World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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# Concentration of heavy metals of produced water in Owaza and agbada oil fields in Niger delta

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World Journal of Advanced Research and Reviews, 2025, 26(02), 2839-2846

Publication history: Received on 23 March 2025; revised on 09 May 2025; accepted on 11 May 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.2.1546

## Abstract

Wasted water from production is a major problem in both Africa and the United States. This study focused on the concentration of heavy metals in produced water of two Oil Fields (Owaza and Agbada) in the Niger Delta. In interval of one month each sample of produced water was collected from Agbada and Owaza oil fields for a total of four months respectively. Standard method was used to determine the heavy metals contents in collected produced water samples of the two oil fields with the use of atomic adsorption spectrophotometer (AAS) to analyze the concentration of heavy metals of Iron (Fe), Barium (Ba), Cadmium (Cd), Cupper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn). The heavy metals parameters in Owaza Oilfields in Niger Delta with highest mean concentration is Iron (Fe) (1.011), Zinc (Zn) (0.124), Cupper (Cu) (0.073), Manganese (Mn) (0.060), Barium (Ba) (0.035), Nickel (Ni) (0.034), Cadmium (Cd) (0.015), Lead (pb) (0.010) respectively. The heavy metals parameters in Agbada oilfield in Niger Delta with highest mean concentration is Iron(fe), (1.011), Zinc (Zn) (0.125), Cupper (Cu) (0.074), Manganese (Mn) (0.060), Barium (Ba) (0.035), Nickel (Ni) (0.034) and Cadmium (Cd) (0.015), lead (Pb) (0.011) respectively. Heavy metal concentrations of the both oil fields except for Iron (Fe) were within standard limits of Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO). However, produced water should be adequately treated before being discharged into the environment to protect the health of oil and gas workers and residence of the study area.

**Keywords:** Niger Delta; Agbada; Owaza; Concentration; Heavy Metals; Oil Fields

## 1. Introduction

Wasted water from production is a major problem in both Africa and the United States. Although the majority is reinjected, there is a portion that may be used for purposes such as treated water, agriculture, or industry (Sullivan et al., 2004). In regions where water is scarce, this residual component might be valuable. Produced water, also known as formation water, is a byproduct of the reservoir's natural processes (EPA, 1995). Chemical analyses of effluent have, up until recently, mainly concerned themselves with determining the concentration of oil in the water (Toril et al., 2003).

There wasn't much of a plan for handling the water that came up with crude oil extraction in the beginning. Poorly treated waste would sometimes be discarded into bodies of water, scattered on the ground, or thrown into subterranean pits where it would eventually evaporate or leak into the earth. Petroleum engineers gradually discovered that increasing output may be achieved by pumping water into oil reservoirs (Gregory et al., 2011).

These days, managing generated water is crucial due to its abundance, high treatment costs, and environmental problems caused by the chemicals it contains. Concerning the discharge of water of a certain quality, some nations that produce oil have enacted regulations and standards.

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### 1.1. Heavy Metals

Heavy metals are ubiquitous in nature and are renowned for their characteristics. As pollutants, they don't decompose when they accumulate in the environment, and they're very poisonous and long-lasting. With an atomic density more than 49/cm3, or at least five times that of water, a group of metals and metalloids are collectively known as heavy metals. Toxic heavy metals (Hg, Cr, Pb, Zn, Cu, Ni, Cd) and other heavy metals (Co, Sn, etc.) make up one group of heavy metals. Additional valuable metals include pd, rhodium, silver, gold, and ruthenium. Nuclear, thorium, and ammonia radionuclides round up the group (Annadural et al., 2012).

Formation water, aquifers, or even crude oil, when combined with water, may be a source of heavy metals in produced water. Both natural and man-made sources contribute to the presence of heavy metals in our water. Industrial waste, animal waste, mining operations, and agricultural chemicals are the primary sources of heavy metal pollution. And you thought industrial effluent with heavy metals couldn't occasionally clog the water system? This is a serious matter. Heavy metals are released into water bodies when acid rain breaks down soils and rocks.

