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Assessment of Some Physicochemical, Bacteriological and Heavy Metals Properties of Effluent from a Chemical Industry in Niger Delta, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author DCB designed the study, followed up the field work, managed the analyses of the study, proofread, did corrections on the returned manuscript and wrote the protocol. Author NNI correlated the analytical data, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Author FCA co-supervised the entire process, followed up the publication formalities and provided payment platform. All authors confirmed the reading and approval of the final manuscript.

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ABSTRACT

Some physicochemical, heavy metals and bacteriological parameters of effluent samples from a chemical industry in Niger Delta, Nigeria, in two sampling seasons (Wet and Dry seasons) were assessed in this work using standard methods of analysis. Results of the physico-chemical parameters obtained from the effluent samples of both seasons revealed that most of the dry season's values were significantly higher ($p<0.05$) than the wet season values. Physico-chemical values obtained for pH, conductivity, TSS, turbidity and Sulphate in both the wet and dry seasons' effluent water samples were higher than their respective Nigeria Department of Petroleum

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Resources (DPR) and/or World Health Organisation (WHO) standard values. Dry season's TDS (4378.00 ± 0.00 mg/l) and phosphate (3.88 ± 0.65 mg/l) values obtained were higher than their respective DPR and WHO limit values. Bacteriological result revealed high T. coliform count of 16.67 ± 2.08 (MPN/100ml) for the wet season's effluent water which was higher than the DPR and/or WHO standard values. Heavy metals results of the effluent water samples in both seasons were all at a 'not detectable' levels except for Zn (wet and dry season). Results of the average values of the seasonal physico-chemical and bacteriological parameters of the effluent water samples showed that the average values of pH (10.25 ± 0.40), conductivity (4520.09 ± 41.06 µS/cm), TDS (2459.00 ± 12.13 mg/l), TSS (124.00 ± 32.69 mg/l), turbidity (110.85 ± 37.47 NTU), sulphate (434.50 ± 77.51 mg/l) and T. coliform (8.34 ± 1.04 MPN/100ml) obtained were significantly higher ($p<0.05$) than their corresponding DPR and/or WHO limit values. This study concludes that there were some deviations of the findings from the stipulated regulatory standard limits and therefore suggests proper assessment and treatment of industrial effluent water before discharging into the environment. The differences observed between the two seasons could be either as a result of higher industrial activities during the dry season and/or due to the much flow of storm/flood water which constantly washes away the substances from the sampling points.

Keywords: Bacteriological; chemical industry; effluent water; heavy metals; physicochemical; storm water; pollution.

1. INTRODUCTION

In the developing countries such as Nigeria, industrialization is seen as the basis of developmental strategies due to its major input to the economic growth and human welfare [1]. The continued change in human societies from traditionalism to modernism with rapid technological advancement and increasing industrial production geared toward satisfying growing human needs and comforts for the improvement of civilization, new lifestyles and increased production activities had resulted in the increase of unexpected industrial pollution. Chemical industries parks are considered high risk areas because they present numerous risks that can damage the environment, such as pollution incidence [2]. The large amount of waste produced by industries are untreated prior to disposal more particularly in Nigeria which has minute or no disposal/ treatment regulations and these wastes are detrimental to the health of the environment [3-4].

As a consequence, pollution sources increase with the development of cities and it affects the environment in different ways by discharging large amount of effluent as waste water in the surrounding water bodies, causing serious problems to the environment [5]. Domestic sewage and industrial waste water/effluent containing large quantities of chemical substances drained into rivers without treatment cause serious water pollution [6]. Besides being a useful source of plant nutrients (Nitrogen, Phosphorus, Potassium, Sulfur, etc), these effluents often contain high amounts of various organic and inorganic materials as well as toxic trace elements which may accumulate in the soils in excessive amounts and lead to some health problems to human beings, plants and animals by entering the food chains [7]. Untreated industrial effluents discharged on land surface, seep into aquifer and affect the ground water values, aquatic flora and microbial lives [8].

