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Evaluation of Heavy Metal Concentrations in Drinking Waters from Poultry Sites, in Crude Oil Exploration Areas of Delta State, Nigeria

Jerome U. Unukevwere[1], O. Everest Atadiose[2], Oghenebrorhie Obakanurhe[3], Ufuoma G. Sorhue[4], and Olatunbosun Odu[5]

[1,2,4]Department of Animal Science, Delta State University, Abraka, Nigeria.
[3]Department of Animal Science, Dennis Osadebe University, Asaba, Nigeria.
[5]Department of Animal Science, University of Ibadan, Nigeria.
Corresponding Author email: unukesjrom@delsu.edu.ng

ABSTRACT

This study examined the levels of Heavy Metal Concentration (HMC): Cadmium (Cd), Iron (Fe), Nickel (Ni), Vanadium (V) and Mercury (Hg), in drinking water across poultry farm locations, associated with crude oil exploration activities in Delta State, Nigeria. Drinking Water (DW) contamination due to heavy metals is a common occurrence in industrialized, oil exploration areas of Niger Delta and this poses a significant threat to animals and public health. Fifteen poultry sites were purposively selected based on the intensity of crude oil exploration and grouped into five zones: Urhobo, Isoko, Ijaw, Itsekiri, and Ukwani. Samples of DW were collected from three poultry sites in each zone and analyzed for HMC (ppm) and results compared with World Health Organization (WHO) standards. Data were analyzed using descriptive statistics and ANOVA (α0.05). Vanadium (V), Cadmium (Cd), Iron (Fe), Nickel (Ni), and Mercury (Hg) concentrations (ppm) in DW ranged from 0.055 (Ukwani) to 29.189 (Itsekiri) V, 8.752 (Ijaw) to 15.682 (Urhobo) Cd, while Fe ranged from 577.10 (Ukwani) to 2002.20 (Isoko). Values of HMC were significantly (P<0.05) higher than the WHO tolerable limits of 0.34 (vanadium), 0.005 (cadmium), and 0.30 (iron) respectively. However, values of Nickel ranged from 0.003 (Ukwani) to 0.017 (Ijaw), while Hg ranged from 0.001 (Urhobo; Ijaw) to 0.030 (Itsekiri), these values were below the WHO recommended limits for water. Crude oil exploration in the Niger Delta, particularly in Delta State, have contributed to increased concentration of heavy metals in the environment, resulting in contamination of drinking water supplied in poultry farms thus, endangering the health of livestock being raised and quality of animal products from the region.

Keywords: *Concentration, metals, pollution, spillage, water*

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INTRODUCTION

Pollution of the environment caused by petrochemical resource development and exploitation activities has resulted in decline of agricultural productivity and a major disastrous impact on the host populations as a result, livestock and people living in the Niger Delta of Nigeria have been adversely affected (Unukevwere et al., 2025, Moslen et al., 2024, Rahman and Singh, 2019). Petroleum resource exploration activities are clearly the causes of majority of the environmental risks in the region (Adewuyi et al., 2012). Substantial environmental deterioration caused by the commercial activities of numerous corporations and organizations in the fossil fuel industry has been found to have negative repercussions on the environment (Nwankwo et al., 2023). Extensive crude oil spillage, seepage, gas flaring, petrochemical effluents, and other industrial wastes release heavy metals, leading to significant environmental and water pollution (Nnaemeka-Okeke and Okeke, 2024). Gas flaring in the Niger Delta also causes acid rain, which further contributes to biodiversity loss, water and crops contamination. Rainwater absorbs impurities from the atmosphere during downpours, resulting in higher concentrations of acid or salts in the region, with levels decreasing further away from the Niger Delta (Nnaemeka-Okeke and Okeke, 2024, Amadi and Enyi, 2024). Therefore, the Niger Delta experiences higher concentrations of acid concentration in rainwater compared to other regions.

