



PHYSICO-CHEMICAL STUDIES OF A TROPICAL URBAN STREAM IN CALABAR SOUTH, CROSS RIVER STATE, NIGERIA

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ABSTRACT

Essiere-Ebom stream is a tropical urban stream in Calabar South Local Government Area, approximately 155m from Nsidung Beach area of the Calabar River, Nigeria. The stream water is used majorly by the inhabitants of the area for recreational activities, domestic purposes and support of aquatic life. The stream water was therefore analysed for physico-chemical parameters such as temperature, dissolved oxygen, pH, conductivity and nutrient (Phosphate and nitrate) to ascertain its suitability for the purpose it is being used for when compared with permissible limits of WHO and FEPA. From the results of the study, surface water temperature ranged between 26.22 – 29.46°C, with a mean of 27.38±1.41°C. Dissolved oxygen was observed to range between 4.24–5.26mg/l, with a mean of 4.87±0.37mg/l, pH ranged between 7.24– 7.52, with a mean of 7.39±0.12, conductivity ranged between 144.32 – 146.43 µs/cm, with a mean of 145.02 ±1.02 µs/cm while phosphate concentration ranged between 0.028–0.048mg/l, with a mean of 0.041± 0.008mg/l and nitrate ranged between 0.044–0.049mg/l, with a mean of 0.0448 ± 0.002mg/l. All parameters analysed were within the WHO and FEPA permissible limits for unpolluted tropical freshwater bodies meant for domestic use and recreational activities in addition to suitability for the sustenance of aquatic life.

KEYWORDS: Essiere-Ebom stream, Physico-chemical parameters, urban stream, Calabar South, Nigeria.

INTRODUCTION

Both humans and biodiversity require water for their physiological functioning. Water is used for different purposes which includes domestic and agricultural uses and for the sustenance of aquatic life (Kalra *et al.*, 2012; Ali *et al.*, 2013; Lestander *et al.*, 2015; Din *et al.*, 2016). Physico-chemical studies of the urban streams include those of Unanam and Akpan (2006), Ali *et al.* (2013), Uzukuhi *et al.* (2013), Lestander *et al.* (2015) and Din *et al.* (2016). Aquatic ecosystems can be significantly altered by diverse human activities such as agricultural practices, irrigation, as well as natural dynamics, which consequently affect the water quality and quantity (Ekanem *et al.*, 2018; Kalu *et al.*, 2018; Job, 2019).

Water serves as a home to a wide variety of organisms, both aquatic plants and animals are found in different water bodies and the interplays of the varied concentration of the physico-chemical parameters are known to influence their well-being (Kalu *et al.*, 2018; Ekanem *et al.*, 2018). This implies that the quality of aquatic ecosystem can generally influence the growth, abundance, diversity distribution and reproduction of both the floral and faunal communities in habiting a particular aquatic ecosystem (Kalra *et al.*, 2012; Lestander *et al.*, 2015; Kalu *et al.*, 2018). Water serves as a home to a wide variety of organisms, both aquatic plants and animals are found in different water bodies and the interplays of the varied concentration of the physico-chemical parameters are known to influence their well-being

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(Kalu *et al.*, 2018; Ekanem *et al.*, 2018). This implies that the quality of aquatic ecosystem can generally influence the growth, abundance, diversity distribution and reproduction of both the floral and faunal communities in habiting a particular aquatic ecosystem (Kalra *et al.*, 2012; Lestander *et al.*, 2015; Kalu *et al.*, 2018). It is argued that the physical and chemical conditions of many streams and rivers in tropical and sub-tropical countries are deteriorating as a result of human population explosions, anthropogenic effects from land use and increased industrialization, all of which interplay to cause changes in the water quality of the affected aquatic ecosystem (Ali *et al.*, 2013; Unanam and Akpan, 2006; Uzukuhi *et al.*, 2013). Water pollution is a serious problem all over the world as almost 70% of the pollution in water bodies are caused by anthropogenic activities (Din *et al.*, 2016; Job & Nshabum, 2024). Array of physico-chemical parameters such as pH, temperature, turbidity, conductivity, total dissolved solids, total suspended solids, total alkalinity and nutrients (Sulphate, nitrate and phosphate) are usually analysed in water samples collected from aquatic systems and accordingly analysed to ascertain the quality of such water samples when compared with permissible limits for human consumption and aquatic life (FEPA, 2001; WHO, 2006; APHA, 2012).

