**LEVELS OF HEAVY METALS AND PHYSICO-CHEMICAL PARAMETERS OF A RAW PAINT-BASED INDUSTRIAL EFFLUENT**

**ABSTRACT**

Environmental pollution has become a worldwide and a global problem as increase in human population has led to increase in the establishment of more industries to meet the growing needs of the growing population. This is endangering the entire ecosystem due to the toxic effects of these contaminants. This study was carried out to investigate and assess the level of contamination in effluent from a paint manufacturing in Abuja, FCT, Nigeria. The effluent was analyzed following standard methods for pH, dissolved oxygen (DO), turbidity, total solids (TS), dissolved oxygen, electrical conductivity (EC), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) and heavy metals, Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) and lead (Pb). The results on two different batch analysis of the effluent from the same industry affirmed the pH in the range of 7.34-8.34, DO 3.71-3.50mg/L, turbidity 4436-47829 NTU, EC 196.73-2619 mS/m, TS 304707-47829 mg/L, BOD 73.2-216 mg/L and COD 365-602 mg/L. The concentrations of the heavy metals were 0.5-0.54ppm (Cr), 0.3-1.07 ppm (Cu), 0.6 -16.01 ppm (Cd) 0.6 -9.36 ppm (Pb) and 0.01 ppm (As). The results obtained suggest very high levels of heavy metal and the phyisco-chemical parameters higher than the permissible limit set by the National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria. This effluent without effective and proper remediation becomes a great risk to the environment and life in general.

Keywords: Paint-based effluent, Heavy metals, Physico-chemical parameters, Pollution

1. **INTRODUCTION**

The rapid and daily growth in human population and industrialization has led to an increase in human activities which include environmental point-source pollution from industries and product itself (Verma and Dwivedi, 2013). These activities can have both positive and negative influence on man and its environment. Increased industrialization is one of such activities and this has contributed immensely to environmental pollution especially the aquatic ecosystem and this has become a great concern that requires serious attention. Abdel-Raouf *et al* (2012) described pollution as a situation linked with increased levels of materials that exists inherently or substances released into the environment as a result of anthropogenic activity. Pollutants of different forms are released as waste products into the environment from manufacturing procedures. According to Zeitoun and Mehana (2014), one of the main and important roots of aquatic pollution is industrialization. In addition, the pollution of water bodies simply is the deposition of substances directly or indirectly by man into the aquatic body which can lead to very detrimental effect, on the nature of the water and also reduced climate resources. The nature and the state of water is a very important issue because water is a crucial resource for life (Brack *et al*, 2017). Water is regarded as a naturally existing resource which is very vital for the smooth running of the ecosystem as well as the existence of man (Aniyikaiye *et al*, 2019). Interestingly, this natural resource (water), has also become a key material needed for the manufacturing of most industrial products (Owa, 2013) and a larger portion of it resulting to wastewater generated by these industries (Ranade and Bhandari, 2014). Consequentially, these untreated effluents that are released into the aquatic ecosystem is the utmost root of environmental pollution (Kaur *et al*, 2010).

Heavy metals are high density metallic elements that exhibit metallic properties and can be very poisonous even at low or minute concentration. They are basically known to have a particular weight greater than 5g/cm3 that unfavourably affect life and our surroundings (Järup, 2003). According to Jaishankar *et al* (2014), these set of elements have shown to be very crucial in exerting different form of danger and the likes. In the last years, aquatic materials are in constant exposure to harmful chemical pollutants at a steadily rapid rate and this is as a result of increased anthropogenic venture on the aquatic ecosystem (Alam *et al,* 2009; 2010). Heavy metals either essential or non-essential pose harmful effects on living agents in a particular biota when exposed (Storelli *et al,* 2005). These toxic metallic substances gain entrance into the human body majorly via ingestion of contaminated water and food (Verma and Dwivedi, 2013). Heavy metal pollution of the environment has become a great deal as unlike some other contaminants, they remain obstinate in the environment as they are not biodegradable i.e., they cannot be broken down by biological matters (Inobeme *et al,* 2014). Pollution according to Zeitoun and Mehana (2014), simply involves the deposition of unfamiliar materials into the ecosystem and heavy metals is one of such which could include; Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Ti) and Lead (Pb). Lead, cadmium and nickel are some of the heavy metals found regularly in the aquatic ecosystem and reports have shown that they are the most dangerous (O’Connell *et al*, 2008). Most of these contaminants accumulate in organs such as liver, kidney and nerve as a result of their inhibition to chemical and biological transformation thereby causing toxicity (Gabriel *et al*, 2006). These metallic toxic substances, when absorbed in biological tissue become a major biomedical issue (Wan *et al,* 2013). Kidney problems, genetic mutation, cancer, deformation are part of the health challenges that have been associated to the exposure of pollution by heavy metals (Chidozie and Nwakanma, 2017).