Pollution of drinking water sources is a recurrent phenomenon in the Niger Delta where most of the drinking water is got from boreholes, wells, streams, uncontained aquifers and shallow water sources for both urban and rural dwellers (Rahman and Singh, 2019, Udofia et al., 2019). Water and food contamination by heavy metals is a major threat to animal and human wellbeing because of their bio-accumulation and bio-magnification along water channels, the food chain and subsequent toxicity in the body. Heavy metals are metallic elements with an average density nearly five times that of water, and they have substantial adverse toxic effects on humans, animals, and the environment even at low concentrations, including those considered as essential minerals (Bhat et al., 2019). These contaminations pose serious health and safety risks to animals, humans, and the ecosystem, particularly in areas with active oil exploration. These water pollutants pose a dangerous threat to the livestock sector, both now and in the future, and it has negative impacts on all aspects of life, including reproduction, growth, and development, affecting not only animals but also humans. The major impact of heavy metals in the human body system involves direct inhibition of enzyme activities and the indirect alteration of equilibrium of the essential metallic ions (Zoroddu et al., 2019).

Environmental studies have revealed the negative impacts emanating from crude oil exploration, oil spillage, petrochemical effluents and wastes on water and food (Unukevwere et al., 2025; Ukhurebor et al., 2021, Ogolo et al., 2022, Dey et al., 2024, Udousor, 2015). The contamination of soil and the food chain by heavy metals has raised serious concerns among researchers. Several authors have reported higher levels of heavy metals, in food crops in areas with intense industrial settlements and operations in Niger Delta compared to areas with no crude oil industrial activities (Amadi and Enyi, 2024, Richard et al., 2022). These negative impacts caused by petroleum activities on drinking water available for poultry have not been evaluated. However, there are still paucity of literatures about the effects of heavy metal concentrations in drinking water of poultry due to crude exploration in the Niger Delta. Thus, this study aims to assess the levels of selected heavy metals in the drinking water of poultry in crude oil exploration areas of Delta State, Nigeria.

MATERIALS AND METHODS

Ethical approval

The current study was conducted following all procedures in accordance with the guidelines approved by the Research and Ethics Committee of the Teaching and Research Farm, University of Ibadan, Nigeria (AWE2018/0013478).

Location of study

This study was conducted in fifteen crude oil exploration locations in Delta State, Nigeria. These locations were purposively selected based on the intensity and history of crude oil exploration and spillages. The selected locations include; Orogun, Ubogo, Jesse, Ubeji, Koko, Omadino, Ogulaha, Burutu, Ogbe-ijoh, Igbide, Oleh, Uzere, Kwale, Ubiarukor, Amai, and so on. These locations were further grouped into five agricultural zones: Urhobo, Isoko, Ijaw, Itsekiri, and Ukwani of Delta State. Each zone consisted of three locations where this study was carried out.

Collection of water samples

Samples of drinking water were collected from a poultry farm in each community, with three communities per zone across five zones undergoing crude oil exploration activities in Delta State. A total of 500mL of drinking water was obtained from the primer head of each borehole and transferred into a well labelled cleaned glass container. The containers were properly capped and immediately transported to the laboratory for the determination of Heavy Metal Concentrations (HMC) in parts per million (ppm), following standard procedures (AOAC, 2005).

Digestion of water samples

The water sample was measured into a volumetric flask, which contained 100 mL. Then, 2mL of concentrated nitric acid was added. To prevent the escape of volatile heavy metals, the flask was covered with a glass lid and heated at low to moderate heat until it reached a volume of 50mL. After heating, the flask was allowed to cool. The digested sample was transferred into a 100 mL volumetric bottle through a Whattman filter paper. To reach the mark, 2% nitric acid was added. The 2% nitric acid was prepared by diluting 20 mL of concentrated nitric acid in a 1 liter volumetric bottle with distilled water. To validate the digestion method, a recovery test was conducted to determine if a good percentage of the metals were recovered or lost during the digestion process. The Atomic

Absorption Spectrometer (AAS) was used to verify by running several samples multiple times and calculating their variation coefficients (Umeoguaju et al., 2022). A variation coefficient of approximately 10% indicates good precision for both instruments and methods used.

Chemical analysis

Digested water samples were analyzed according to (AOAC, 2005) guidelines. The concentration of heavy metals, including vanadium (V), cadmium (Cd), iron (Fe), nickel (Ni), and mercury (Hg), was determined using an Atomic Absorption Spectrophotometer (AAS) (model AA 701). The results were compared to the recommended acceptable limits for drinking water by the World Health Organization (WHO).

Statistical Analysis

Analysis of the data was carried out using ANOVA, while separation of means was done using Fisher's Least Significant Difference (LSD) on (Statistical software (SAS) (1999)).