The Esiere-Ebom stream is an urban stream located between latitude 04°15'28" N and longitude 008°10'45.0" E (Egbai and Job, 2021), in the catchment area of the Calabar River, Nigeria, about 155m from the shore of the Calabar River at Nsidung Beach. The stream is used for recreational activities by the inhabitants of the area (bathing and washing of clothes). Some of the inhabitants of the area also use the stream water for domestic purposes (Egbai and Job, 2021). From available literature, physico-chemical studies on urban streams include those of Lestander *et al.*, 2018; Ekanem *et al.*, 2018 and Egbai & Job, 2021. None of these studies, however, reported on that of Esiere-Ebom stream

MATERIAL AND METHODS

Study Area

The study area is Calabar South Local Government Area. The stream (Esiere – Ebom stream) (Plate 1) is located between Latitude 04°15'28" N and Longitude 008°10'45". (Egbai and Job, 2021). The stream is an urban stream in the catchment area of the Calabar River, Nigeria, about 155m from the shore of the Calabar River at Nsidung Breach (Fig 1). The stream is used for recreational activities by the inhabitants of the area for bathing and washing of clothes. The stream water is also used for domestic purposes (Egbai and Job, 2021).



Plate 1: Esiere-Ebom Stream, Calabar South, Calabar, Nigeria, where the study was conducted

Field studies

Insitu measurements

Insitu measurements of fast changing parameters (temperature, pH, DO and conductivity) were carried out using appropriate instruments.

Temperature was measured in degrees Celsius (°C), using mercury-in-glass thermometer. This was performed by Scooping the stream surface water with a-500ml capacity glass beaker and placing it on a balanced ground surface. Then, the thermometer bulb

was dipped into the water and allowed to stand for between 3-5minutes, during which time, the water temperature was read-off. Duplicate readings were obtained. Measurements of pH, DO and conductivity were performed *insitu* by use of hand-held HANNA instrument (Model: HI8915 ATC) (USA). The instrument was calibrated using a suitable buffer (pH 7). The probe of the instrument was dipped in the buffer solution in a glass beaker and the knob adjusted to the zero mark and allowed to stand for at least 3-5

minutes, after which time, the probe was rinsed with distilled water and was ready for use following the method of Ekanem *et al.* (2018). The surface water was scooped using the glass beaker to the 100ml mark and the probe of the instrument dipped into it. The knob of the meter was then adjusted to the desired parameter, and the readings allowed to become steady before recordings were taken in duplicates, following the methods of Ekanem *et al.* (2016) and Kalu *et al.* (2018).

Surface water samples for nutrients (phosphate and nitrate) studies were collected on a monthly basis for

six months (December, 2022 – May 2023), using sterilized 1 litre plastic containers. The surface water samples were collected by first of all rinsing the containers with stream water and then submerging the containers to be filled with the water sample, after which the containers were corked underwater before they were taken out and stored in an ice-chest. They were then transported to the University of Calabar Central Analytical Laboratory for analysis.

Laboratory studies

In the laboratory, nutrients concentrations in the surface were analysed following the methods outlined in APHA (2000). Duplicate readings were obtained and recorded appropriately in tabular form.