Over time, heavy metals in the environment may accumulate and disrupt ecosystems, among other issues. Nickel, for example, is known to cause major problems with the kidneys and lungs. The reproductive system, kidneys, and liver may all be negatively affected by lead poisoning. The toxic symptoms of nickel poisoning often include anaemia, sleeplessness, migraines, vertigo, irritability, hallucinations, and problems with the kidneys. Heavy metals will contaminate the environment and aquifers as a result of mining operations. In order to address these contaminants, we need to investigate novel treatment methods (Annadural et al., 2012). Reducing the possibility of soil contamination and preventing an increase in pollution rates caused by the negligent disposal of mining waste and other materials is of the utmost importance. The troublesome metals in polluted soils accumulate in plants' tissues and organs because plants absorb them. Animals that consume polluted food or drink, as well as marine organisms that spend time in environments rich in heavy metals, may absorb these metals into their bodies and experience some very nasty side effects.

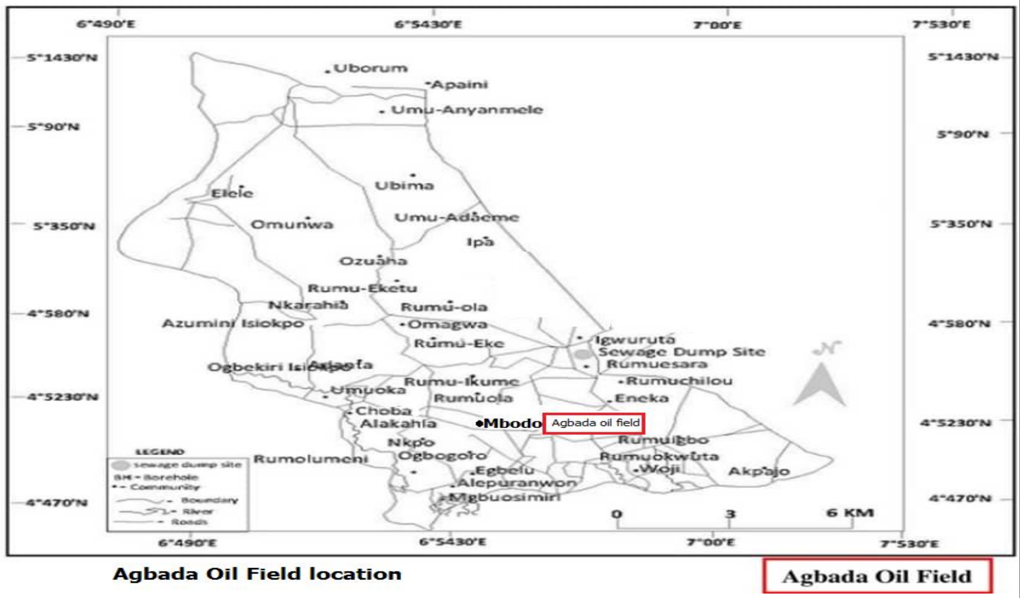
## 2. Materials and methods

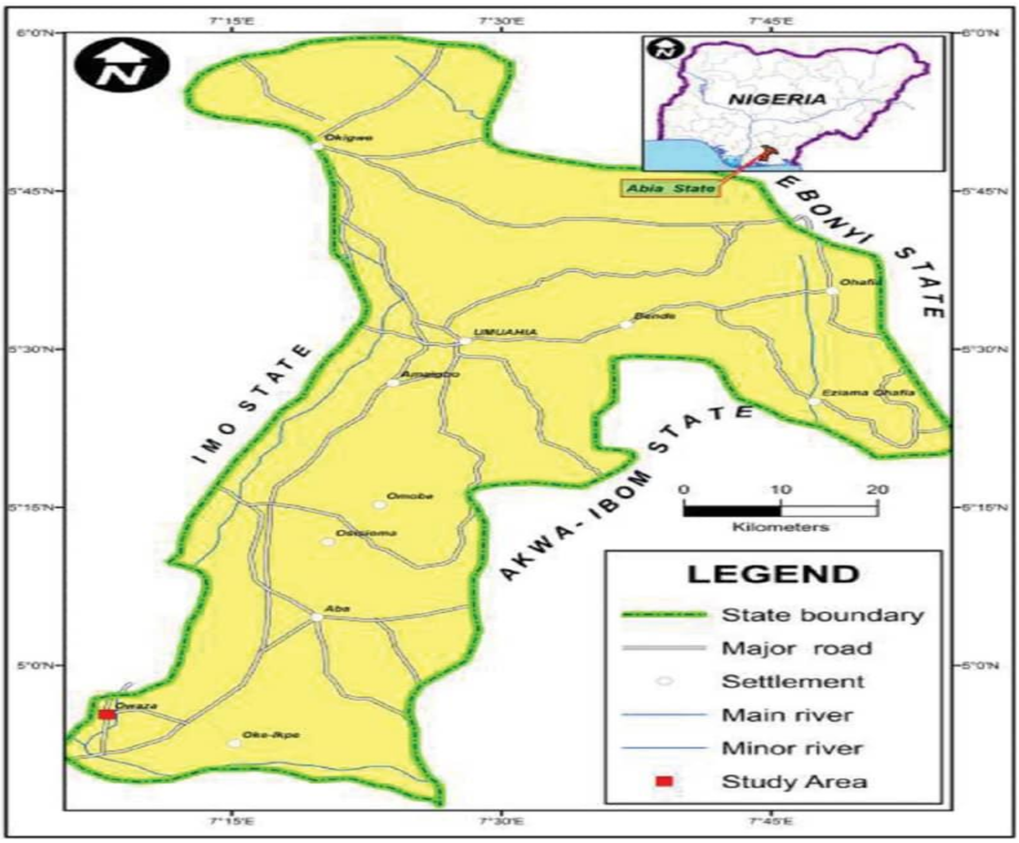
### 2.1. Study Area

Niger Delta region has most of the country's crude oil deposit and is known as the largest delta in Africa and third largest in the world. However, the region estimates for about 23% of Nigeria's total population (HBW, 1999).

Agbada flow station is located at Agbada farmland in Aluu in Ikwerre Local Government Area of Rivers State, Niger Delta Nigeria, lies between longitude 4 470o N to 5 143 00 N and latitude 6 490 0E to 7 530 oE. It is moderately populated sub-urban environment. Agbada is vulnerable to crude oil pollution due to the network pipelines connecting Rumuekpe and Ibaa communities located in the outskirts of Port Harcourt City in Rivers State.