RESULTS

Heavy Metal Concentrations (ppm) in Water Samples in Zone One (Urhobo)

The heavy metal concentrations in samples of drinking water from Zone One are presented in (Table 1). In zone one, the concentration of HM in drinking water samples ranged from 0.031 (Udu) to 0.105 (Orogun) for vanadium, 12.57 (Orogun) to 17.47 (Udu) for cadmium. The highest value (1353.3) was recorded in Orogun, while the lowest was observed in Udu (206.6) for iron (Fe). The levels of nickel (Ni) in the water samples showed no significant ($P<0.05$) variation across the different locations. However, the levels of mercury (Hg) in Orogun (0.012) were significantly higher ($P<0.05$) when compared to those in Udu (0.009) and Jesse (0.006), respectively. These results indicate that the concentrations of vanadium (V), nickel (Ni), and mercury (Hg) in the drinking water samples from poultry farms in Zone One were below the tolerable range set by WHO. On the other hand, the concentrations of cadmium (Cd) and iron (Fe) exceeded the recommended limits.

Heavy Metal Concentration (ppm) in Water Samples from Zone Two (Isoko)

Table 2 presents the levels of Cadmium (Cd), Vanadium (V), Iron (Fe), Nickel (Ni), and Mercury (Hg) in drinking water samples in zone two. The Vanadium concentration had a significantly ($P<0.05$) higher value of 6.72 (Uzere) compared to Oleh (0.02) and Igbide (0.13), respectively. The cadmium concentration was significantly ($P<0.05$) lower in Igbide (14.88) than in Oleh (16.12) and Uzere (16.45), with no significant ($P<0.05$) variations between Oleh (16.12) and Uzere (16.45). The HMC in water ranged from 165.0 (Oleh) to 1445.0 (Igbide) for Fe, and from 0.007 (Uzere) to 0.021 (Oleh) for Ni, with Uzere having the lowest concentration. Similarly, the Hg content in water samples from Oleh (0.003) had the lowest concentration, while Igbide (0.016) and Uzere (0.015) did not show any significant ($P<0.05$) variation between them. These results indicate that the V, Ni, and Hg concentrations in the drinking water samples from poultry farms in zone one was below the WHO tolerable range, while those of Cd and Fe were above the recommended limits.

Heavy Metal Concentrations (ppm) in Drinking Water from Zone Three (Itsekiri)

Table 3 shows heavy metal concentrations in the water sample from zone three, and the levels of HMC in the water samples had significant ($P<0.05$) variation across the locations. The HMC in water ranged from 14.49 (Ubeji) to 23.97 (Koko) for vanadium, the Cadmium level was lowest at 13.60 (Ubeji) and highest at 14.91 (Koko). Also, levels of iron were at least 310.00 (Ubeji) and highest at 1413.00 (Koko), However, the levels of Nickel were highest at 0.02 (Koko) and differed significantly ($P<0.05$) from those observed in Ubeji (0.01) and Omadino (0.01) respectively. While, the mercury level was highest at 0.06 in Omadino, with the least (0.01) concentration observed in Koko.

Heavy Metal Concentrations (ppm) in Water from Zone Four (Ijaw)

The levels of HMC in water samples from Ijaw are shown in (Table 4). The concentrations of vanadium in Ogulaha (0.07) and Ogbe-ijoh (0.07) respectively were not significantly ($P<0.05$) different from each other, but were higher than the value obtained in Burutu (0.04). Cadmium concentration in Burutu (9.03) and Ogbe-ijoh (9.06) did not indicate significant ($P<0.05$) variation between them, both were higher and varied significantly ($P<0.05$) from that of Ogulaha (8.17). However, iron concentration ranged from 340.00 (Ogbe-ijoh) to 849.67 (Ogulaha) in drinking water samples. Similarly, the levels of Nickel in water were the least (0.00) in Ogbe-ijoh and highest (0.03) in Burutu. Water samples contained mercury concentrations ranged from 0.00 in Ogbe-ijoh and Burutu to 0.01 in Ogulaha.