It is so worrisome to note that due to the rising quantity of waste produced, the environment as well as human well being is suffe ring serious damage. In Port Harcourt, Rivers Sta te of Nigeria, the place of urban development an d industrial activities are increasing constantly, s o also is the amount of waste generated. Accord ing to [9], approximately, 117,825 tons of municipal solid waste are generated monthly in Port Harcourt. Man in its pursuits to boost his food bank, get uncontaminated water for consumption and reduce damage and injury to his healthiness but the industrial materials, waste and chemicals supposedly meant for his benefits had become a quiet vanquisher and danger to his life [10].

This paper aimed at evaluating and comparing some physicochemical characteristics, heavy metal levels and bacteriological properties of the industrial effluents in dry and wet seasons and the objective was to ascertain if there were differences in these parameters in both seasons and any possible deviations from the regulatory standards.

2. DESCRIPTION OF STUDY AREA

This study was conducted in a chemical industry located in the Niger Delta Nigeria. This chemical industry was selected for these evaluations due mainly to her comprehensiveness in activities suitable for complete environmental monitoring coupled with their unbiased openness and collaborations. The industry produces and repackages organic and inorganic chemicals/industrial gases and other allied chemical products at regular basis during the hours of work between 8am and 5.0pm.The climate of the area is a humid torrential rain type of weather with prolonged and profound rainy seasons and very short dry season. December and January are the only months that are eligible for dry season months in the area. Normally, December is often the least rainy month of the year with average rainfall of 20 mm. The heaviest precipitation occurs during September with an average of 367 mm of rain. Temperatures all through the year are frequently stable, presenting slight deviation all through the year. On the average, the temperature range is normally between 25ºC and 28ºC.

2.1 Sample Collection

Effluent water samples were collected within the working hours of the industry between 8am and 5.30 pm in pre cleaned plastic bottles from the waste water drainage system and the sedimentation tank of the chemical industry respectively in two sampling seasons (July, 2015 in wet/rainy season and December, 2015 in dry season). The design of the industry has it that after treatment of the effluent, the treated water then passes via the drainage system to the surroundings hence the need to evaluate the later alongside the sedimentation tank before discharge to the environment. Variable parameters were observed in-situ. The samples were taken to the laboratory where it was stored in a refrigerator to avoid deterioration or change in the original status prior to analysis.

2.2 Analysis of Samples

Standard analytical procedures according to [11-13] were employed in the analysis of the following Physicochemical, bacteriological and heavy metals effluent water quality parameters; pH, Conductivity, TDS, TSS, Turbidity, Sulphate, Phosphate, Salinity as Cl, Nitrate, COD, BOD, THC, BTEX, T. coliform, Lead, Cadmium, Chromium, Nickel, Mercury and Zinc.

2.3 Statistical Analysis

The effluent water quality has been assessed by comparing the wet season parameters to the dry season parameters, using student t-test, employing the Statistical Package for Social Sciences (SPSS) and comparing each parameter with the standard desirable limit of that parameter as prescribed by DPR and WHO.

3. RESULTS AND DISCUSSION

Comparative Physico-chemical and Bacteriological Results of the Seasonal Changes of the Effluent Water Samples from the Chemical Industry are summarized and presented on Table 1.

Table 2 presents the summarized Results of the average concentrations of the Seasonal Physico-chemical and Bacteriological Parameters of the Effluent water Samples from the Chemical Industry.

pH value 12.35 ± 0.33 obtained for the dry season effluent water samples was significantly higher than the 8.10 ± 0.46 pH value obtained for the wet season effluent water samples. The wet season pH value was within the 6.5-8.5 and 6.5-9.2 pH limits set by DPR and WHO respectively. Whereas, the dry season pH value was above the DPR and WHO pH limit values for effluent waters. [14] reported pH value of 6.25, while [15] reported pH range of 9.56-13.65 in similar studies carried out in Nigeria.

The conductivity value obtained for the dry season effluent water samples was 7960.67 ± 33.3 (µS/cm). This value was significantly higher than the 1079.50 ± 48.79 (µS/cm) conductivity value obtained for the wet season effluent water samples. Conductivity limit value was not stated by DPR. However, the dry season conductivity value was higher than the 1200 (µS/cm) maximum limit value set by WHO for effluent water conductivity. Conductivity of the effluent water samples is a linear function of the concentration of dissolved ions [16].

