Asian Journal of Applied Chemistry Research

Volume 15, Issue 4, Page 147-156, 2024; Article no.AJACR.121758
ISSN: 2582-0273

Winkler Titration Assessment of Biochemical Oxygen Demand (BOD_5) in Oka Creek, Toru-Orua, Bayelsa State

Victoria Bennett [a*] and Douye Parkinson MarkManuel [b]

[a] Department of Chemical Sciences, Faculty of Basic and Applied Sciences, University of Africa, Toru-Orua, Sagbama, Nigeria.
[b] Department of Chemical Sciences, Faculty of Science, Niger Delta University, Amassoma, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajacr/2024/v15i4303

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121758

Original Research Article

Received: 28/06/2024
Accepted: 30/08/2024
Published: 09/09/2024

ABSTRACT

Aim: The aim of study was to investigate the Biochemical Oxygen Demand (BOD) levels in water samples from the Oka Creek.
Study Design: Qualitative study design.
Place and Duration of Study: Water samples were collected from the Oka Creek, located in Toru-Orua in Sagbama Local Government Area, Bayelsa State, Nigeria. The study lasted for twenty days.
Methods: Water samples were collected from four different locations and depths in the Oka Creek, Toru-Orua, Sagbama Local Government Area of Bayelsa State, Nigeria, at various times. Each sample was transferred into 250 ml bottles labeled L1, L2, L3, and L4. The temperatures of the samples were recorded before transporting them to the chemistry laboratory for treatment. Winkler titration method was employed in analyzing the samples.

**Corresponding author: Email: vkalapoi@gmail.com; victoria.bennett@uat.edu.ng;*

Cite as: *Bennett, Victoria, and Douye Parkinson MarkManuel. 2024. "Winkler Titration Assessment of Biochemical Oxygen Demand (BOD5) in Oka Creek, Toru-Orua, Bayelsa State". Asian Journal of Applied Chemistry Research 15 (4):147-56. https://doi.org/10.9734/ajacr/2024/v15i4303.*

Results: Location L1 recorded the highest BOD value, 28.38 mg/L, measured at sunset (25 °C), from a relatively stagnant region. The high BOD at this location is attributed to minimal photosynthetic activity and significant oxygen consumption by microorganisms. In contrast, L2, collected from the same region at 35 °C during peak sunlight, exhibited a BOD value of 21.76 mg/L. The lower BOD at L2 is due to increased photosynthetic activity. These high values suggest significant sludge deposits, domestic sewage and agricultural runoffs, which could lead to oxygen depletion and negatively impact aquatic life. Sample L3, taken from a deeper, stagnant region at sunset (25 °C), recorded a BOD value of 4.50 mg/L. This moderate BOD level suggests the presence of moderate sludge deposits and agricultural runoff, but higher water flow speed helped mitigate these effects. Location L4, with the lowest BOD value of 3.74 mg/L, was collected during peak sunlight (35 °C). Deeper location and high water flow speed contributed to reduced BOD levels, indicating better water quality and a healthier aquatic environment.

Conclusion: The BOD values at L1 and L2 (28.38 mg/L and 21.76 mg/L) exceed acceptable limits for fish growth. Conversely, BOD values at L3 and L4 (4.50 mg/L and 3.74 mg/L) fall within acceptable limits, suggesting healthier aquatic environment, as evidenced by the yearly bountiful fish harvests in these sections of the Oka Creek.

Keywords: Oxygen; water; BOD; factors; analysis; oka creek.

1. INTRODUCTION

Oxygen is the most abundant element on Earth. It exists primarily in two forms: O_2 (molecular oxygen) and O_3 (ozone). Oxygen is the most abundant element in the Earth's crust. It primarily exists in two forms: O_2 (molecular oxygen) and O_3 (ozone). Additionally, oxygen is a component of numerous compounds, including water (H_2O), and can be found dissolved in water as O_2 molecules. Oxygen is also a component of numerous compounds, such as water (H_2O), and can be found dissolved in water as O_2 molecules [1]. The amount of dissolved oxygen (DO) that water can retain is primarily influenced by temperature, salinity, and atmospheric pressure [2].

The stream system both produces and consumes oxygen. It absorbs oxygen from the atmosphere and from plants through photosynthesis [3]. Oxygen consumption in water can result from various sources, including respiration by aquatic animals, decomposition of organic matter, stormwater runoff from farmland or urban streets, feedlots, failing septic systems, and various chemical reactions [4]. The biochemical oxygen demand (BOD) refers to the quantity of oxygen that aerobic bacteria require to decompose organic waste [5].