Heavy Metal Concentrations (ppm) in Water Samples from Zone Five (Ukwani)

Table 5 presents the heavy metal concentrations in drinking water from zone five. The values of HMC in drinking water ranged from 0.01 (Ubiaroko) to 0.13 (Amai) for Vanadium, and 9.75 (Ubiaroko) to 14.09 (Amai) for Cadmium. Similarly, Iron concentrations ranged from 150.00 (Kwale) to 1308.00 (Ubiaroko). However, the levels of Nickel in water samples were not significantly ($P<0.05$) different from one another. Also, level of mercury in Kwale (0.03) was noticed to be higher and varied significantly ($P<0.05$) when compared with those from Ubiaroko (0.01) and Amai (0.01) respectively.

Table 1: Heavy Metal Concentrations (ppm) in Water Samples from Zone One (Urhobo).

Parameters	Udu	Orogun	Jesse	SEM	Permissible Limits
Vanadium	0.031^{c}	0.105^{a}	0.065^{b}	0.011	0.09-0.34
Cadmium	17.467^{a}	12.567^{b}	16.903^{a}	0.792	0.00-0.005
Iron	206.6^{c}	1353.3^{a}	446.7^{b}	21.425	0.30
Nickel	0.010	0.011	0.007	0.002	0.00-1.12
Mercury	0.009^{b}	0.012^{a}	0.006^{b}	0.003	1.00-2.68

abc: means within the rows with different superscripts are different significantly ($P<0.05$). MSE: Mean Standard Error. Permissible limits of heavy metals (ppm) in water [abc: means along the same row with the same superscripts are not significantly ($P<0.05$). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)].

Table 2: Heavy Metal Concentrations in Water Samples from Zone Two (Isoko).

Parameters	Oleh	Igbide	Uzere	SEM	Permissible Limits
Vanadium	0.02^{b}	0.13^{b}	6.72^{a}	0.946	0.09-0.34
Cadmium	16.120^{a}	14.883^{b}	16.453^{a}	0.249	0.00 - 0.005
Iron	165.0^{b}	1445.0^{a}	1408.0^{a}	203.189	0.30
Nickel	0.021^{a}	0.011^{b}	0.007^{c}	0.002	0.00-1.12
Mercury	0.003^{b}	0.016^{a}	0.015^{a}	0.003	1.00 - 2.68

abc: means within the rows with different superscripts are different significantly ($P<0.05$). MSE: Mean Standard Error. Permissible limits of heavy metals (ppm) in water [abc: means along the same row with the same superscripts are not significantly ($P<0.05$). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)].

Table 3: Heavy metal concentrations (ppm) in water from zone three (Itsekiri).

Parameters	Koko	Ubeji	Omadino	SEM	Permissible Limits
Vanadium	23.97^{a}	14.49^{c}	20.10^{b}	3.71	0.09-0.34
Cadmium	14.91^{a}	13.60^{b}	13.95^{b}	2.04	0.00–0.005
Iron	1413.00^{a}	310.00^{c}	1263.00^{b}	81.80	0.300
Nickel	0.02^{a}	0.01^{b}	0.01^{b}	0.01	0.00-1.12
Mercury	0.01^{c}	0.03^{b}	0.06^{a}	0.01	1.00–2.68

abc: means within the rows with different superscripts are different significantly ($P<0.05$). MSE: Mean Standard Error. Permissible limits of heavy metals (ppm) in water [abc: means along the same row with the same superscripts are not significantly ($P<0.05$). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)].

Table 4: Heavy Metal Concentrations (ppm) in Water from Zone Four (Ijaw).

Parameters	Ogulaha	Ogbe-ijoh	Burutu	SEM	Permissible Limits
Vanadium	0.07^{a}	0.07^{a}	0.04^{b}	0.00	0.09-0.34
Cadmium	8.17^{b}	9.06^{a}	9.03^{a}	0.15	0.00–0.005
Iron	849.67^{a}	340.00^{c}	670.00^{b}	74.69	0.30
Nickel	0.02^{a}	0.00^{b}	0.03^{a}	0.00	0.00-1.12
Mercury	0.01^{a}	0.00^{b}	0.00^{b}	0.00	1.00-2.68

abc: means within the rows with different superscripts are different significantly ($P<0.05$). MSE: Mean Standard Error. Permissible limits of heavy metals (ppm) in water [abc: means along the same row with the same superscripts are not significantly ($P<0.05$). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)].

Table 5: Heavy Metal Concentrations (ppm) in Water Samples in Zone Five (Ukwani)..