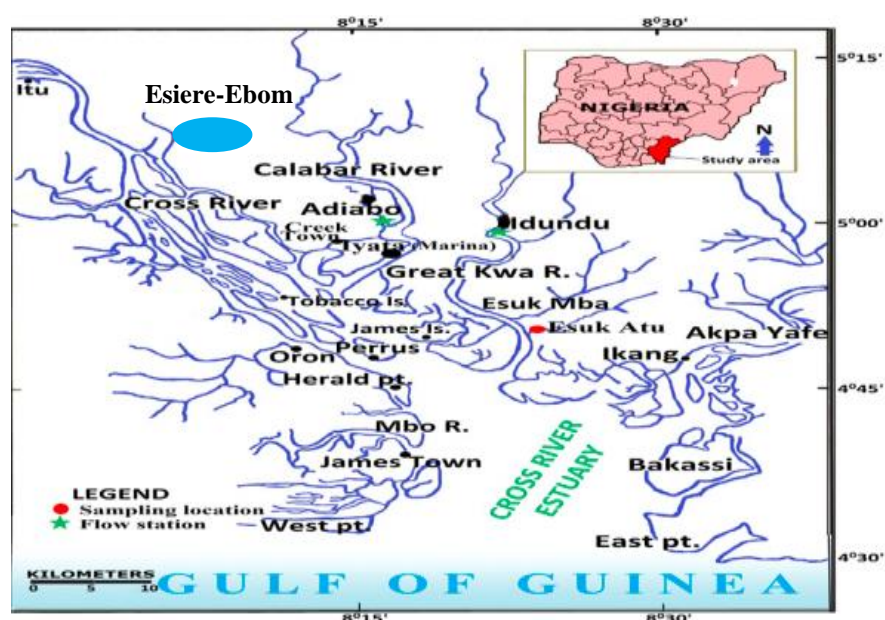


Figure 1: Map of Calabar River showing the sampling station (Esiere-Ebom stream)

Data analysis

Means and standard deviations of the values of the physico-chemical parameters were determined accordingly and compared with International Standards of World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA), respectively.

Results

The monthly values, ranges, standard deviations and the permissible limits of each of the analysed surface water physico-chemical parameters of Esiere-Ebom stream during the period of study are presented in Table 1.

Table 1: Physico-chemical parameters of Esiere-Ebom Stream, Calabar, Nigeria, (Pooled Data) (December 2022 – May 2022).

Parameters	Dec. 2022	Jan. 2022	Feb. 2022	March 2022	April 2022	May 2022	Range	Mean \pm SD	WHO (2006)	FEPA (2001)
1 Surface water Temperature ($^{\circ}$ C)	29.46	28.68	27.46	26.24	26.22	26.22	26.22-29.46	27.38 \pm 1.41	12.0-32.8	20.0-35.0
2 Dissolved Oxygen (Do(mg/l))	4.84	4.82	4.80	4.24	5.24	4.26	4.24-5.26	4.87 \pm 0.37	6.5-8.0	6.0-8.0
3 PH	7.24	7.24	7.46	7.42	7.52	7.44	7.24-7.52	7.39 \pm 0.12	6.5-8.5	6.0-9.0
4 Conductivity μ s/cm	144.34	144.32	146.40	146.43	144.28	140.34	144.32-146.43	145.62 \pm 1.08	150.0-500	20-1500
5 Phosphate (mg/l)	0.028	0.044	0.048	0.048	0.044	0.034	0.028-0.48	0.041 \pm 0.008	0.03-3.70	> 5.0
6. Nitrate (mg/l)	0.049	0.044	0.044	0.044	0.044	0.044	0.044	0.0448 \pm 0.002	3.0-3.70	10.0

Surface Water Temperature: This ranged between 26.22-29.46 $^{\circ}$ C with a mean of 27.38 \pm 1.41 $^{\circ}$ C. Mean surface water temperature was observed to be within WHO and FEPA recommended values for domestic use and aquatic life.

Dissolved oxygen concentration: This ranged between 4.24-5.26mg/l with, a mean of 4.87 \pm 0.37mg/l and was within limits recommended for domestic use and aquatic life.

Hydrogen ion concentration, pH: This ranged between 7.24-7.52, with a mean of 7.39 \pm 0.12 and was observed to be within the recommended values of 6.5-8.5 and 6.0-9.0 of WHO and FEPA, respectively for domestic use and aquatic life. The surface water was generally alkaline in nature, throughout the period of study.

Conductivity (μ s/cm): The conductivity of the surface water ranged between 144.32–146.43 μ s/cm, with a

mean of 145.02 \pm 1.08 μ s/cm and was observed to be within the respective limits of WHO and FEPA for domestic use and aquatic life.

Nutrients: Phosphate concentration ranged between 0.028-0.048mg/l, with a mean value of 0.041 \pm 0.008mg/l and was observed to fall with the permissible concentration WHO and FEPA values for domestic use and aquatic of 0.03-0.06mg/l and >5.0mg/l, respectively, while nitrate was observed to range between 0.044-0.049mg/l, with a mean of 0.0448 \pm 0.002mg/l, and was observed to be below the WHO and FEPA limits of 3.0-3.70mg/l and 10.0mg/l respectively.

