes in tissue structures. The research looked at the effects of the following heavy metals (Cadmium, Nickel, Mercury, Chromium, Lead, and Arsenic) on the physiology, gill ,liver, blood and fin functions of fingerlings, juveniles and table size *Clarias albopunctatus* in the laboratory of the Fisheries and Aquaculture Department of Ebonyi State University, Abakaliki.

Water body analysis

Temperature: A 0.01 graduated centigrade thermometer in °C was employed for recording the water temperature at the sites.

pH (Hydrogen ion concentration): WTW (wissenchaft lieh-technische werk-statten) multiline-p_4 (merk) made in Germany was used.

Procedure: The probe was cleaned and calibrated by switching on and was directly inserted into the water and the value recorded after 10 minutes.

Dissolved Oxygen: WTW multiline –p_4 was used for disolved oxygen estimation but must be inserted up to 25 cm depth and the value recorded in mg/l.

Free Carbondioxide (CO_2): Immediately the sample was collected with a Nessler's tube, 2 (two) drops of phenolphtalein reagent were added and the number of drops calculated thus: N/10 NaOH required x 20 = ppm of free carbondioxide.

Transparency: The water transparency was measured by using Secchi disc. The Secchi transparency is the mean depth of the point where emergent white disk disappears or match with the water physically. Hence, the exact depth or point of disappearance of the disk from the surface level of water was recorded as the transparency of the existing water at a particular time.

Result presentation

The seasonal variation in physicochemicals is shown in Table 1. In dry season, water temperature of Mkpume river and pond water were statistically similar ($p > 0.05$). However, their values differed significantly of those of Ameka Dam, Enyigba River and Ebonyiriver. The pH in dry season across study areas was similar for Ameka Dam and Enyigba River and these were significantly higher ($p < 0.05$) than those of other study areas, which did not differ significantly ($p > 0.05$) among themselves. Mkpume river, Ebonyi river and Ameka Dam had statistically similar DO values ($p > 0.05$) while Enyigba and pond water had insignificantly different DO concentration ($p > 0.05$). The CO_2 concentration in dry season was significantly higher in

Mkpume river followed by Ameka dam but the CO_2 of Ameka dam was not significantly different ($p > 0.05$) from those of Ebonyi river and pond water. Enyigba River had the least CO_2 concentration. Water had it highest transparency in Enyigba river ($p < 0.05$) followed by those of Mkpume river, pond water, Ebonyi River and Ameka dam. During rainy season, water temperature in Mkpume river was significantly different ($p < 0.05$) from those of other study areas while the water temperature of Ameka Dam was the least. Mkpume river also had the highest pH value but it does not differ significantly ($p > 0.05$) from that of Ebonyi river. However, the pH of pond water was significantly low ($p < 0.05$). There was no significant difference in the DO concentration of all study area during the rainy season. Carbon (iv) oxide concentration in Ameka dam, Enyigba, Ebonyi and Pond water were statistically similar ($p > 0.05$) but their values were significantly lower that of Mkpume river ($p < 0.05$). Transparency was significantly higher ($p < 0.05$) in Enyigba river when compared to those of other study areas. Comparing the season of different study area for different parameters, significant variations were also observed. For water temperature, Rainy season values were significantly higher ($p < 0.05$) for Mkpume river and Ebonyi river ($p < 0.01$) while for pond water, the dry season water temperature was significantly higher ($p < 0.0001$). In other study areas, no significant difference was observed between seasons. The pH of Enyigba ($p < 0.05$), Mkpume ($p < 0.0001$) and Ebonyi ($p < 0.0001$) rivers was significantly higher ($p < 0.05$) in rainy season while for DO all study areas showed seasonal difference ($p < 0.0001$) except Ebonyi river. For CO_2, significant difference between dry and rainy season was noted in Enyigba ($p < 0.05$) and Mkpume ($p < 0.0001$) rivers. The water in all study areas were significantly more transparent in dry season than in rainy ($p<0.05$) except that of Enyigba river.

Discussion

In Table 1 discussed the different physiochemical parameters of the water bodies five in number for two years.

Seasonal variation in physiochemical parameters

The seasonal variation in physicochemicals is shown in Table 1. In dry season, water temperature of Mkpuma river and pond water were statistically similar ($p > 0.05$). However, their values differed significantly of those of Ameka Dam, Enyigba River and Ebonyiriver. The pH in dry season across study areas was similar for Ameka Dam and Enyigba River and these were significantly higher ($p < 0.05$) than those of other study areas, which did not differ significantly ($p > 0.05$) among themselves. Mkpume river, Ebonyi river and Ameka Dam had statistically similar DO values ($p > 0.05$) while Enyigba and pond water had insignificantly different DO concentration ($p > 0.05$). The CO_2 concentration in dry season was significantly higher in Mkpume river followed by Ameka dam but the CO_2 of Ameka dam was not significantly different ($p > 0.05$) from those of Ebonyi river and pond water. Enyigba River had the least CO_2 concentration. Water had it highest transparency in Enyigba river ($p < 0.05$) followed by those of Mkpume river, pond water, Ebonyi River and Ameka dam.