Parameters	Kwale	Ubiaruko	Amai	SEM	Permissible Limits
Vanadium	0.05^{b}	0.01^{c}	0.13^{a}	0.02	0.09-0.34
Cadmium	11.58^{b}	9.73^{c}	14.09^{a}	0.63	0.00–0.005
Iron	150.00^{b}	1308.00^{a}	273.33^{b}	185.37	0.30
Nickel	0.01	0.01	0.01	0.00	0.00-1.12
Mercury	0.03^{a}	0.01^{b}	0.01^{b}	0.01	1.00-2.68

abc: means within the rows with different superscripts are different significantly ($P<0.05$). MSE: Mean Standard Error. Permissible limits of heavy metals (ppm) in water [abc: means along the same row with the same superscripts are not significantly ($P<0.05$). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)].

Heavy Metal Concentrations (ppm) in Water from Five zones in Delta State

The concentrations of Vanadium, Nickel, Iron, Mercury and Cadmium in drinking water from five zones within Delta State are shown in (Table 6). Significant ($P<0.05$) differences were observed across the zones. Water samples from Isoko (22.29) and Itsekiri (29.19), had the highest values for vanadium compared to those of Urhobo (0.067), Ijaw (0.059), and Ukwani (0.055). Cadmium levels

Table 6: Heavy Metal Concentrations (ppm) in Water in Five Zones in Delta State.

Parameter	Urhobo	Isoko	Itsekiri	Ijaw	Ukwani	SEM	*P. Limits
Vanadium	0.067^{b}	22.290^{a}	29.189^{a}	0.059^{b}	0.055^{b}	2.261	0.09-0.34
Cadmium	15.682^{a}	14.819^{a}	12.317^{b}	8.752^{c}	11.800^{bc}	0.828	0.00-0.005
Iron	1334.6^{ab}	2002.2^{a}	1162.0^{ab}	619.9^{b}	577.1^{b}	118.127	0.3
Nickel	0.010^{ab}	0.013^{a}	0.001^{b}	0.017^{a}	0.003^{b}	0.002	0. 00-1.12
Mercury	0.001^{b}	0.009^{b}	0.030^{a}	0.001^{b}	0.003^{b}	0.002	1.00-2.68

abc: means along the same row with the same superscripts are not significantly (P<0.05). SEM: Standard Error of Mean. *P: Permissible limits (World Health Organization, WHO (2004; World Health Organization, WHO (2008)).

15.68 (Urhobo) and 14.82 (Isoko) were similar, and both were significantly (P<0.05) higher when compared to those observed in Itsekiri (12.32), Ijaw (8.75) and Ukwani (11.80), respectively. Iron concentrations, 2002.20 (Isoko) presented a significantly (P<0.05) higher value than those of Ijaw (619.9) and Ukwani (577.1), but not significantly (P<0.05) different from those in Urhobo (1334.6) and Itsekiri (1162.0). For Nickel, there was no significant (P<0.05) difference between Isoko (0.013) and Ijaw (0.017), while both were significantly (P<0.05) higher when compared with those of Itsekiri (0.001) and Ukwani (0.003) respectively. However, Urhobo (0.001), Isoko (0.009), Ijaw (0.001), Ukwani (0.003) and Ika (0.002) were signisficantly (P>0.05) lower when compared with values in Itsekiri (0.030) for mercury concentrations in drinking water.

DISCUSSION

Results of the drinking water samples taken from different zones of Delta state with crude oil exploration activities showed varying concentrations (ppm) of vanadium, cadmium, iron, nickel, and mercury. The results indicated that high levels of heavy metals were present in the water samples taken from poultry sites across the zones. Specifically, vanadium, cadmium, and iron exceeded the permissible limits set by national and international standard organizations (World Health Organization, WHO (2008)). These results were significantly higher compared to the findings of (Ezekwe et al., 2014) for a polluted freshwater marsh in the Mgbede oil field, South-South Nigeria. In a recent study by (Akaninyene et al., 2022), they reported higher levels of metals in the affected location compared to the control, indicating that the spilled oil within the area perhaps infiltrated via the soil into the aquifer, thus increasing heavy metals concentrations in the water.