The monthly variations in the mean values of the physico-chemical parameters are depicted in Figure 2a-e, while the variations in the mean values of the physico-chemical parameters are depicted in Figure 3.

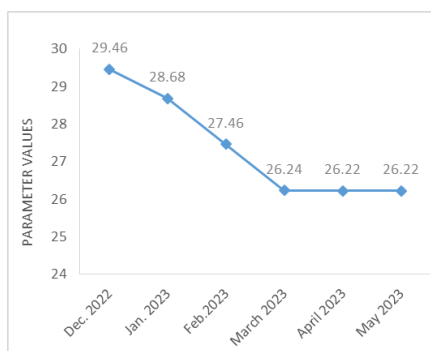


Fig. 2a: Monthly variation in surface water Temperature ($^{\circ}$ C) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

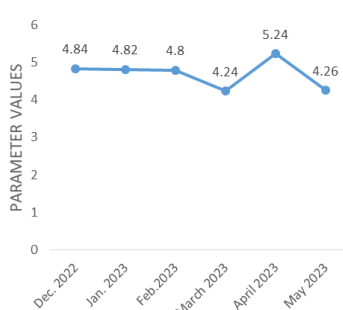


Fig. 2b: Monthly variation in Dissolved Oxygen (mg/l) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

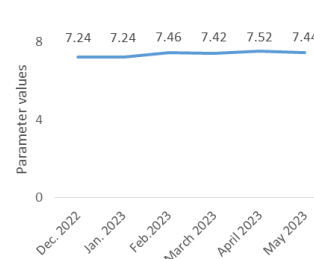


Fig. 2c: Monthly variation in Hydrogen concentration (pH) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

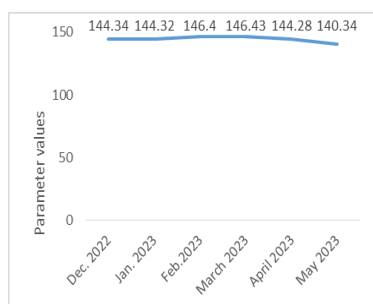


Fig. 2d: Monthly variation in conductivity ($\mu\text{s}/\text{cm}$) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

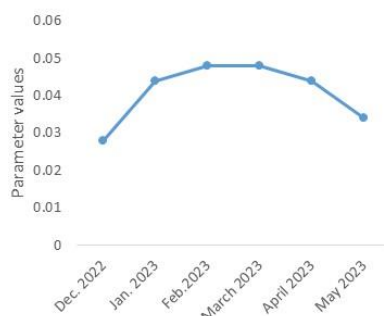


Fig. 2e: Monthly variation in Nitrate (mg/l) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

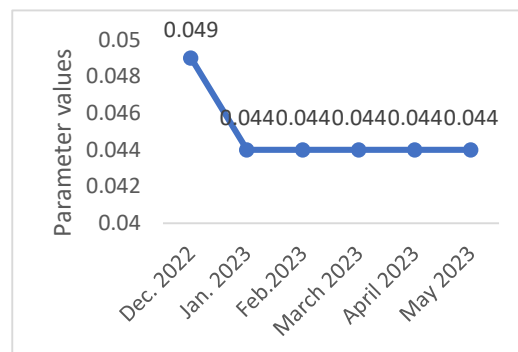


Fig. 2f: Monthly variation in Nitrate (mg/l) Esiere-Edom Stream, Calabar, Nigeria during the period of study (Dec. 2022-May 2023).