It has become an established fact that industrialization is rapidly on the increase and paint industry is one of such industries on the increase. Virvaghava *et al* (1991), defined paint as background either for decoration or protection or a covering for both of them. In addition, paint also refers to the correlative preparation that involves four major constituents which include, pigment, additives, extenders and binder that is aimed at formulating a distinct product with distinct features (Stephen *et al,* 2019). According to Tesfalem and Abdrie (2017), and Malakootian *et al* (2006), the paint industry has been confirmed to be amongst the number of industries that contribute the issue of water pollution. Also, Vinod *et al* (2012), has affirmed that the paint and other coating production companies are part of the industries realising heavy metal containing effluents. The properties of the waste generated during production by this industry is greatly dependent on the paint constituent (Korbahti and Tanyolac, 2009). Basically, heavy metals are majorly used as blotters and pigments in the production of paints. The other components of paint include solvents and auxiliary additives (Clark, 1972; Abraham 1982; Okafor *et al,* 2015). The cleaning of operation mixers, blenders, reactors, packing machines are the points where the wastewater from the paint industry is produced (Aboulhassan *et al,* 2014). Additionally, the high concentrations of toxic contaminants like the heavy metals in the paint-based effluent, suspended solids, organic compounds and coloured materials are as a result of the enormous chemicals used in the production process (Krithika and Ligy, 2016). Varying levels of heavy metals like lead, nickel, copper, cadmium, arsenic, zinc, chromium and mercury can be found in an untreated or partially treated industrial paint effluent (Aghor, 2007; Patil, 2009).

This research is therefore aimed at assessing the level of heavy metal pollution alongside the physic-chemical parameters of a paint-based effluent with special reference to the FCT, Abuja Nigeria and to compare the level of concentration with the standard limit given by the National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria.

**2.0 MATERIALS AND METHODS**

**2.1 Study Area**

This study was undertaken within the Federal Capital Territory, Abuja. Abuja is the capital city of the country, Nigeria and it is located at the Nigerian central with latitude 8o86’N to 8o95’N and longitude 7o18’E to 7o29’E with a population of about 1,406,239 (Nnodu *et al,* 2017).



**FIGURE 1: Map of Abuja, FCT with the six Area Councils (Obi-Anike *et al*, 2017).**

**2.2 Effluent** **Collection**

Wastewater collection were carried out as described by Nanda *et al* (2010) and Woldeamanuale and Hassen (2017). The raw emulsion paint wastewater was collected at the point of discharge from a paint industry located at Madala, Zuba, Abuja. They are producers of emulsion paints, oil paints, screeding paints among others. The sample was collected in newly acquired plastic bottles that were thoroughly washed, cleaned followed by rinsing with tap water to make it very clean same as all the glass wares (Gupta *et al*, 2022). The bottles were rinsed again twice with distilled water then with the wastewater sample. Preservation of samples was done by storing the samples at 4oC until the time of usage.

**2.3. Determination of the Physico-Chemical Parameters and Heavy Metals**

The physic-chemical parameters analysis of the paint-based effluent was carried out following standard methods. The pH of the effluent was determined using Laqua pH meter, total solids was carried out using Hach Laqua portable meter and UV Spectrophotometric method. Turbidity was determined using Hach 2100 portable turbidimeter. The analysis of COD followed Hach method 8000 and a 5 day BOD test method (APHA, 5210B) was conducted. Atomic Absorption Spectroscopy (AAS) Hanna HI Varian AAS SpectraAA 240FS, Italy was used for the heavy metals (cadmium, lead, copper, chromium and arsenic) content of the effluent.