Surface pollutants have a detrimental impact on aquatic life. Contaminants like heavy metals, pesticides, and industrial chemicals can directly poison aquatic organisms, causing illness, deformities, and even death [6,7]. Hydrocarbons from oil spills coat the water's surface, suffocating fish and disrupting the natural behaviors of aquatic organisms [8]. Certain pollutants can mimic or disrupt the natural hormones of aquatic organisms, causing reproductive and developmental abnormalities. These contaminants may also affect egg viability, resulting in lower hatching success and a decline in population [9]. Excessive nutrient runoff, mainly nitrogen and phosphorus from agricultural and urban sources, often triggers algal blooms. As these algae die and decompose, they consume oxygen, leading to hypoxic or anoxic conditions that can suffocate aquatic life. Additionally, sediment runoff from erosion can bury aquatic habitats, covering spawning grounds and depriving benthic organisms of oxygen [10].

Pollutants can disrupt organisms, causing behavioral changes that impair their ability to locate food, evade predators, or reproduce. Some pollutants also weaken the immune systems of aquatic life, increasing their vulnerability to diseases and infections. This can lead to a decline or even extinction of sensitive species, which reduces biodiversity and weakens ecosystem resilience. Changes in species composition and abundance can upset ecological interactions, resulting in imbalances within the ecosystem. Prolonged exposure to pollutants can cause population declines and degrade ecosystems. Additionally, certain pollutants may induce genetic mutations in aquatic organisms, potentially impacting future generations and reducing genetic diversity within populations.

Maintaining suitable dissolved oxygen (DO) levels is essential for safeguarding aquatic ecosystems and ensuring the well-being of water bodies. It is vital to regularly monitor and manage these levels to prevent issues like eutrophication and pollution, which can lead to dangerously low DO conditions [11]. Biochemical Oxygen Demand (BOD) is a key indicator in water quality management, offering essential insights into organic pollution levels and the health of aquatic ecosystems. Traditional methods for measuring BOD include the Dilution method, Manometric method, Respirometric method, and Electrode method. In the Dilution method, samples are incubated for a set period (5 days at 20 °C for BOD_5 in the standard test) in dark bottles. The initial and final oxygen levels are then measured using either an amperometric sensor or iodometric titration.

Uwidia and Ejeomo [12] investigated the correlation between COD and BOD_5 using domestic sewage samples from a sewage treatment plant. Their regression analysis revealed a robust correlation between these two parameters. Yang [13] employed Near-Infrared Spectrometry to simultaneously measure Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) in wastewater, achieving satisfactory results. Rudaru et al. [14] evaluated the biodegradability of various water types in Romania by analyzing the BOD_5/COD ratio (biodegradability index) and found that this ratio varied depending on the type of water studied.

Al-Sulaiman and Khudai [15] investigated the correlation between BOD_5 and COD in the sewage at the Al-Diwaniyah wastewater treatment plant and reported a high degree of correlation.

Alewi et al. [16] investigated the relationship between BOD_5 and COD in 108 water samples from Iraq's southern region, finding a strong correlation with a coefficient of 0.908 and a determination coefficient (R^2) of 0.89. In 2019, Andrio and others [17] demonstrated that ozonation pretreatment improved the BOD_5/COD ratio in co-substrates such as tofu wastewater and cow dung. Additionally, tannery wastewater with elevated BOD_5 levels was effectively treated using a ZnO-Zn/Fe_2O_4 composite photocatalyst supported on activated carbon, which removed 90 % of BOD_5 within two hours [18].

Ayawei and Bennett [19] measured Biochemical Oxygen Demand (BOD) levels in water samples from Ntanwoba Creek, Port Harcourt, Rivers State, Nigeria. They found elevated BOD values, which were linked to runoff wastewater from nearby agricultural activities and automobile workshops. In contrast, Kwak et al. [20] created software sensors using multiple regression analysis, incorporating dissolved organic carbon (DOC) concentration and UV light absorbance to estimate BOD_5 of river water. Their research demonstrated that these software sensors were effective in predicting BOD_5 levels in river water.

Dasgupta and Yildiz [21] investigated three types of wastewater in Morris County, USA, finding that industrial wastewaters exhibited the highest BOD_5 values, while pharmaceutical wastewaters had the lowest. Sha and Wei-Xing [22] used spectrophotometric titration to measure Biochemical Oxygen Demand in 20 waste samples within 40 minutes. Mohammed et al. [23] conducted kinetic studies on BOD_5, COD, and chromium removal in tannery effluent using a $ZnO/ZnFe_2O_4$ composite photocatalyst supported on activated carbon, reporting that the photodecomposition followed the pseudo first-order Langmuir-Hinshelwood model. Faiza et al. [24] documented BOD_5 values ranging from 5.04 to 6.18 mg/L in the Wupa River, Federal Capital Territory, Abuja, Nigeria, highlighting anthropogenic impacts on water quality. Yang [13] simultaneously determined Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) in wastewater using Near-Infrared Spectrometry.