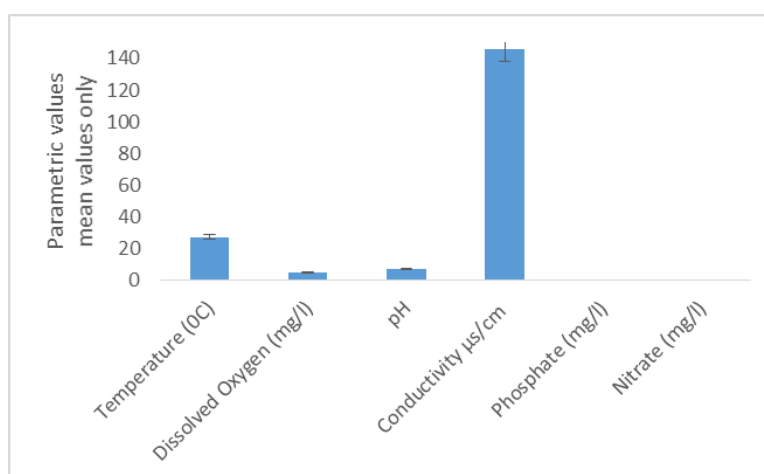


Fig. 3: Variations in the mean values of the physico-chemical parameters in Esiere-Ebom stream, Calabar South, Nigeria, during the period of study (Dec. 2022 – May 2023).

DISCUSSION

Physico-chemical parameters refer to the physical and chemical characteristics of a substance or environment that can be measured and qualified (Din *et al.*, 2016). From the results of the study all the analysed parameters (surface water, temperature, dissolved oxygen, pH, conductivity, phosphate and nitrate) were all within the WHO (2006) and FEPA (2001) permissible limit for domestic use and for the sustenance of aquatic life.

The range of surface water temperature of between $26.22\text{--}29.46^{\circ}\text{C}$ in this study also agrees with those of Habib and Yousuf (2012), who studied the physico-chemical status of Yousmang and Dooyanga streams in Kashmir Himalaya, India and those of Unanam, and Akpan (2006) who reported on the physico-chemical characteristics of some freshwater bodies in Essien Udim Local Government Area, Ikot Ekpene, Akwa Ibom state, Nigeria. The ranges of other parameters such as dissolved oxygen, pH and conductivity reported in this study are also in agreement with those of Belal *et al.* (2017) who reported on the water quality

in Western Lagoon and Timsah lake in Egypt and those of Uzukwu *et al.* (2013), who reported physical characteristics of the upper reaches of the New Calabar river, Nigeria, and Ekanem *et al.* (2018) who reported on the physico-chemical parameters of the Great Kwa River, Nigeria, and they were all within the permissible limit of WHO (2006) and FEPA (2021).

In an unpolluted tropical aquatic fresh water system, especially lotic water bodies, pH values of between 6.5-8.0, are known to support stable ecological settings in the system that favour aquatic life and even for domestic use (Abubakar, 2013; APHA, 2012; WHO, 2006; FEPA, 2001). Surface water range of between $20.0\text{--}35.0^{\circ}\text{C}$ and $12.0\text{--}32.8$, respectively has been recommended by FEPA (2001) and WHO (2006) as being suitable for aquatic life. The results of the present study are also consistent with those of Francis *et al.* (2007) and Andem *et al.* (2012) and Ekanem *et al.* (2018), who respectively reported temperature range of between $25.0\text{--}30.3^{\circ}\text{C}$ during their studies on benthic macro invertebrates of Ona River, Nigeria, in

relation to physico-chemical parameters and physico-chemical parameters of Andoni, River System, Niger Delta, Nigeria, respectively. Temperature is known to generally play a crucial role in determining the health and characteristics of aquatic ecosystems as it affects metabolic rates, growth and distribution of aquatic life (Dodds *et al.*, 1998; Allan and Castillo, 2007; Dodds, 2001). Tropical unpolluted freshwater ecosystems are reported to often have slightly acidic to neutral pH levels, ranging from 6.5-7.5, which supports a diverse range of aquatic life (Allan and Catillo, 2007; Poff and Ward, 1989). Generally, an alkaline aquatic ecosystem is known to be suitable for human and aquatic life (Dodds *et al.*, 1998; Dodds, 2001; Allan and Castillo, 2007). This was the case in Esiere-Ebom stream.

The range of conductivity of between 144.32-146.43 μ S/cm recorded in this study aligns with those of Kadiri (2001) and Asuquo *et al.* (2009). WHO (2006) and FEPA (2001) recommends conductivity range of 150-500 μ S/cm and 20-1500 μ S/cm, respectively for unpolluted tropical lotic freshwater bodies. Conductivity is the measure of dissolved ions, influencing water chemistry and aquatic life. (Paerl *et al.*, 1989). Changes or inconsistency in conductivity have been reported to have adverse effects on water, such as increase pollution, disruption of the balance of aquatic ecosystems, hence affecting the distributions and abundance of aquatic life leading to changes in species composition and potential harm to sensitive species and making the water less suitable for human consumption, recreation, or other uses (WHO, 2006; Patile *et al.*, 2012).