Furthermore, the samples of drinking water taken from farm sites in Isoko and Itsekiri exceeded the permissible limits for vanadium, while iron and cadmium concentrations in water samples from the zones studied in Delta state were all above the recommended values. These results in this investigation were higher than those reported by (Akaninyene et al., 2022) for heavy metals in boreholes near mining villages in Northern Ghana. This indicates water contamination and poor water quality in the study area against the standards requirement (World Health Organization, WHO (2004). These findings are supported by (Eyankware et al., 2023), who reported high levels of iron in water from hand dug wells and some boreholes. Iron is an essential dietary element, an important component of haemoglobin in human and animal bodies. Iron facilitates the oxidation of carbohydrates, proteins, and fats to control body weight (Lal, 2020, Szklarz et al., 2022). Low iron levels can lead to gastrointestinal infections, nose bleeding, and myocardial infarctions (Umeoguaju et al., 2022, Cotter et al., 2020).

These findings clearly demonstrate the risks of water contamination, with considerable cadmium and vanadium deposits originating from petrochemical industrial operations, as well as poor water treatment and management procedures in locations near crude oil exploration activities. These issues have serious health implications for both humans and animals. Similar findings have been observed in previous studies. Oyeyemi et al. (2024), reported increased levels of cadmium concentrations in drinking water from boreholes, during an assessment study on the levels of serum heavy metals concentration, oxidative stress and health risk among residents of Ugbegugun in Niger Delta region of Nigeria. Also, in a systematic review and meta-analysis conducted by (Umeoguaju et al., 2022) on the concentration of heavy metals in groundwater pooled from various scholarly data base. Reviewed studies from 2000 - 2019 suggested that Ni, Cd, Cr, and Pb were significantly higher in the ground water in Niger Delta Region compared to WHO recommended levels. The present study has established that the levels of Nickel and Mercury in drinking water were below the permissible limits set by 9World Health Organization, WHO (2008)). Even at low concentrations, heavy metals have diverse and adverse effects on animal life, including carcinogenic and neurotoxic actions (Sun et al., 2022). The contamination of water by mercury is a serious problem that poses a threat to the safety of both animals and humans, and it is a challenge for public health globally. Mercury is a potent industrial and environmental contaminant that causes severe alterations and malformations in animal tissues (Zafar et al., 2024, Wu et al., 2024). These toxic metals and wastes have harmful effects on animals, but there is no clear homeostatic mechanism to counteract their effects (Mitra et al., 2022, Gashkina, 2024). They are generally categorized as highly toxic and poisonous to animals.

Conclusion

The presence of crude oil operations in Delta State has considerably contributed to environmental contamination, resulting in elevated levels of Nickel and Mercury, as well as other heavy metals such as Vanadium, Cadmium, and

Iron, in drinking water samples available in poultry farm locations. These findings give concerns and raise alarms, especially since heavy metals can bio-accumulate in the body and pose serious health risks to animals in the long term. Heavy metals in drinking water samples are associated with chronic diseases and have a negative impact on animals' health status. They have no beneficial effects on animals or humans, and there is no known homeostasis mechanism to regulate their presence in the body. Heavy metals are generally considered the most toxic to animals and humans, and even at low concentrations, their adverse effects on human health are diverse and include neurotoxic and carcinogenic actions. They accumulate in the body tissues and pose severe health threat such as inflammation, cancer, vomiting, fever, joint calcification, and more. The possible health risks to animals and locals highlight the need for the government to do a thorough clean-up of the site utilizing effective bio-remediation techniques to fully restore the ecosystem.

Competing interests

The authors declared that there is no competing interest with the present study.

Ethical considerations

The authors of the current study confirmed that this manuscript is an original submission, prepared and submitted for the first time, and not under consideration elsewhere, authors checked the ethical criteria for publication.

Authors' contributions

All authors significantly contributed to the study. Unukevwere Jerome U and Olatunbosun Odu conceptualized and designed the study, Atadiose O. Everest was involved in the laboratory analysis, data interpretation, and manuscript preparation, Obakanure Oghenbrorie reviewed and edited the manuscript, Ufuoma G. Sorhue assisted with data analysis, and Olatunbosun Odu also supervised the experiment. All the authors concern read the final edition of the manuscript and agreed to publication.

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Availability of data and materials

Materials and data supporting this study are available and shall be tendered upon proper request by interested readers to the corresponding author to access the data.

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