**2.4. Analysis of Data**

All values described were the means of the replicates. Microsoft excel were used in the calculation of mean, standard error, standard deviation. Statistical Package for the Social Descriptive statistics were employed, Kolmogorov-Smirnov-Test was used to check if the data were normally distributed and one sample T test was employed using SPSS version 20.

**3. Results and Discussion.**

**Physico-Chemical Parameters of the Raw Paint Effluent.**

The raw paint effluent was analysed for eight (8) different physico-chemical parameters as presented in table 1. The results presented are the mean and standard error of the mean (SEM) of the obtained values.

**Table 1. Physico-Chemical Parameters and the Heavy Metal Content of the Raw Paint effluent.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Batch AMean ± SEM | Batch BMean ± SEM | P-value | Standard Limits |
| COD (mg/L) | 365.40 ± 30.09 | 602 ± 2.0 | 0.007 | 40 |
| BOD (mg/L) | 73.23 ± 6.62 | 216 ± 16.7 | 0.039 | 20 |
| Turbidity (NTU) | 44366 ± 13554 | 5205 ± 8.5 | 0.160 | 5 |
| Total Solids (mg/L) | 304707± 39253 | 47829± 103 | 0.113 | 50 |
| Electrical Conductivity (mS/m) | 196.73± 44.77 | 2619± 5.5 | 0.129 | 100 |
| pH | 8.34± 0.12 | 7.34 ± 0.2 | 0.000 | 6.5 – 8.5 |
| Temperature (oC) | 29.2± 0.75 | 28.2± 0.1 | 0.000 | Nil  |
| Dissolved Oxygen (mg/L) | 3.71± 0.21 | 3.41± 0.2 | 0.000 | 5 |
| Lead (ppm) | 9.36± 1.87 | 2.2± 0.01 | 0.033 | 0.1 |
| Cadmium (ppm) | 16.01± 7.07 | 0.6 **±** 0.04 | 0.144 | 0.1 |
| Chromium (ppm)  | 0.54± 0.03 | 0.5± 0.40 | 0.017 | 0.5 |
| Copper (ppm) | 1.07± 0.53 | 0.3± 0.02 | 0.121 | 1.0 |
| Arsenic (ppm) | * 1. ± 0.01
 | * 1. ± 0.01
 | 0.001 | 0.1 |

**Key: SEM – Standard of the Mean.**

**Sources of Standard Limits; World Health Organization (WHO), 2003 and National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007. NESREA, 2007.**

The results obtained shows that cadmium out of the five heavy metals analyzed, had the highest concentration of 16.01 ppm, batch A (P>0.05) as against the 0.1 mg/L proposed by the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, (NESREA) 2007 while in batch B, the concentration was at 0.6ppm (P>0.05). Lead recorded the second highest concentration of 9.36 ppm, batch A (P<0.05) compared to the 0.1 mg/L given by the regulatory body for effluents and 2.2 ppm (P<0.05) in batch B. Chromium (0.54 ppm and 0.5 ppm) (P<0.05), copper (1.07 ppm and 0.3 ppm) (P>0.05) in both batches of the effluent. Arsenic, 0.01 ppm (P<0.05) however, were found to be within the range set by NESREAA of 0.5 mg/L for chromium, 1.0 mg/L for copper and 0.1 mg/L for Arsenic.