Phosphate levels were observed to vary during the period of study. In December 2022, a value of 0.028mg/l was obtained with 0.044mg/l in January, 2022, an indication of increase phosphate concentration in the surface water of the stream. It then increased to 0.048mg/l in February and March, 2023. This was observed to drop to 0.444mg/l and 0.034mg/l, respectively in April and May, 2023. These fluctuations in the phosphate levels were similarly reported in Ona River, Nigeria, by Francis *et al.* (2007), in the Great Kwa River, Nigeria by Ekanem *et al.* (2018), in Mairua reservoir, Katsina State, Nigeria by Lawal *et al.* (2023), in fresh water bodies in Essien Udim, Akwa Ibom State, Nigeria, by Unanam and Akpan (2006).

Variations in phosphate levels in water bodies have been reported to be due to interplays of factors such as the geology, vegetation and aquatic life of the investigated water body. For example, Paerl *et al.* (2016), reported that the geology of the watershed can influence nutrients levels, with some rocks releasing more nutrients, and that vegetation in the watershed can also impact nutrients level through processes like nutrients cycling and release. Smith *et al.* (1999) maintained that variations in nutrient levels in aquatic systems could be as a result of nutrients cycling and excretion by aquatic life.

Esiere-Ebom stream is bordered by a combination of varied vegetation types and have the tendency for the occurrence of nutrient uptake and release that may interplay with the aquatic life in the stream to bring about the observed nutrient level variations during the period of study. The ranges of the phosphate level are however in line with the permissible limits of WHO (2006) and FEPA (2001).

The observed constant value (0.048mg/l) of phosphate recorded in the months of February and March, 2023, might be due to similarity in the rate of nutrient cycling processes as previous reported by Uzukwu *et al.* (2013) in the new Calabar River. Again, the premise for this scenario might have been due to stable hydrology of the stream ecosystem in those months, a result which is in agreement with those of Abubakarr (2013) in Kowa Dan, Gombe State, Nigeria, and Lawal *et al.*, (2023) in Mairua reservoir, Katsina State, Nigeria.

Nitrate levels were observed to be constant in January 2023 through May, 2023, with a value of 0.044mg/l, while a value of 0.049mg/l was observed in December, 2022. The high value recorded in December, 2022, might be due to high nitrate input into the stream ecosystem from runoff. The WHO (2001) limits for nitrate are respectively, 3.0-3.70mg/l and 10.0mg/l. In this study nitrate level ranged between 0.044-0.049mg/l, with a mean of 0.0448 \pm 0.002mg/l, which are below the limit permissible by WHO (2006) and FEPA (2001). The constant values of nitrate observed in January, 2023 through May, 2023, might again be due to factors such as the components of aquatic life (Allan and Castillo, 2007). Stable by hydrology (Smith *et al.* 1999) and buffering capacity (Dodds *et al.*, 1998). Similar ranges in nitrate levels have been reported in stream ecosystem in Essien Udim, Ikot Ekpene, Akwa Ibom State, Nigeria by Unanam and Akpan (2006), Abubakar (2013) in Kowa Dam Gombe State, Nigeria and Lawell *et al.* (2003) in Mairua reservoir, Funtua Katsina State, Nigeria, who attributed the stability of nitrate concentrations to stable hydrology of the aquatic ecosystems they investigated.

CONCLUSION

Physico-chemical parameters of Esiere-Ebom stream, a tropical urban stream in Calabar South Local Government were investigated for six months between December, 2022 and May, 2023 on a monthly basis. The investigation was aimed at assessing the suitability of the stream water for domestic use and aquatic life. The following physico-chemical parameters were analysed: surface water temperature, dissolved oxygen, pH, conductivity, nutrients (phosphate and nitrate). The analysis of fast changing parameters such as temperature, dissolved oxygen, pH and conductivity were done *insitu* using appropriate instruments, while nutrients were analysed in the laboratory bases of standard methods.