Liu and Chen [25] predicted biochemical oxygen demand with genetic algorithm-based support vector regression, and reported that support vector regression (SVR) with genetic algorithm (GA) optimizer achieved the best performance with R^2 of 0.694. Qambar and Khalidy [26] proposed an integrated framework of remote sensing and machine-learning techniques to predict municipal wastewater influent biochemical oxygen demand (BOD_5) in wastewater treatment plants (WWTPs). They compared the performance of wastewater received by two WWTPs in South Kingdom of Bahrain with several supervised machine-learning algorithms and reported that the gradient boost algorithm model obtained the best results. Ngoc et al., [27] used simple BOD biosensor to estimate BOD_5 in food processing wastewater. They concluded that there was a statistical agreement between the results

Picture 1. Fresh fish harvested from Oka Creek during the 2024 fishing festival

obtained from the rapid BOD biosensor and the conventional methods, even with treated wastewater samples. Alotaibi and colleagues [28] used a High Salinity Bioreactor-Based, Wastewater Treatment Plant to correlate the results of Biochemical Oxygen Demand and Chemical Oxygen Demand and reported that R^2 values obtained made it impossible to predict the result of BOD_5 based on COD.

The aim of our research is to measure the Biochemical Oxygen Demand (BOD) levels of Oka Creek in Toru-Orua community of Bayelsa State, Nigeria, using the Winkler method. This river is unique due to its fishing prohibition until the ceremonial four-day fishing festival held annually on February 3rd. During this festival, the community celebrates with plentiful catches, as illustrated in Picture 1, which shows fish caught during the 2024 festival. By analyzing the BOD levels, the research aims to assess the water quality and its capacity to support aquatic life, especially in the context of the community's fishing practices and the annual festival.

2. MATERIALS AND METHODS

2.1 Meterials

All chemicals utilized in the experiments were of analytical reagent grade, sourced from Acros Organics, and were used as received without additional purification.

2.2 Methods

2.2.1 Reagents preparation

0.017 M potassium iodate (KIO_3): 0.89 g of KIO_3 was weighed and dissolved in distilled water in a volumetric flask, and the solution was made up to a total volume of 250 ml.

Alkaline Sodium Iodide (NaI): 5.6 g of sodium hydroxide and 16.6 g of potassium iodide were dissolved in distilled water, and the solution was diluted to a final volume of 100 ml with distilled water.

0.538 M manganese (II) sulphate tetrahydrate ($MnSO_4{\cdot}4H_2O$): 120 g of manganese (II) sulphate tetrahydrate was dissolved in distilled water, and the solution was brought up to a final volume of 250 ml.

Fresh starch solution: To prepare a fresh starch solution using established methods, 2.00 g of soluble starch was dissolved in a 100 ml conical flask. This solution was quickly poured into 250 ml of boiling water. The resulting mixture was boiled for an additional 5 minutes. After boiling, 0.02 g of sodium iodide was added, and the mixture was allowed to cool [29].

1.1 H_2SO_4 solution: 30 ml of concentrated sulfuric acid was transferred into a 100 ml flask, followed by the addition of 30 ml of distilled water.

0.1 M solution of sodium thiosulphate: 12.60 g of sodium thiosulfate was weighed and dissolved in distilled water. The solution was then made up to a total volume of 500 ml with distilled water.

Standardization of sodium thiosulfate ($Na_2S_2O_3$) using potassium Iodate (KIO_3):

Standardization of $Na_2S_2O_3$ was calculated using equation (1) and (2).

$$\frac{MS_2O_3{}^{2-}VS_2O_3{}^{2-}}{MIO_3{}^{-}\ VIO_3{}^{-}} = \frac{nS_3O_3{}^{2-}}{nIO_3{}^{-}} \quad (1)$$

$$MS_2O_3{}^{2-} = \frac{MIO_3{}^{-}\ VIO_3{}^{-}\ nS_3O_3{}^{2-}}{VS_2O_3{}^{2-}\ nIO_3{}^{-}} \quad (2)$$

Where

$MS_2O_3{}^{2-}$ is the molarity of sodium thiosulphate
$MIO_3{}^{-}$ is the molarity of the iodate
$VIO_3{}^{-}$ is the volume of the iodate
$VS_2O_3{}^{2-}$ is the volume of thiosulphate
$nIO_3{}^{-}$ is the number of moles of iodate and s the number of moles of thiosulphate
$nS_3O_3{}^{2-}$ is the number of moles of thiosulphate

To get $VS_2O_3{}^{2-}$, 25 ml of potassium iodate solution was transferred into a 250 ml volumetric flask. 5 ml of 1:1 H_2SO_4 and 15 ml of potassium iodide solution were added to the flask to liberate iodine (I_2). The liberated iodine was then titrated with sodium thiosulphate until a pale yellow solution was obtained. Three drops of freshly prepared starch solution were added, causing the solution to change to a dark greenish-blue color. The titration with sodium thiosulphate was continued until the solution turned colorless, indicating the endpoint. $ns_2O_3{}^{2-}$ and $nIO_3{}^{-}$ were obtained from equation (3).