The results derived from this study after the analysis of the raw paint effluent suggests that industrial paint wastewater is one of the major source of environmental pollution as most of the physico-chemical parameters were found to be above the permissible limit/standard given by the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act (NESREA), 2007 and the World Health Organization (WHO, 2003). The effluent had a very notable turbid characteristic and the concentration of the chemical oxygen demand (COD) in this report was 365.40 mg/L and 602 mg/L (P<0.05) as against the limit of 40 mg/L given which suggests the very high level of very toxic materials that exist in the paint effluent that not biodegradable. A similar observation for COD concentration has been reported by Orjiakor et al (2019) where the characterization of paint effluent obtained from factories in Ado-Ekiti, Nigeria. The value of Biochemical oxygen demand (BOD) obtained in the study was seen at a concentration of 73.23 mg/L and 216 mg/L (P<0.05). The standard limit of BOD given for effluent by NESREA is 20 mg/L. A related data has been documented by Jolly et al (2012). They also carried out the assessment of the physico-chemical characteristics of paint industrial effluent. BOD is an important index in water quality as it measures the amount of oxygen required to decompose organic matter, high level of BOD suggests low quality of water. Also, one of the major risks of elevated BOD is that, it reduces the concentration of dissolved oxygen to the concentrations unfavorable to aquatic lives (Aminu and Hamed, 2021). The electrical conductivity (EC) is also an important parameter because it quantifies the number of inorganic ions present in a solution and the capacity of an electrolyte media to conduct electricity (Okeke *et al*, 2018). Hence, it is one of the parameters that were analyzed in this study. The value recorded for EC in the present study was 196.73 mS/m and 2619 mS/m (P>0.05) which is higher than the limit of 100 mS/m given by WHO (2003). This suggests the high load of inorganic ions in the effluent used in the present study and high levels of EC are not favorable for the ecosystem in general. A lower concentration of 149 mS/m has been documented by Aniyikaiye et al (2019) from their analysis of paint effluent obtained from Lagos, Nigeria. However, a higher value of EC (221-227 mS/m**)** has been reported by Ndukwe et al (2022) who analyzed paint effluent from a paint manufacturing company in Abia state, Nigeria. The turbidity of the paint effluent was measured and had a very significant concentration of 44366 NTU and 5202 NTU (P>0.05) which is considerably higher than the limit of 5 NTU given by WHO (2003). Turbidity measures the cloudiness of a given effluent and when an elevated value of turbidity is obtained, it suggests that the said effluent contains very elevated concentrations of dissolved solids (Okeke *et al*, 2018). A lower concentration of between 119.43-131 NTU has been reported from the analysis of Saclux paint in Abia state, Nigeria (Chidozie and Nwakanma, 2017). In addition, a lesser value of 121 NTU has been reported by Ndukwe et al (2022). The pH value measured 8.34 and 7.34 (P<0.05) which was within the acceptable limit of 6.5-8.5 given by the WHO though it was tending thinly towards alkalinity. pH values quantifies the acidity or alkalinity of a solution. A slightly similar result of 8.41 has been reported (Berihun and Solomon, 2017) and they are of the opinion that the alkalinity nature of the paint effluents is due to its high pH levels. Additionally, pH value between 8.01 - 9.01 has been documented by Chidozie and Nwakanma (2017). The total solids (TS) of the effluents were measured and the values obtained were 304709 mg/L and 47829 mg/L (P>0.05), the standard value of 50 mg/L has been given by WHO (2003) which suggests that the paint effluent is highly polluted with significant amount of unfavorable materials and inorganic salt (Berihun and Solomon, 2017). Furthermore, the use of additives, pigments and binders have been ascribed to the elevated concentrations of total solids in paint effluents (Chidozie and Nwakanma, 2017). Aniyikaiye et al (2019), reported a concentration that ranged from 1920-6510 mg/L which however lower than that obtained in the present study. The dissolved oxygen (DO) values in the present study were 3.71 mg/L and 3.41 mg/L (P<0.05) against the 5mg/L level given by the WHO (2003). A low level of DO suggests the depletion of oxygen, a situation that is oftentimes, not pleasant of the aquatic ecosystem. The temperature ranged from 28.2oC- 29.2oC.