Results revealed that surface water temperature ranged between 26.22-29.46°C, with a mean of 27.38±1.41°C, dissolved oxygen (4.24-5.26mg/l), with a mean of 4.87±0.37mg/l, pH (7.24-7.52) with a mean of 7.39±0.12, conductivity (144.32-146.43µs/cm) with a mean of 145.02±1.08µs/cm, phosphate (0.028-0.048mg/l), with a mean of 0.041±0.008mg/l and nitrate (0.044-0.049mg/l), with a mean of 0.0448±0.002mg/l. All the analysed parameters were in the permissible limits of WHO and FEPA for domestic use and aquatic life.

DISCLOSURE STATEMENT

We declare that this work has no potential conflict of interest.

REFERENCES

- Abubakar, U. M., 2013. Physic-chemical parameters in relation to fish production of Kowa Dam, Gombe State, Nigeria. Proceedings of the 28th Annual Conference of the Fisheries Society of Nigeria, FISON, 25th – 29th November, 2013, Pp 211-213.
- Ali, S.; Hussain, A.; Ali, A. and Awan, M. S., 2013. Dodds, W. K., 2001. Freshwater Ecology: Concepts and Environmental Applications Academic Press, San Diego, California, 386pp.
- Dodds, W. K.; Jones, J. R. and Welch, E. B., 1998. Suggested classification of stream trophic state: distribution of temperate stream types by chlorophyll total nitrogen and phosphorus. Water Research, 32(5):1455-1462.
- Egbai, O. O and Job, B. E., 2021. Bio-survey of plankton as indicators of water quality for recreational activities in Esiere-Ebom stream, Calabar South, Cross River State, Nigeria. Proceedings of the 11th Annual Conference of Nigeria Association of Hydrological Sciences held at the Senate Chambers of the University of Calabar, Calabar – Nigeria, 9th -12th August, 2021, Pp 58-62.
- Ekanem, A. P.; Job, B. E. and Essien, A. E., 2018. Influence of some physic-chemical parameters on the Spatio-temporal abundance and diversity of phytoplankton in the Great Kwa River, Southeast Nigeria. European Academic Research, 4:1774-1796.
- Francis, A.; Sikoki. F. D. and Ansa, E. J., 2007. Physico-Chemical parameters of the Andoni River System, Niger Delta, Nigeria. Journal of Fisheries International, 2(1):27-31.
- Drinking water Quality Assessment in some selected villages of Nagar Valley, Gilgit-Baltistan, Pakistan. Journal of Chemical, Biological and Physical Sciences, 3(1):567-574.
- Allan, J. D. and Castillo, M. M., 2007. Stream Ecology: Structure and Function of Running Waters. Springer, 364p.
- Andem, A. B.; Okofofor, K. A.; Udofia, U.; Okete, J. A. and Ugwumba, A. A. A., 2012. Composition, distribution and diversity of benthic macro invertebrates of Ona River, Southeast Nigeria. European Journal of Zoological Research, 1(2): 47-53.
- APHA, 2012. Standard Methods of Examination of Water and Waste Water. American Public Health Association, Washington Dc, 22nd Edition.
- Din, S. U. D.; Ali, S.; Nafees, M. A. and Raza, E., 2016. Physic-chemical assessment of water samples collected from some selected streams and rivers in District Gilgit, Pakistan. Journal of Mountain Area Research, 2:9-15.
- Gorde, S. P. and Jadhav, M. V., 2013. Assessment of water quality parameters: A Review. International Journal of Engineering Research and Application, 3(6):2029-2035.
- Habib, S. and Yousuf, A. R., 2012. Benthic Macro invertebrate community of Yousmarg stream (Doodgange Stream and Khanshah Manshah canal) in Kashmir Himalaya, India. Journal of Ecology and the Natural Environmental, 4(11): 280-289.
- <https://www.sciencedirect.com> curled from science Direct on 20th April, 2023.
- Job, B. E., 2019. Assessment of phytoplankton species composition, abundance and diversity within the Itu bridge-end area of the lower Cross River System, Nigeria. International Journal of Fisheries and Aquatic Studies, 7(4):398-405.
- Job, B. E. and Nshabum, T. G., 2024. A Review of Adaptation to Climate Change Strategies by phytoplankton, Zooplankton, Benthic and fish communities in a tropical and sub-tropical coastal Estuaries Ecosystem. Global Journal of Fare and Applied Sciences, 30: 383-390.