$$IO_3{}^{-} + 6H + 6S_2O_3{}^{2-} \longrightarrow 3S_4O_6{}^{2-} + I^{-} + 3H_2O \quad (3)$$

2.3 Collection of Water Samples

Water samples were collected from four different locations and depths, Fig. 1, in Oka Creek, Toru-Orua, Sagbama Local Government Area, Bayelsa State, Nigeria, at four different times.

Each sample was transferred into 250 ml bottles labeled L1, L2, L3, and L4. The temperatures of the samples were recorded before transporting them to the laboratory for treatment and analysis. To minimize experimental errors, the time between sample collection and treatment was kept between 30 minutes and 2 hours [30].

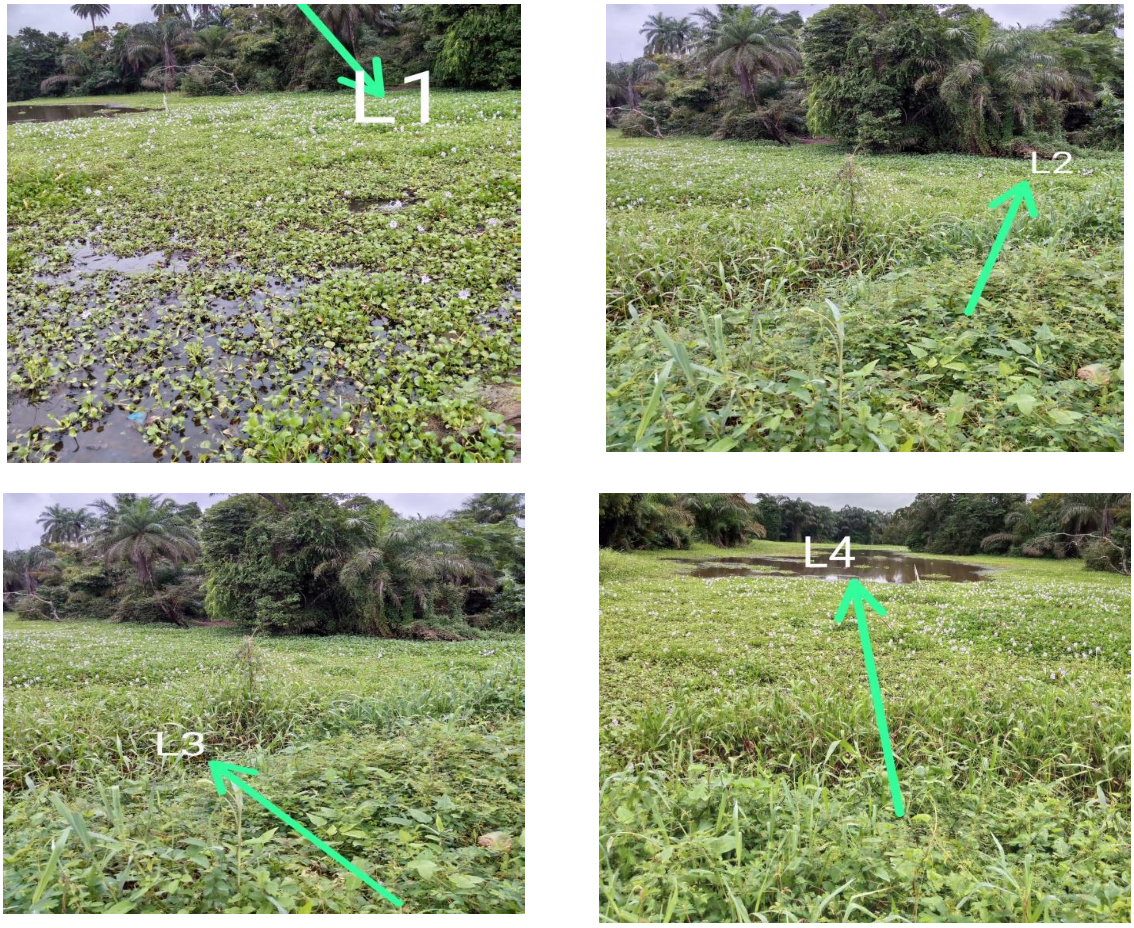

Fig. 1. Locations water samples were collected from in Oka Creek

2.4 Treatment of Water Samples

The Winkler titration method was used to determine the Biochemical Oxygen Demand (BOD) values of the water samples. Each sample was treated with 2 ml of alkaline NaOH solution, and the bottles were tightly sealed to eliminate air bubbles. The samples were manually equilibrated for 20 minutes, and inverted for 5 minutes. Following this, 2 ml of 1:1 H_2SO_4 was added, and the bottles were agitated and inverted again for 5 minutes. A clear yellow solution was achieved as the precipitates dissolved. The procedure was repeated three times, and the average BOD value was calculated.