Total dissolved solids (TDS) value 4378.00 ± 0.00 (mg/l) obtained for the dry season effluent water samples was significantly higher than the 450.00 ± 24.25 (mg/l) TDS value obtained for the wet season effluent water samples. The wet season TDS value was in compliance with the 2,000 (mg/l) DPR limit as well as with the 1,500 (mg/l) WHO maximum possible limit for TDS in

effluent water samples. The high TDS value obtained for the dry season sample could be correlated to the concentration of dissolved solutes such as sulphate and nitrate as well as to the concentration of salinity of the effluent waters. Obot et al. (2007) reported TDS value of 284.00 ± 0.14 (mg/l), while [14] reported TDS value of 224 (mg/l) in similar studies carried out in Nigeria.

Table 1. Comparative physico-chemical and bacteriological results of the seasonal changes of the effluent water samples from the chemical industry

Parameters	Season		DPR limit (s)	WHO standards max. permissible
	Wet	Dry		
pH	8.10 ± 0.46[a]	12.35 ± 0.33[a]	6.5 – 8.5	6.5 – 9.2
Conductivity (µS/cm)	1079.50 ± 48.79[a]	7960.67 ± 33.33[a]	NS	1,200
TDS (mg/l)	540.00 ± 24.25[a]	4378.00 ± 0.00[a]	2,000	1,500
TSS (mg/l)	37.50 ± 1.44[a]	210.50 ± 63.93[a]	30	NS
Turbidity (NTU)	19.00 ± 0.69[a]	202.70 ± 74.24[a]	10	5.0
SO_4^{3-} (mg/l)	22.50 ± 4.91[a]	410.00 ± 150.11[a]	NS	400
PO_4^{3-} (mg/l)	0.24 ± 0.13[a]	3.88 ± 0.65[a]	NS	NS
Salinity as Cl (mg/l)	42.00 ± 4.62[a]	584.90 ± 0.00[a]	600	600
NO_3^- (mg/l)	1.80 ± 0.98[a]	2.95 ± 0.20[b]	NS	50
COD (mg/l)	0.90 ± 0.03[a]	3.76 ± 0.28[a]	10	NS
BOD_5 (mg/l)	0.60 ± 0.02[a]	2.66 ± 0.28[a]	NS	NS
THC (mg/l)	0.88 ± 0.14[a]	0.16 ± 0.09[b]	0.16	10
BTEX (mg/l)	0.00 ± 0.00[a]	0.00 ± 0.00[b]	<0.001	NS
T. Coliform (MPN/100ml)	16.67 ± 2.08[a]	0.00 ± 0.00[a]	0	0

Results presented are Means ± SEM for n = 3. Values in the same row with the same superscript (a) are significantly different (p < 0.05).
Legend: NS = Not Stated.
DPR = Department of Petroleum Resources
WHO = World Health Organization

Table 2. Results of the average concentrations of the seasonal physico-chemical and bacteriological parameters of the effluent water samples from the chemical industry

Parameters	Average concentration	DPR limit(s)	WHO standards max. permissible
pH	10.25 ± 0.40	6.5 – 8.5	6.5 – 9.2
Conductivity (µS/cm)	4520.09 ± 41.06	NS	1,200
TDS (mg/l)	2459.00 ± 12.13	2,000	1,500
TSS (mg/l)	124.00 ± 32.69	30	NS
Turbidity (NTU)	110.85 ± 37.47	10	5.0
SO_4^{3-} (mg/l)	434.50 ± 77.51	NS	400
PO_4^{3-} (mg/l)	2.06 ± 0.39	NS	NS
Salinity as Cl (mg/l)	313.45 ± 2.31	600	600
NO_3^- (mg/l)	2.38 ± 0.59	NS	50
COD (mg/l)	2.33 ± 0.16	10	NS
BOD_5 (mg/l)	1.63 ± 0.15	NS	NS
THC (mg/l)	0.52 ± 0.12	0.16	10
BTEX (mg/l)	0.00 ± 0.00	<0.001	NS
T. Coliform (MPN/100ml)	8.34 ± 1.04	0.00	0

Legend: NS = Not Stated.
DPR = Department of Petroleum Resources
WHO = World Health Organization.