- Kalre, N.; Kumar, R.; Yadav, S. S. and Singh, R. T., 2012. Physico-chemical analysis of ground water taken from five blocks (Udwanthnagar, Tarari, Charpokhar, Piro, Sahar) of Southern Bhojpur (Bihar). *Journal of Chemical and Pharmaceutical Research*, 4(3): 1827-1832.
- Kalu, U. U.; Job, B. E. and Stephen, I. P., 2018. Influence of physico-chemical parameters on the biodiversity and distribution of Macro-invertebrates along the coastline of Great Kwa River, Southeast Nigeria. *Biomedicine and Nursing*, 4(3): 31-47.
- Karume, K.; Bagalwa, M.; Bagula, E.; Yalire, M.; Hanakaramo, P.; Byamukama, J. and Mushagalusa, N., 2019. Water quality in and around Lake Edward Basin of the Greater Virunga Landscape, D. R. Congo Side. *Journal of Environment Protection*, 10(9):36-42.
- Lawal, N.; Abdullahi, S. A. and Abolude, D. S., 2023. Physico-chemical characteristics and fish abundance and diversity of Mairua reservoir water, Funtua, Katsina State, North-Western Nigeria. *Applied Science and Environmental Management*, 27(1):125-132.
- Lestander, R.; Lofgren, S.; Henrikson, L. and Agren A. M., 2015. Relationship between structural features and water chemistry in boreal headwater streams: Evaluation based on results from two water management survey tools suggested for Swedish Forestry. *Environment monitoring Assessment*, 187: 190 – 210.
- Nigam, V.; Behl, N. and Kanehan, M. C., 2013. Physico-chemical parameters for testing of water: A Review. *International Journal of Pharmacy and Biological Science*, 3 (2): 523-527.
- Patil, P. N.; Sawant, D. V. and Deshmukh, R. N., 2012. Physico-Chemical parameters for testing water: A Review: *International Journal of Environmental Sciences*, 3(3):377-380.
- Pearl, H. W.; Scott, J. T.; McCarthy, M. J. Newell, S. E.; Gardner, W. S.; Havens, K. E.; Hoffman, D. K.; Wilhelms, S. W. and Wurtsbaugh, W. A., 2016. Dual Nutrients and Reductions to Protect Lakes and Downstream Ecosystem. *Environmental Science and Technology*, 50 (20): 10805-10813 (Documents 3, 4, 5).
- Poff, N. L. and Ward, J. V., 1989. Implications of stream flow variability and predictability for lotic community structure: a regional analysis of stream flow patterns. *Canadian Journal of Fisheries and Aquatic Sciences*, 46 (10): 1805 – 1818.
- Smith, V. H.; Tilman, G. D. and Nekola, J. C., 1999. Eutrophication: Impacts of excess nutrients inputs of freshwater, marine and terrestrial ecosystem. *Environmental Pollution*, 100 (1-3): 179-196.
- Tamrakar, A.; Upadhyay, K. and Bajpai, S., 2023. Spatial Variation of physico-chemical parameters and water quality assessment of urban pools at Ripur, Chhattisgarh, India. *Earth and Environment Science*, 1032.
- Tigga, T. M and Pandey, V. K., 2023. A Review on physico-chemical parameters of the quality of water. *International Journal for Multidisciplinary Research*, 5(1):2160-2582.
- Unanam, A. E. and Akpan, A. W., 2006. Analysis of physico-chemical characteristics of some freshwater bodies on Essien Udim Local Government Area of Akwa Ibom State, Nigeria. *Proceeding of the 21st Annual Conference of the Fisheries Society of Nigeria FISON, Calabar 13th-17th November, 2006, Pp 310-312.*
- Uzokwu, P. U.; Leton, T. G. and Jamabo, N. A., 2013. Survey of physical characteristics of the upper reaches of New Calabar River, Niger Delta, Nigeria. *Proceedings of the 28th Annual Conference of the Fisheries Society of Nigeria (FISON), 25th-29th November, 2013, Pp 206-210.*