25 mL of the treated water (first fraction) was titrated with a 0.0975 M $Na_2S_2O_3$ solution. The solution initially appeared pale yellow. Following this, 3 drops of freshly prepared starch solution were added, and the titration was continued with the $Na_2S_2O_3$ solution [31,32,33,34]. The method was performed in triplicate, and the average value was determined. Equation (4) was used to calculate the number of moles of $S_2O_3^{2-}$.

$$4I^- + O_2 + 4H^+ \longrightarrow 2I_2 + 2H_2O \qquad (4)$$

The second fraction of the treated samples were stoppered to avoid air penetration (oxidation) and incubated in a dark cupboard for five (5) days at 20°C. The samples were incubated to stall further photosynthesis process in the samples. At the end of day 5, the samples were analyzed to determine the final Dissolved Oxygen (DO). The difference between the initial dissolved oxygen and the final dissolved oxygen gave the investigated Biochemical Oxygen Demand (BOD) of the water samples [19].

The value of dissolved oxygen in the four locations was calculated using the formula:

$$BOD_5 = D_1 - D_2$$

Where BOD_5 = biochemical oxygen demand after incubation
D_1 = initial dissolved oxygen
D_2 = final dissolved oxygen.

3. RESULTS

Biochemical Oxygen Demand (BOD) levels were measured in water samples from Oka Creek, in Toru-Orua, Bayelsa State, Nigeria, using the Winkler titration method. All titrations were performed in triplicate and the results are as presented in Table 1, and graphically represented in Fig. 2,

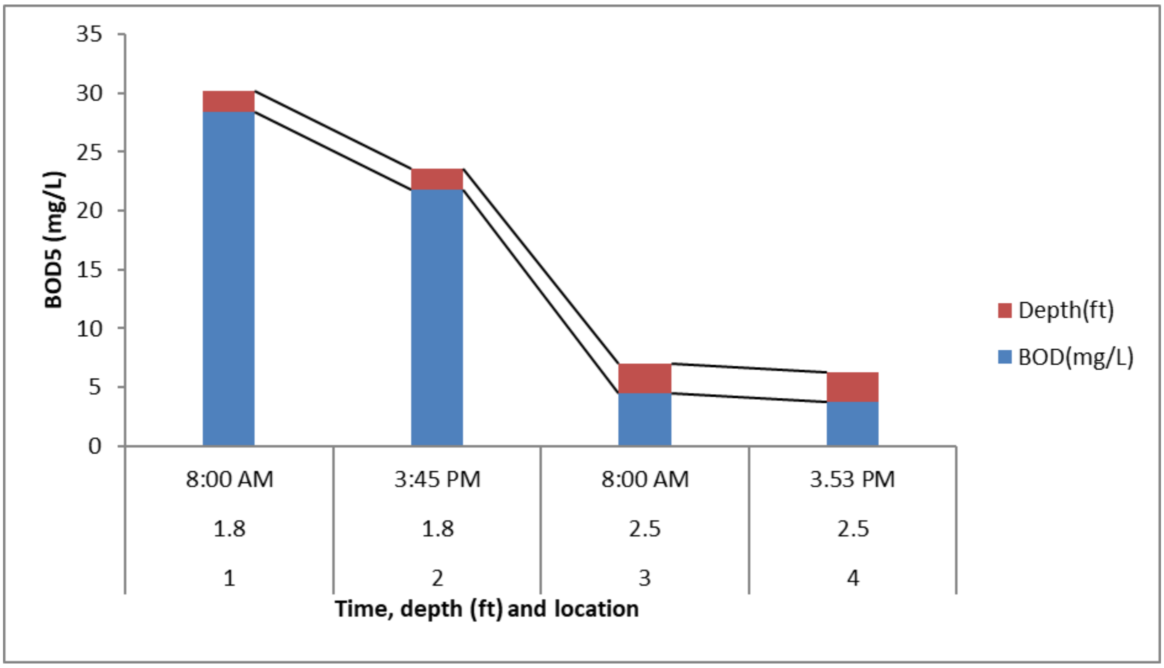

Fig. 2. Graphical representation of the data showing the depth and BOD_5 values at different locations, along with the time of sample collection from Oka Creek