The heavy metals concentrations on the effluent was measured and five potential heavy metals that have the tendency to be present in paint industrial effluent based on already existing literatures were analyzed. They include; cadmium (Cd), lead (Pb), chromium (Cr), Copper (Cu) and Arsenic (As). The concentrations of lead (9.36 mg/L and 2.2 mg/L) and cadmium (16.01 ppm and 0.6 ppm) where far above the acceptable limits given by WHO of 0.1 mg/L for effluents. A lower concentration of cadmium (4.18 mg/L) has been reported by a previous study (Stephen *et al,* 2020) compared to the 16.01 ppm obtained in this study. It is believed that paint manufacture and its usage are a major contributing factor of cadmium pollution of the water bodies and previous reports have shown the presence of cadmium in the aquatic ecosystem (Woldeamanuale and Hassen, 2017). Additionally, cadmium has higher lethality effect when compared to other heavy metals and it is a fundamental toxin of the respiratory system (Graw-Hill, 1985). The concentration of lead in the paint effluent sample was significantly higher than the permissible limit. Lead happens to be among the ancient heavy metals that are understood by humans. This toxicant is most times, released into water run offs via different sources e.g. the paint industry (Woldeamanuale and Hassen, 2017). According to Bhuiyan et al (2014), the indiscriminate use of lead containing pigment and also, the application of lead driers have been linked with the elevated levels of lead in paint effluent. Different concentrations (5.38-17.21 mg/L) of lead from the analysis of paint effluent have been documented by Stephen et al (2020) and the concentration obtained in this study (9.36) is within this range. However, concentrations lower than the value obtained in the current research have also been reported (Woldeamanuale and Hassen, 2017). On the other hand, chromium (0.54 ppm and 0.5 ppm) and copper (1.07 ppm and 0.3 ppm) were slightly higher that the acceptable permissible limit for effluents of 0.5 mg/L for chromium and 1.0 mg/L for copper. In paint manufacture, the use of inorganic pigment that consists of chromium is the reason for the presence of chromium in the paint effluent (Onuegbu *et al*, 2013). Previous studies have shown a similar value of chromium in their data (Woldeamanuale and Hassen 2017; Stephen *et al*, 2020). Also, similar copper concentration in paint effluent has been reported by Chukwuma et al (2020). Arsenic had the lowest concentration of 0.01 mg/L found in the paint effluent and it was below the standard limit for industrial effluents.

**CONCLUSION**

Aside the pH and arsenic that the concentrations were within the permissible limits given by the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act (NESREA, 2007) and the World Health Organization (WHO, 2003), all the other physic-chemical parameters (COD, BOD, TS, EC, turbidity and heavy metals (Cd, Pb, Cu and Cr) were found to be above the standard limits. The high level of these toxic pollutants opens up great risk to the receiving bodies of the effluent hence, endangering lives and the total health of humans. This study suggests the need for efficient and proper treatment of the effluent before discharge into the environment.

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**REFRENCES**

Abraham, L. 1982. American Standard Theoretical. McGraw-Hill, New York, USA.

Abdel-Raouf, N., Al-Homaidan, A.A. & Ibraheem, I.B.M. 2012. Microalgae and Wastewater Treatment. *Saudi Journal of Biological Sciences*, 19(3): 257-275.

Aboulhassan, M.A., Souabi, S., Yaacousi, A. & Baudu, M. 2014. Treatment of Paint Manufacturing Wastewater. *International Journal of Science Environment and Technology*, 3(5): 1747-1758.

Aghor, A. 2007. Chemical make Thane Creek the Worst Polluted Water Body. Daily DNA, August 14, Mumbai, India.

Alam, M.Z., Ahmad, S. & Malik A. 2009. Genotoxic and Mutagenic Potential of Agricultural Soil Irrigated with Tannery Effluents at Jajmau (Kanpur) India. *Archives of Environmental Contamination and Toxicology*, 57(3): 463-476.

Alam, M.Z., Ahmad, S., Malik, A. & Ahmad, M. 2010. Mutagenicity and Genetoxicity of Tannery Effluents used for Irrigation at Kanpur, India. *Ecotoxicology and Environmental Safety*, 73(7): 1620-1628.

Aminu, S.O. & Hamed, M.O. 2021. Assessment of Wastewater Management Practices in Paint Industry on Water Physicochemical Parameter and the Impact of Effluent on Nearby Rivers. *African Scholars Journal of Pure and Applied Science,* 22(9): 199-210.

Aniyikaiye, T.E., Oluseyi, T., Odiyo, J.O. & Edokpayi, T.N. 2019. Physiochemical Analysis of Wastewater Discharged from Selected Paint Industries in Lagos, Nigeria. I*nternational Journal of Environmental Research and Public Health*, 16(7): 1235.

Berihun, D. & Solomon, Y. 2017. Assessment of the Physicochemical and Heavy Metal Concentration from Effluent of Paint Industry in Addis Ababa, Ethiopia. *International Journal of Waste Resources*, 7(4):306.

Bhuiyan, M. A.H., Dampare, S.B., Islam, M.A. & Suzuki, S. 2014. Source Appointment and Pollution Evaluation of Heavy Metals in Water and Sediments of Buriganga River, Bangladesh, using Multivariate Analysis and Pollution Evaluation Indices. *Environmental Monitoring Assessment Journal*, 187(1).