Owaza flow station is located in Ukwa West Local Government Area of Abia State, lies between longitude 5 00 N and 5 450 N and latitude 7 150 E and 7 450 E. This area is rich mangrove vegetation which lies along the Imo River. The discharge point of produced water is about 5km upstream from the shores of the Imo River which some inhabitants of the area still use for their daily domestic activities.




Source: Field survey 2024

**Figure 1** Agbada oil field location Figure 2 Owaza Oil Field location

### 2.2. Sample Collection/Analysis of Heavy Metals

In interval of one month each sample of produced water was collected from Agbada and Owaza oil fields for a total of four months respectively. Standard method was used to determine the heavy metals contents in collected samples. The concentration of 8 metals Iron (Fe), Barium (Ba), Cadmium (Cd), copper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn) was analyzed using atomic adsorption spectrophotometer. All glassware was soaked in 25% v/v nitric acid (HNO3) prior to use for several days, rinsed with hot nitric acid and then rinsed several times with de-ionized water.

100 ml sample was mixed with acid preserved sample (5ml concentrated HNO3 per litre of sample) was transferred to a 150-mL beaker, and 5 ml of HCI was added. Then the beaker was placed on the hot plate in a fume hood for solution evaporation. The volume of the sample aliquot was reduced to about 20 ml by gentle heating for about two hours. After beaker had cooled the sample solution was transferred quantitatively to a 100-ml volumetric flask, diluted to volume with reagent water, stoppered and finally mixed for direct analysis by the use of Atomic Adsorption spectrophotometer.