Table 1. BOD_5 values in Oka Creek

S/N	Location	Depth(ft)	Time of sample collection (Central African Time)	D_1 (mg/L) Mean ± S.D	D_2 (mg/L) Mean ± S.D	BOD_5 (mg/L) Mean ± S.D
1.	L1	1.8	8:00 am	64.10 ± 0.03	35.72 ± 0.02	28.38 ± 0.01
2.	L2	1.8	3:45 PM	59.20 ± 0.02	37.44 ± 0.01	21.76 ± 0.01
3.	L3	2.5	8:00 am	25:30 ± 0.03	21:50 ± 0.01	4:50 ± 0.01
4.	L4	2.5	3:53 PM	19 34 ± 0.03	15.60 ± 0.02	3.74 ± 0.01

4. DISCUSSION

This study was conducted during the summer season in January 2024, just before the festive period in February, and the selection of 1.8 and 2.5 feet as sampling depths for BOD analysis in the Oka Creek was a deliberate choice aimed at capturing the variations in oxygen demand across distinct environmental conditions. By selecting these depths, the study leveraged the anticipated differences in light penetration, photosynthetic activity, and human impact at the 1.8-foot level, as well as the expected reduction in these factors at the 2.5-foot level. The 1.8-foot depth, closer to the surface, was expected to reflect higher BOD levels due to the more pronounced influence of these environmental variables. Meanwhile, the 2.5-foot depth, representing a slightly deeper zone, was anticipated to reveal lower BOD values as a result of the better mixing and reduced accumulation of organic matter. This strategic depth selection allowed for a comprehensive analysis of how BOD varies with depth, providing critical insights into the Creek's oxygen dynamics under varying environmental conditions.

The results as presented in Table 1 and Fig. 1, demonstrate how location, depth, water flow rate, time of sampling, and temperature significantly affect BOD values and, consequently, the health of the aquatic ecosystem.

Location L1 recorded the highest BOD value of 28.38 mg/L, indicating severe organic pollution. This sample was collected from a relatively stagnant area at sunrise with a temperature of 25 °C. The absence of sunlight at sunset reduced photosynthetic activity, which typically contributes to oxygenation of the water. Consequently, there was an increased consumption of dissolved oxygen by microorganisms decomposing organic material, leading to the high BOD value. The elevated BOD levels reflect substantial pollution from sources such as sludge deposits, domestic sewage, and agricultural runoff. Such high levels of organic matter can severely deplete the dissolved oxygen in the water, creating an environment that is detrimental to fish and other aquatic organisms that rely on oxygen for survival. The results suggest that the ecological health of this area is significantly compromised due to high pollution levels.

Location L2 had a BOD value of 21.76 mg/L, measured at midday with a temperature of 35 °C. The increase in temperature and sunlight during midday enhances photosynthesis, which can lead to an increase in dissolved oxygen and a slight reduction in BOD compared to L1. Despite this improvement, the BOD value at L2 remains elevated, indicating continued significant organic pollution. The slightly reduced BOD levels compared to L1 highlight that while increased sunlight can help mitigate some of the pollution effects, it is not sufficient to bring the BOD within acceptable limits. The persistence of high BOD values at L2 underscores the need for addressing pollution sources to improve water quality.

Location L3 exhibited a lower BOD value of 4.50 mg/L, with the sample taken from a deeper, stagnant area at sunrise and a temperature of 25 °C. Although the sample was collected at a time similar to L1, the lower BOD at L3 suggests that the impact of organic pollutants was less severe. This can be attributed to the higher water flow rate at L3, which likely facilitated the dispersion of pollutants and reduced bacterial loads. Additionally, the depth of the water at L3 may have contributed to better mixing, preventing the accumulation of high concentrations of organic matter. The lower BOD indicates that the water quality at L3 is relatively better, and the conditions are more favorable for aquatic life compared to L1 and L2.

Location L4 had the lowest BOD value of 3.74 mg/L, sampled at midday with a temperature of 35 °C. The combination of increased sunlight and a higher water flow rate promoted photosynthesis and further reduced the BOD.

The deeper water at L4 likely contributed to better mixing and reduced accumulation of organic matter, resulting in significantly improved water quality. The low BOD value at L4 reflects minimal impact from organic pollution, suggesting that this location offers a healthier environment for aquatic organisms. The conditions at L4 are more favorable compared to the other locations, supporting the notion that sunlight and water flow play crucial roles in improving water quality.

Overall, the high BOD values at Locations L1 (28.38 mg/L) and L2 (21.76 mg/L) exceed the acceptable limits [19] for aquatic life, indicating severe organic pollution that could adversely affect fish and other aquatic species. In contrast, the lower BOD values at Locations L3 (4.50 mg/L) and L4 (3.74 mg/L) are within acceptable limits, reflecting better water quality and a more suitable environment for aquatic organisms. The yearly bountiful fish harvest in these locations could be attributed to these favorable conditions.