During rainy season, water temperature in Mkpume river was significantly different ($p < 0.05$) from those of other study areas while

Water temperature			
Study areas	**Dry season**	**Rainy season**	**P value**
Ameka Dam	24.42 ± 0.76^{b}	25.64 ± 0.41^{c}	0.166
Enyigba River	25.25 ± 0.98^{b}	27.09 ± 0.62^{b}	0.123
Mkpume River	28.51 ± 0.78^{a}	30.19 ± 0.36^{a}	0.06
Ebonyi River	23.59 ± 0.76^{b}	26.47 ± 0.43^{bc}	0.02*
Pond water	28.67 ± 0.27^{a}	26.29 ± 0.59^{bc}	<0.0001**
Ph			
Ameka Dam	7.63 ± 0.03^{b}	7.61 ± 0.06^{c}	0.72
Enyigba River	7.53 ± 0.06^{a}	7.76 ± 0.78^{bc}	0.03*
Mkpume River	6.95 ± 0.09	7.94 ± 0.06^{a}	<0.0001***
Ebonyi River	7.19 ± 0.14^{b}	7.79 ± 0.06^{ab}	<0.0001***
Pond water	7.03 ± 0.01^{b}	7.05 ± 0.02^{d}	0.388
Dissolved oxygen			
Ameka Dam	7.59 ± 0.22^{ab}	9.61 ± 0.42^{a}	<0.0001***
Enyigba River	6.99 ± 0.25^{b}	8.63 ± 0.27^{a}	<0.0001***
Mkpume River	8.21 ± 0.13^{a}	9.57 ± 0.17^{a}	<0.0001***
Ebonyi River	8.28 ± 0.39^{a}	8.83 ± 0.42^{a}	0.335
Pond water	7.04 ± 0.09^{b}	8.86 ± 0.40^{a}	<0.0001***
	Carbon (iv) oxide		
Ameka Dam	4.61 ± 0.36^{b}	4.74 ± 0.12^{b}	0.745
Enyigba River	3.62 ± 0.17^{c}	4.43 ± 0.35^{b}	0.044*
Mkpume River	5.79 ± 0.16^{a}	6.73 ± 0.10^{a}	<0.0001***
Ebonyi River	3.92 ± 0.31^{bc}	4.13 ± 0.18^{b}	0.555
Pond water	4.32 ± 0.30^{bc}	4.17 ± 0.19^{b}	0.66
Transparency			
Ameka Dam	55.34 ± 3.85^{c}	64.22 ± 1.89^{b}	0.045*
Enyigba River	117.17 ± 11.14^{a}	109.18 ± 11.71^{a}	0.624
Mkpume River	78.83 ± 1.96^{b}	68.44 ± 3.04^{b}	0.006**
Ebonyi River	72.90 ± 2.89^{b}	65.10 ± 1.52^{b}	0.02*
Pond water	73.13 ± 2.17^{b}	65.62 ± 1.65^{b}	0.009**

Mean values in a column with different alphabets as superscripts are significantly different ($p < 0.05$)
*significant difference between dry and seasons at $p < 0.05$
** high significant difference between dry and rainy seasons at $p < 0.01$
*** very high significant difference between dry and rainy season $p < 0.0001$

Table 1: Seasonal variations in physicochemical parameters.

the water temperature of Ameka Dam was the least. Mkpume river also had the highest pH value but it does not differ significantly ($p > 0.05$) from that of Ebonyi river. However, the pH of pond water was significantly low ($p < 0.05$). There was no significant difference in the DO concentration of all study area during the rainy season.

Carbon (iv) oxide concentration in Ameka dam, Enyigba, Ebonyi and Pond water were statistically similar ($p > 0.05$) but their values were significantly lower that of Mkpume river ($p < 0.05$). Transparency was significantly higher ($p < 0.05$) in Enyigba river when compared to those of other study areas. Comparing the season of different study area for different parameters, significant variations were also observed. For water temperature, Rainy season values were significantly higher ($p < 0.05$) for Mkpume river and Ebonyi river ($p < 0.01$) while for pond water, the dry season water temperature was significantly higher ($p < 0.0001$). In other study areas, no significant difference was observed between seasons. The pH of Enyigba ($p < 0.05$), Mkpume ($p < 0.0001$) and Ebonyi ($p < 0.0001$) rivers was significantly higher ($p < 0.05$) in rainy season while for DO all study areas showed seasonal difference ($p < 0.0001$) except Ebonyi river. For CO_2, significant difference between dry and rainy season was noted in Enyigba ($p < 0.05$) and Mkpume ($p < 0.0001$) rivers. The water in all study areas were significantly more transparent in dry season than in rainy ($p < 0.05$) except that of Enyigba river (Table 1).

Recommendations

- There should be periodic monitoring of the heavy metals concentration in both the fishes and river system to ensure continuous safety of people in the area.
- Safe disposal of domestic wastes and control of industrial effluents should be practical and where possible recycled to avoid these metals and other contaminants from going into the environment.
- Neutralization of effluent water is recommended as a modern treatment practice such as lime precipitation of effluent water.
- World health /bank should please assist the state Government in making available good quality refined urban tap water to the villages and subborbs so as to save the lives of both Urban and Rural dwellers.

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