The total suspended solids (TSS) value obtained for the dry season's effluent water sample was 210.50 ± 63.93 (mg/l). This value was significantly higher than the 37.50 ± 1.44 (mg/l) TSS value obtained for the wet season samples. Both the wet and dry season TSS values were higher than the 30 (mg/l) limit value set by DPR for TSS in effluent waters. WHO standard limit value for TSS in effluent waters was not stated. TSS is significant in observing water clarity as water becomes less clear in the presence of more solids [17].

Turbidity result of the dry season's effluent water samples was 202.70 ± 74.25 (NTU) which was significantly higher than the 19.00 ± 0.69 (NTU) value obtained for the wet season's effluent water samples. These values were higher than the 10 (NTU) and 5 (NTU) limit values set by DPR and WHO respectively, for turbidity of effluent water samples. These high turbidity values could be linked to the TDS values of the effluent water sample.

The dry season sulphate value of the effluent water samples was 410.00 ± 150.11 (mg/l) which was significantly higher than the 22.50 ± 4.91 (mg/l) sulphate value obtained for the wet season effluent water samples. The wet season sulphate value was in agreement with the 400 (mg/l) maximum permissible limit value set by the WHO for sulphate in effluent waters, on the other hand, the dry season sulphate value was higher than the WHO maximum permissible limit for sulphate in effluent waters. Higher sulphate concentrations are undesirable because of their laxative effects. People not used to drinking water with high levels of sulphate can experience dehydration and diarrhea [16].

Result of the phosphate value of 3.88 ± 0.65 (mg/l) obtained for the dry season effluent water samples was significantly higher than the 0.24 ± 0.13 (mg/l) value obtained for the wet season effluent water samples. Though the DPR and WHO permissible limit values for phosphate in effluent water samples were not stated, these values were similar to the 0.98 ± 0.01 - 4.34 ± 0.00 (mg/l) phosphate range value reported by [18] in a similar study.

The dry season's salinity value of 584.90 ± 0.00 (mg/l) obtained for the effluent water samples was significantly higher than the 42.00 ± 4.62 (mg/l) salinity value obtained for the wet season's effluent water samples. These values were, however, in compliant with the 600 (mg/L) salinity limit value set by the DPR and WHO for effluent water samples.

Nitrate values of the seasonal effluent water samples were 2.95 ± 0.20 (mg/l) for dry season's samples and 1.80 ± 0.98 (mg/l) for wet season's samples. Though the dry season's value was slightly higher than the wet season's value, there was however, no significant difference ($p<0.05$). Both the wet and dry seasons' nitrate values complied favorably with the 50 (mg/l) limit value set by WHO for nitrate in effluent water samples. [14] reported nitrate value of 0.25 (mg/l) in a related study carried out in Nigeria.

The Chemical Oxygen Demand (COD) value of the effluent water samples of the dry season was 3.76 ± 0.28 (mg/l), which was significantly higher than the 0.90 ± 0.03 (mg/l) COD value obtained for the wet season effluent water samples. Though the COD limit value was not stated by WHO, these COD values obtained for both wet and dry season samples were in agreement with the 10 (mg/l) COD limit value set by DPR for COD in effluent water samples [18] and [14] reported higher COD values of 28.00 ± 0.14-30.10 ± 0.02 (mg/l) and 1072.00 (mg/l) respectively in similar studies carried out in Nigeria.

The Biochemical Oxygen Demand (BOD) value of 2.66 ± 0.28 (mg/l) obtained for the dry season's effluent water samples was significantly higher than the 0.60 ± 0.02 (mg/l) BOD value obtained for the wet season effluent water samples. Though BOD limit values were not stated by the DPR and WHO, these values obtained were similar to the 2.04 ± 0.01 – 6.12 ± 0.00 (mg/l) BOD values reported by [18] in a related study carried out in Nigeria.

Comparative Heavy Metals Results of the seasonal changes of the effluent water samples from the Chemical Industry is presented in Table 3.

The results of the average concentrations of the seasonal heavy metal parameters of the effluent water samples from the Chemical Industry are summarized and presented on Table 4.