### 2.3. Statistical Analysis

One-way ANOVA was used to test the mean differences between the difference location and samples. It was used since the samples are more than two and locations are considered to be one-direction. However, the method of data analysis on mean concentration was calculated using the mean formula of derivation after (Gupta et al., 2002) as stated below:

$$x = \frac{\sum fx}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn. 1)}$$

to test the hypothesis with mean difference in the location/variables we done using one-way ANVOA

$$X_{ij} = \propto + x_j + Y_j + \sum_{ij} \quad \ldots\ldots\ldots\text{- (Eqn. 2)}$$

where $\propto$ = overall mean

$X_i$ = observed response based on heavy metal physicochemical parameters

$\sum_{ij}$ = random error term.

## 3. Results

### 3.1. Concentrations of Heavy Metals

**Table 1** Results of Produced Water Samples Concentration (Mg/L) Of Eight (8) Heavy Metals Parameters in Agbada Oilfield in Niger Delta.

| S/N | Parameters | Sample 1 Concentration (Mg/L) | Sample 2 Concentration (Mg/L) | Sample 3 Concentration (Mg/L) | Sample 4 Concentration (Mg/L) | Mean Concentration |
|---|---|---|---|---|---|---|
| 1. | Lead (pb) | 0.010 | 0.010 | 0.011 | 0.011 | 0.011 |
| 2. | Zinc (Zn) | 0.125 | 0.124 | 0.124 | 0.125 | 0.125 |
| 3. | Cupper (Cu) | 0.075 | 0.074 | 0.073 | 0.074 | 0.074 |
| 4. | Manganese (Mn) | 0.059 | 0.061 | 0.060 | 0.060 | 0.060 |
| 5. | Iron (Fe) | 1.010 | 1.011 | 1.011 | 1.010 | 1.011 |
| 6. | Cadmium (Cd) | 0.014 | 0.014 | 0.015 | 0.015 | 0.015 |
| 7. | Nickel (Ni) | 0.035 | 0.034 | 0.033 | 0.034 | 0.034 |
| 8. | Barium (Ba) | 0.035 | 0.035 | 0.034 | 0.034 | 0.035 |

Source: Field Survey (2024).

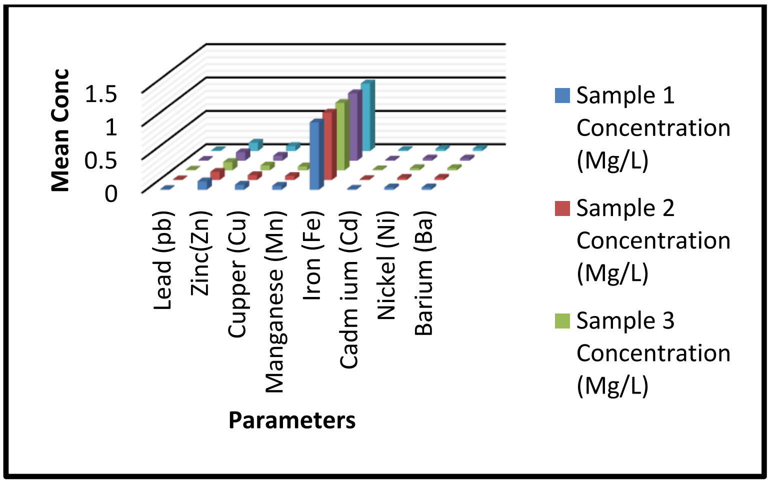



**Figure 2** Mean concentration of Produced Water Samples Concentration (Mg/L) Of Eight (8) Heavy Metals Parameters in Agbada Oilfield in Niger Delta

The heavy metals parameters in Agbada oilfield in Niger Delta with highest mean concentration is Iron(fe), (1.011), Zinc (Zn) (0.125), Cupper (Cu) (0.074), Manganese (Mn) (0.060), Barium (Ba) (0.035), Nickel (Ni) (0.034) and Cadmium (Cd) (0.015) Lead (Pb) (0.011) respectively.