These findings emphasize the critical need for targeted pollution management strategies to address the sources of high BOD and to improve overall water quality in the Oka Creek. Effective pollution control measures and continuous monitoring are essential to maintaining the health and sustainability of the Creek's ecosystem. Addressing the identified pollution sources, enhancing water flow, and increasing sunlight exposure in polluted areas could help mitigate the adverse effects and ensure the long-term viability of aquatic life in the creek [35].

5. CONCLUSION

This study assessed the Biochemical Oxygen Demand (BOD) levels in the Oka Creek at Toru-Orua, Bayelsa State, Nigeria, revealing significant spatial and temporal variations influenced by environmental factors such as location, depth, water flow rate, time of sampling, and temperature. Location L1 recorded the highest BOD value of 28.38 mg/L, indicating severe organic pollution, likely due to sludge deposits, domestic sewage, and agricultural runoff. The high BOD levels at L1, coupled with stagnant water and minimal sunlight, pose a substantial threat to aquatic life, far exceeding acceptable limits for fish growth.

In contrast, Location L4 exhibited the lowest BOD value of 3.74 mg/L, reflecting significantly improved water quality. This low BOD is attributed to conditions favoring photosynthesis, such as increased sunlight and higher water flow, which help to reduce organic pollution. The moderate BOD values at Locations L2 and L3, 21.76 mg/L and 4.50 mg/L respectively, further highlight the influence of environmental factors on water quality, with L2 still showing notable pollution and L3 indicating more favorable conditions.

These findings emphasize the critical need for targeted environmental management strategies, particularly in areas with high BOD values, to mitigate pollution and safeguard aquatic ecosystems. Continuous monitoring of BOD levels is essential to ensure sustainable water quality and preserve the ecological health of the Oka Creek.

6. RECOMMENDATION

To improve water quality in the Oka Creek, reduce pollution by improving waste management and enforcing discharge regulations, enhance flow by increasing water circulation in stagnant areas, promote vegetation by establishing buffer zones to absorb runoff, monitor regularly by tracking BOD and water quality, and engage the community through education and involvement.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. LennTech. "Oxygen (O) and Water" Available:https://www.lenntech.com › periodic › oxygen-and-water. Accessed 10 June 2024
2. pHionics. "Factors Affecting Dissolved Oxygen". Available:https://www.phionics.com › Accessed 10 June 2024
3. IN.gov. "Nonpoint Source Environmental Parameters".

Available:https://www.in.gov › idem › nps › nonpoint-source-envi. Accessed 29 July 2024

4. Sasakova N, Gregova G, Takacova D, Mojzisova J, Papajova I, venglovsky J, szaboova T, Kovacova S. Pollution of Surface and Ground Water by Sources Related to Agricultural Activities. Frontiers in Sustainable Food system. 2018;(2):1-11.
5. Sawyer NC; McCarty LP; Parkin FG. Chemistry for environmental engineering and science (5th ed.). New York: McGraw-Hill. ISBN 978-0-07-248066-5.; 2003.
6. United State Environmental Protection Agency. Toxics in the Food Web. Available:https://www.epa.gov › salish-sea › toxics-food-web. Accessed 11 June 2024
7. AtlasScientific. 7 effects of water pollution; 2023. Available:https://atlas-scientific.com. Accessed 11 June 2024
8. Perhar G, Arhonditsis GB. Aquatic ecosystem dynamics following petroleum hydrocarbon perturbations: A review of the current state of knowledge. Journal of Great Lakes research. 2014;40(3):56-72.
9. Gonsioroski A, Mourikes VE, Flaws JA. Endocrine disruptors in water and their effects on the reproductive system. International Journal of Molecular Science. 2020;21(6):1929.
10. Devlin M, Brodie J. Nutrients and Eutrophication. In: Reichelt-Brushett, A. (eds) Marine Pollution – Monitoring, Management and Mitigation. Springer Textbooks in Earth Sciences, Geography and Environment. Springer, Cham; 2023.
11. Akinnawo SO. Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. Environmental Challenges. 2023;(12):100733.
12. Uwidia I, Ejeomo C. Prediction of five-day biochemical oxygen demand (BOD5) from chemical oxygen demand (COD) values in raw and biologically treated domestic sewage. Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences. 2015;58(3):172-174.
13. Yang Q. Simultaneous determination of chemical oxygen demand (COD) and biological oxygen demand (BOD_5) in wastewater by near-infrared spectrometry. Journal of Water Resource and Protection. 2009;1(4):286-289.
14. Rudaru D, Lucaciu IE, Fulgheci A. Correlation between BOD_5 and COD – biodegradability indicator of wastewater. Romanian Journal of Ecology & Environmental Chemistry. 2022;4(2):80-86.
15. Al-Sulaiman AM, Khudai BH. Correlation between Bod_5 and Cod For Al-Diwaniyah Wastewater Treatment Plants To Obtain The Biodigrability Indices. Pakistan Journal of Biotechnology. 2018;15(2):423-427.
16. Alewi H, Obeed W, Abdulridha M, Ali G. An inquiry into the relationship between water quality parameters: Biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) in Iraqi Southern region. AIP Conf. Proc. 2404080007; 2021.
17. Andrio D, Asmura J, Yenie E, Putri K. Enhancing BOD_5/COD ratio co-substrate tofu wastewater and cow dung during ozone pretreatment. MATEC Web of Conferences. 2019;276:60270.
18. Mohammed HA, Hamza A, Adamu IK, Ejila A, Waziri SM, Mustapha SI. BOD_5 removal from tannery wastewater over ZnO-$ZnFe_2O_4$ composite photocatalyst supported on activated carbon. Chemical Engineering and Materials Science. 2013; 4(6):80-86.
19. Ayawei N, Bennett V. Investigation of biochemical oxygen demand (BOD) in ntanwoba creek using dilution method. Research and Reviews: Journal of Chemistry. 2022;11(5):1-5.
20. Kwak J, Khang B, Kim E, Kim H. Estimation of biochemical oxygen demand based on dissolved organic carbon, UV absorption, and fluorescence measurements. Hindawi Publishing Corporation Journal of Chemistry. 2012; (2013):1-9.
21. Dasgupta M, Yildiz Y. Assessment of biochemical oxygen demand as indicator of organic load in wastewaters of Morris County, New Jersey, USA. Journal of Environmental Analytical Toxicology. 2016; 6(3):378.
22. Sha OU and Wei-Xing MA. Spectrophotometric Determination of Biochemical Oxygen Demand in Water Sample by I3 – - Acridine Red-Polyvinyl Alcohol System. Asian Journal of Chemistry. 2011;23(8):3576-3580.
23. Mohammed AH, Hamza A, Waziri SM, Adamu IK, Ejila. A. Kinetic studies of BOD_5, COD and Chromium removal in tannery effluent using ZnO-$ZnFe_2O_4$ composite photocatalyst supported on activated carbon. International Research Journal of Engineering Science,