Total hydrocarbon concentrations (THC) of the seasonal effluent water samples were 0.88 ± 0.14 (mg/l) and 0.16 ± 0.09 (mg/l) respectively for the wet and dry seasons' samples. These values

Table 3. Comparative heavy metals results of the seasonal changes of the effluent water samples from the chemical industry

Parameters	Season		DPR limit (s)	WHO standards max. permissible
	Wet	Dry		
Pb (mg/l)	0.00 ± 0.00^a	0.00 ± 0.00^b	0.05	0.05
Cd (mg/l)	0.00 ± 0.00^a	0.00 ± 0.00^b	NS	0.003
Cr (mg/l)	0.00 ± 0.00^a	0.00 ± 0.00^b	0.03	0.05
Ni (mg/l)	0.00 ± 0.00^a	0.00 ± 0.00^b	NS	0.02
Hg (mg/l)	0.00 ± 0.00^a	0.00 ± 0.00^b	NS	0.001
Zn (mg/l)	0.05 ± 0.01^a	0.14 ± 0.02^a	1.0	3.0

Results presented are Means ± SEM for n = 3. Values in the same row with the same superscript (a) are significantly different (p<0.05).
Legend: NS = Not Stated.
DPR = Department of Petroleum Resources
WHO = World Health Organization

Table 4. Results of the average concentrations of the seasonal heavy metal parameters of the effluent water samples from the chemical industry

Parameters	Average concentration	DPR limit (S)	WHO standards max permissible
Pb (mg/l)	0.00 ± 0.00	0.05	0.05
Cd (mg/l)	0.00 ± 0.00	NS	0.003
Cr (mg/l)	0.00 ± 0.00	0.03	0.05
Ni (mg/l)	0.00 ± 0.00	NS	0.02
Hg (mg/l)	0.00 ± 0.00	NS	0.001
Zn (mg/l)	0.1 ± 0.02	1.0	3.0

Legend: NS = Not Stated.
DPR = Department of Petroleum Resources
WHO = World Health Organization

were not significantly different ($p<0.05$) and were in compliant with the 10 (mg/l) maximum permissible limit value set by WHO for Total hydrocarbons(THC) in effluent water samples. According to [19] hydrocarbons are the most significant cause of toxicity in sediment samples. [18] reported THC value of 0.79 ± 0.00 (mg/l) in a related study carried out in Nigeria.

The seasonal concentrations of benzene, toluene, ethyl benzene and xylene (BTEX) of the effluent water samples were at a 'not detectable' levels in both the wet and dry seasons' effluent water samples. These concentrations were therefore in compliant with the < 0.001 (mg/l) limit value set by the DPR for BTEX in effluent water samples.

Total coliform microbes were not detected in the dry season effluent water samples. The wet season effluent water samples however had a total coliform value of 16.67 ± 2.08 (MPN/100ml) which was higher than the 0.00 (MPN/100) limit set by the DPR and WHO for total coliform microbes in effluent water samples. Coliform bacteria are considered as "indicator organisms', their presence in water may indicate contamination by fecal waste that may contain other bacteria, viruses, parasites or disease causing organisms [20].

The seasonal heavy metals values of Pb, Cd, Cr and Hg obtained for both the wet and dry season effluent water samples were at 'not detectable' levels of less than 0.001 (mg/l) concentrations. Zn had a value of 0.14 ± 0.02 (mg/l) for the dry season effluent water samples which was significantly higher than the 0.05 ± 0.01 (mg/l) value obtained for the wet season effluent water samples. These results were, however, in compliance with the DPR and WHO standard limit values for heavy metals in effluent water samples.

4. CONCLUSION

This study had shown that the average concentrations of the seasonal physicochemical and bacteriological parameters of the effluent water samples of the chemical industry had high

values of pH, electrical conductivity, TDS, TSS, Turbidity, Sulphate and total coliform which were not in compliance with the DPR and/or WHO set standards. Though the values in some cases were lower than the maximum allowable limits, the continued discharge of improperly treated waste into the environment may result in severe accumulation of the contaminants. On this basis, it is therefore important for chemical industries to properly treat their waste before discharge so as to save the receiving water bodies and the entire environment from degradation and contamination.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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