**Table 2** Results of Produced Water Samples Concentration (Mg/L) Of Eight (8) Heavy Metals Parameters in Owaza Oilfields in Niger Delta

| S/N | Parameters | Sample 1 Concentration (Mg/L) | Sample 2 Concentration (Mg/L) | Sample 3 Concentration (Mg/L) | Sample 4 Concentration (Mg/L) | Mean Concentration |
|---|---|---|---|---|---|---|
| 1. | Lead (pb) | 0.009 | 0.010 | 0.009 | 0.010 | 0.010 |
| 2. | Zinc (Zn) | 0.123 | 0.124 | 0.124 | 0.123 | 0.124 |
| 3. | Cupper (Cu) | 0.073 | 0.072 | 0.075 | 0.073 | 0.073 |
| 4. | Manganese (Mn) | 0.060 | 0.060 | 0.060 | 0.060 | 0.060 |
| 5. | Iron (Fe) | 1.010 | 1.011 | 1.011 | 1.011 | 1.011 |
| 6. | Cadmium (Cd) | 0.015 | 0.016 | 0.015 | 0.015 | 0.015 |
| 7. | Nickel (Ni) | 0.134 | 0.134 | 0.033 | 0.034 | 0.034 |
| 8. | Barium (Ba) | 0.036 | 0.035 | 0.035 | 0.034 | 0.035 |

Source: Field Survey (2024)

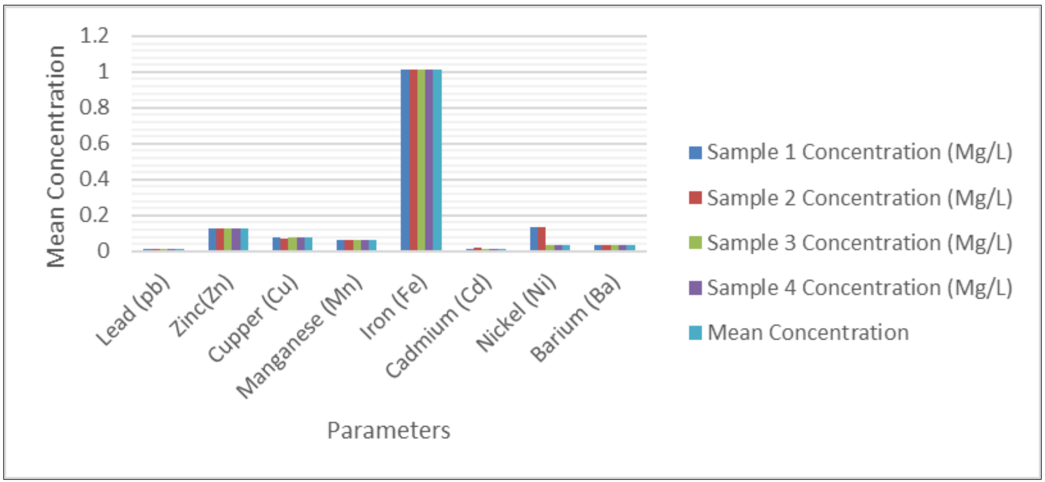



**Figure 3** The multiple Bar Chart Representing the Results of Produced Water Samples Concentration (Mg/L) Of Eight (8) Heavy Metals Parameters in Owaza Oilfields in Niger Delta

The heavy metals parameters in Owaza Oilfields in Niger Delta with highest mean concentration is Iron (Fe) (1.011), Zinc (Zn) (0.124), Cupper (Cu) (0.073), Manganese (Mn) (0.060), Barium (Ba) (0.035), Nickel (Ni) (0.034), Cadmium (Cd) (0.015), Lead (pb) (0.010) respectively.