Technology and Innovation. 2014;3(3):31-34.
24. Faiza M, Adamu KM, Yakubu MM. Anthropogenic impact on some water quality characteristics of wupa river federal capital territory, Abuja, Nigeria. Biological Sciences and Pharmaceutical Research. 2022;10(3):30-38.
25. Liu YZ and Chen Z. Prediction of biochemical oxygen demand with genetic algorithm-based support vector regression. Water Quality Research Journal. 2023; 58(2):87–98.
26. Qambar AS and Khalidy MMA. Prediction of municipal wastewater biochemical oxygen demand using machine learning techniques: A sustainable approach. Process Safety and Environmental Protection. 2022;(168):833-845.
27. Ngoc LTB, Tu TA, Hien LTT, Linh DN, Tri N, Duy NPH, Cuong HT, Phuong PTT. Simple approach for the rapid estimation of BOD_5 in food processing wastewater. Environmental Science and Pollution Research International. 2020;(27):20554–20564.
28. Alotaibi M, Munshi F, Refaat A, Said ME, Nasir M. Correlation between biochemical oxygen demand and chemical oxygen demand, at high salinity bioreactor-based, wastewater treatment plant in Al-Hasa Saudi Arabia. Journal of Water. 2023; 1(2):35-47.
29. Ratnayake SW, Jackson SD. Starch gelatinization. Advances in Food and Nutrition Research. 2009;(55): 221-68.
30. Tuser C. What is Biological Oxygen Demand (BOD)? Wastewater Digest Available:https://www.wwdmag.com › utility-management › article; 2009. Accessed 29 July 2024.
31. Carvalho A, Costa R, Neves S, Oliveira MC, Bettencourt da Silva JNR. Determination of dissolved oxygen in water by the Winkler method: Performance modelling and optimisation for environmental analysis. Microchemical Journal. 2021;(165):106129.
32. Helm I, Jalukse L, Vilbaste M, Leito I. Micro-Winkler titration method for dissolved oxygen concentration measurement. Analytica Chimica Acta. 2009;648(2):167-73.
33. Jouanneau S, Recoules L, Durand M, Boukabache A, Picot V, Primault Y, Lakel A, Sengelin M, Barillon B, Thouand G. Methods for assessing biochemical oxygen demand (BOD): A Review. Water Research. 2014;(49)62–82
34. Susilowati S, Sutrisno J, Masykuri M, Maridi M. Dynamics and factors that affects DO-BOD concentrations of Madiun River. AIP Conf. Proc. 2018;2049: 020052.
35. Water Education Foundation. Biochemical Oxygen Demand. Available:https://www.watereducation.org › aquapedia-background Accessed 29 July 2024.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121758