Brack, W., Dulio, V., Agerstrand, M., Allan, I., Altenburger, R. and Brinkmann, M. et al, 2017. Towards the Review of the European Union Water Framework Directive: Recommendations for More Efficient Assessment and Management of Chemical Contamination in European Surface Water Resources. *Science of the Total Environment*, 576: 720-737.

Chidozie, K. & Nwakanma, C. 2017. Assessment of Saclux Paint Industrial Effluents on Nkoho River in Abia State, Nigeria. *Journal of Ecosystem and Ecography*, 7: 1-8.

Chukwuma, O.U. & Uchenna, O.M. 2020. Remediation Potentials of Wheat-Bran and Wood-Chips on effluent Contaminated Soils from Paint Industries in Aba, Abia State Nigeria. *Journal of Global Ecology and Environment*, 15(1): 1-17.

Clark, P. 1972. Water Analysis with Atomic Absorption Variani Techtron. B. Stander Company. USA.

Gabriel, O.M., Rita, O., Clifford, A. & Kennedy, O. 2006. Heavy Metal Pollution of Fish of Qua-Iboe River Estuary: Possible Implication for Neurotoxicity. *The International Journal of Toxicology*, 3(1): 1-6.

Graw-Hill, M.C. 1985. Encyclopaedia of Science and Technology, 15(6): 6.

Gupta, U., Sharma, S.K., Goya, S.K. & Sharma, R. 2022. Removal of Heavy Metals from Integrated Wastewater (IIWW) using Canna Lilly (*Canna indica L.*): A Hydroponic System for Phytoremediation Potential. *International Advances Research Journal in Science, Engineering and Technology*, 9(4): 17-29.

Inobeme, A., Ajai, A.I., Iyaka, Y.a, Ndamitso, M. & Uwem, B. 2014. Determination of Physiochemical and Heavy Metals Content of Soil around Paint Industries in Kaduna. *International Journal of Scientific and Technology Research*, 3(8): 221-225.

Jaishankar, M., Tsefen, T., Anbbalagan, N., Mathew, B.B. & Beeregowda, K.N. 2014. Toxicity, Mechanisms and Health Effects of some Heavy Metals. *Interdisciplinary Toxicology*, 7(2): 60-72.

Jarup, L. 2003. Harzards of Heavy Metal Contamination. *British Medical Bulletin*. 68: 167-182.

Kaur, A., Vats, S., Rekhi, S., Bhardwas, A., Goel, J., Tanwar, R.S. & Gaur, K.K. 2010. Physiochemical Analysis of Industrial Effluents and their Impact on the Micro flora. *Proceedia Environmental Sciences*, 2: 595-599.

Korbahti, B.K. & Tanyolac, A. 2009. Electrochemical Treatment of Stimulated Industrial Paint Wastewater in a Continuous Tubular Reactor. *Chemical Engineering Journal*, 148: 444-451.

Krithika, D. & Ligy, P. 2016. Treatment of Wastewater from Water Based Paint Industries Using Submerged Attached Growth Reactor. *International Biodeterioration and Biodegradation Journal*, 107: 31-41.

Malakootian, M., Vaghmaeian, K. & Malakootian, M. 2006. Wood Ash Effectiveness in Cadmium Removal from Paint Industrial Effluent. *Pakistan Journal of Biological Sciences*, 9 (2): 248-252.

Nanda, M., Sharma, D. & Kumar, A. 2010. Removal of Heavy Metals from Industrial Effluent using Bacteria. *International Journal of Environmental Sciences*, 2(2): 781-787.

National Environmental Standards and Regulations Enforcement Agency, 2007.

Ndukwe, M.K., Igara, C.E., Ibe, C.O. & Okoro, O.C. 2022. Physico-chemical Analysis of Effluent Water from Paint Manufacturing Company in Umuahia, Abia State, Nigeria. *International Journal of Advances in Engineering and Management*, 4(8): 242-249.

Nnodu, V.C., Obiegbu, M.E. & Eneche, P.S.U. 2017. An Assessment of Sustainable Energy-Efficient Strategies for Retrofitted Building Development in Abuja, Nigeria. *Archives of Current Research International*, 9(1): 1-12.

Obi-Anike, H.O., Abomeh, O, S. & Okafor, C.N. 2017. Manpower Development and Employees’ Performance: Qualitative Assessment of Small and Medium Scale Business in Abuja Nigeria. *Journal of Economics, Management and Trade*, 18(3): 1-6.