**Table 3** General Linear Model Univariate (One Factor ANOVA) for the mean concentration of heavy metals parameters in Agbada and Owaza Oilfields in Niger Delta

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 0.114[a] | 15 | 0.008 | 41.496 | 00.010 |
| Intercept | 0.098 | 1 | 0.098 | 535.711 | 0.210 |
| Heavy Metal | 0.066 | 7 | 0.009 | 51.592 | 0.060 |
| Samples | 0.014 | 1 | 0.014 | 73.938 | 0.070 |
| Heavy Metal * Samples | 0.034 | 7 | 0.005 | 26.524 | 0.500 |
| Error | 0.010 | 56 | 00.000 | | |
| Total | 0.216 | 72 | | | |
| Corrected Total | 0.125 | 71 | | | |
| a. R Squared = .917 (Adjusted R Squared = .895) | | | | | |

Table above presents the results of the General Linear Model Univariate (One Factor ANOVA) analysis for heavy metals in produced water samples from Agbada and Owaza Oilfields in the Niger Delta. The analysis reveals a significant difference in mean produced water samples between Agbada and Owaza oilfields [F(7,56) = 73.938, p-value = 0.070].Furthermore, the results indicate a significant effect of heavy metal concentrations on produced water samples [F(7,56) = 26.524, p-value = 0.500], since the estimated p-values are greater than 0.05.Therefore, we accept the null hypothesis (H0) stating that there is no significant different in the mean concentration of heavy metals parameters in Agbada and Owaza Oilfields in Niger Delta. Conversely, we reject the alternative hypothesis (H1) indicating there is significant different in the mean concentration of heavy metals parameters in Agbada and Owaza Oilfields in Niger Delta. The R-Squared value of 0.917 shows that 91.7% of the variation in mean produced water Concentrations can be explained by heavy metal concentrations, while 8.3% is attributed to other factors not captured in the model.

## 4. Discussion

The results of the General Linear Model Univariate (One Factor ANOVA) analysis for heavy metals in produced water samples from Agbada and Owaza Oilfields, as presented in Table 4.11, offer insight into the relationship between heavy metal concentrations and the quality of produced water at these locations. According to the analysis, there is no significant difference in the mean concentrations of heavy metals between the two oilfields, as indicated by the F-value of 73.938 and a p-value of 0.070. Since the p-value is greater than 0.05, we fail to reject the null hypothesis (H0), which suggests that there is no significant difference in the mean concentration of heavy metal parameters between Agbada and Owaza Oilfields. The analysis shows that the concentration of heavy metals does not have a significant effect on the produced water samples, as the F-value for the effect of heavy metals on water quality is 26.524, with a p-value of 0.500. Since this p-value is also greater than 0.05, we accept the null hypothesis (H0), meaning that heavy metal concentrations do not significantly influence the characteristics of the produced water in either of the oilfields. This result implies that, contrary to the expectations, the levels of heavy metals present in the produced water samples from both Agbada and Owaza Oilfields do not have a meaningful impact on water quality.

However, the R-squared value of 0.917 is significant. This means that 91.7% of the variation in the mean concentrations of produced water samples can be explained by the heavy metal concentrations, while the remaining 8.3% is attributed to other factors that were not included in the analysis model. This relatively high R-squared value suggests that, although the heavy metal concentrations do not significantly affect the water quality, they still account for a substantial portion of the variability in the produced water samples' characteristics.

In summary, while heavy metals play a considerable role in the overall variation in produced water concentrations, the ANOVA results suggest that there is no statistically significant difference in heavy metal concentrations between the Agbada and Owaza Oilfields. Therefore, any observed differences in water quality between the two oilfields are not attributed to variations in heavy metal levels.

Further study should consider the concentrations of heavy metals not considered in this study with respect to the studied oil fields.

There is significant difference in the concentration of heavy metals of produced water of Agbada and Owaza oil fields and the previous study by Erakhrumen A.A. 2015 on the concentration of heavy metals in untreated produced water from a crude oil production platform in Niger Delta.

## 5. Conclusion

In evaluating the effectiveness of region-specific materials in removing heavy metals at various Concentrations intervals, the research offers practical insights into affordable and sustainable water Concentrations methods. These findings are particularly valuable for policymakers and environmental managers seeking to implement cost-effective, local solutions that can address water quality issues in oil-producing regions like the Niger Delta.

Heavy metal concentrations are crucial factors influencing water quality. However, there is also a need to consider additional variables, such as operational practices and environmental factors, that could affect produced water quality.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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