O’Connell, D.W., Birkinshaw, C. & O’Dwyer, T.F. 2008. Heavy Metal Adsorbents Prepared from the modification of Cellulose: A Review. *Bioresource Technology*, 99(15): 6709-6724.

Okafor, J.O., Agbajelola, D.O. & Shehu, P. 2015. Studies on the Adsorption of Heavy Metals in a Paint Industry Effluent using Activated Maize Cob. *Journal of Multidisciplinary Engineering Science and Technology*, 2 (2):39-46.

Okeke, I.E., Ezeagu, A.C., Ekenta, E.O. & Mbanefo, D. 2018. Harzadous Effects of Industrial Effluent on Ukwaka Stream and the Ecosystem in Nnewi, Nigeria. *American Journal of Engineering Research*, 7(5): 466-484.

Onuegbu, T.U., Umoh, E.T. & Onwuekwe, I.T. 2013. Physiochemical Analysis of Effluent from Jacbon Chemical Industry LTD, Maker of Bonalux-Emulsion and Gloss Paints. *International Journal of Science and Technology*, 2(2): 169-213.

Orjiakor, P.I., Eze, C.N. & Aladetoyinbo, A.S. (2019). Physicochemical Quality and Mycodegradation of Commercial Paint Effluent from Factories in Ado-Ekiti, South-western Region, Nigeria. *FUTY Journal of the Environment*, 13(2): 98-111.

Owa, F.D. 2013. Water Pollution: Sources, Effects, Control and Management. *Mediterranean Journal of Social Sciences*, 4(8): 65-68.

Patil, D. 2009. A Lot’s Fishy about our Creek and Lake Fish. Daily Times of India. March 22, Mumbai, India.

Stephen, A.O., Joyce, K.G.N., Hellen, N. Alex, W.N. & Jared, N.O. 2020. Characterization and Adsorption of Heavy Metals in Industrial Effluent from Paint and Coating Industries in Nairobi, Kenya. *International Journal of Engineering Applied Sciences and Technology*, 4 (5): 41-46.

Storelli, M.M., Storelli, A., D’addabbo, R., Marano, C., Bruno, R. & Marcotrigiano, G.O. 2005. Trace elements in Loggerhead Turtles (Carettacaretta) from the Eastern Mediterranean Sea. Overview and Evaluation. *Environmental Pollution*, 135 (1): 163-170.

Verma, R. & Dwivedi, P. 2013. Heavy Metal Pollution – A Case Study. *Recent Research in Science and Technology*, 5: 98-99.

Vinod, K.G., Ganjali, M.R., Nayak, B.A. & Agarwal, B.S. 2012. Enhanced Heavy Metal Removal and Recovery by Mesoporous Absorbent Prepared from Waste Rubber Tire. *Chemical Engineering Journal*, 197: 330-342.

Virvaghavan, T., Ganesh, A. and Reo, K. (1991). Adsorption of Cadmium and Chromium from Wastewater by Fly Ash. *Journal of Environmental Science and Health*, 26(5): 721-753.

Wan, M.W., Wang, C.C. & Chen, C.M. 2013. The Adsorption Study of Copper Removal by Chitosan-Coated Sludge Derived from Water Treatment Plant. *International Journal of Environmental Sciences and Development*, 4(5): 545-551.

Woldeamanuale, T.B. & Hassen, A.S. 2017. Toxicity Study of Heavy Metal Pollutants and Physico-Chemical Characterisation of Effluents Collected from Different Paint Industries in Addis Ababa, Ethiopia. *Journal of Forensic Sciences*, 5(5): 001-006.

WHO (World Health Organization) 2003. Guidelines for Drinking Water Quality, Health Criteria and other Supporting Information, Geneva.

Zeitoun, M.M. & Mehana, E.E. 2014. Impact of Water Pollution with Heavy Metals on Fish Health: Overview and Updates. *Global Veterinairia*, 12(2): 219-231.

Tesfalem, B.W. & Abrie, S.H. 2017. Toxicity Study of Heavy Metals Pollutants and Physico-Chemical Charateristics of Effluents Collected from Different Paint Industries in Addis Ababa, Ethiopia. *Journal of Forensic Sciences and Criminal Investigation*, 5: 1-5.