PHYSICOCHEMICAL AND MICROBIAL ANALYSIS OF THE INDUSTRIAL WASTES IN A COPPER AND STEEL FACTORY IN NNEWI, ANAMBRA STATE NIGERIA

Authors:

Igbokwe Adaolisa Millicent [1], Ugwu Chidiebere Emmanuel[1*], Dike Charles Chijioke [1], Mbachu Nancy Amara[1], Maduka Hugh Clifford Chima[1].

Author Affiliation:

[1]Department of Human Biochemistry, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University Awka, Nnewi Campus Anambra State Nigeria.

*Corresponding author:

ce.ugwu@unizik.edu.ng

+2348063276355.

ABSTRACT

Background: Waste from industrial processes in modern civilization contributes to water pollution, particularly contaminating groundwater through leaching and industrial effluents.

Aim of study: The aim of this study was to evaluate the toxicological and environmental impacts of a copper and steel factory wastes on the physicochemical and microbial qualities of the liquid effluent, water and soil around a copper and steel factory.

Methodology: A purposive sampling technique was employed for the study. The samples were grouped into 6 groups: 1 (soil samples from the factory), 2 (effluent discharge from factory), 3 (water sample from boreholes in the factory), 4 (water sample from borehole around the factory), 5 (soil sample from non-industrial site) and 6 (water sample from borehole, non-industrial site). Physicochemical properties (turbidity, electrical conductivity, pH, total hardness, total dissolved solids) and microbial analysis were determined using known standard methods. Analysis of the results was done using known standard methods and the results were statistically analyzed.

Results: The results showed that all physicochemical properties were within WHO permissible limit except turbidity levels in factory effluent and boreholes ($P < 0.05$), suggesting the samples from the factory may contain suspended and colloidal matter, and microorganisms. Microorganisms such as *E. coli, Streptococcus Spp., Coliform Spp*. and *Klebsiella spp*. were found in samples.

Conclusion: The industrial processes of the factory may have polluted the borehole water, thereby making it unsafe for both drinking and domestic use.

Key words: Physicochemical, microbial, industrial processes, copper, steel, pollution.

Introduction

Industrial pollution poses a threat to the health and wellbeing of millions of people and the global ecosystem[1]. Rapid growth of industrialization, urbanization and increase in human population around the globe has led to high demand for good quality water for domestic, recreational, industrial and other purposes[2].

The nature of industrial waste depends on the industrial processes from which it originates. Effluents from different industries are discharged into the adjoining environment and water bodies. The effluents discharged may have undergone some kind of treatment or not at all. Among the toxins and pollutants found in effluents are disease-causing microorganisms like bacteria and viruses, heavy metals, organic pollutants, and biodegradable organics. These contaminants have a serious impact on the ecosystem[3].

In developing countries including Nigeria, the reliance on groundwater over surface water for domestic use is very high. Industrial effluents and inorganic matters are the major sources of contamination of groundwater and other water sources[4]. The quality of groundwater in a given area can be determined by the physical and chemical properties of the water. The physical parameters that determine water quality include temperature, turbidity, colour, taste, and odour of water. As indicated by Peni and Listyani[5], the chemistry of the groundwater can be seen from the total dissolved solids (TDS), pH, and chemical composition. In terms of the chemical composition, the remarkable areas of attention are the acidity and the hardness.

The copper processing industries play an important role in manufacturing copper wires, copper burners, pesticides, ceramics, and cupric dyes for tanning industries. Effluents from metal finishing factories contains pollutants such as heavy metals, organic substances, cyanides, dissolved and suspended solids at levels which are harmful to the people. Steel industry effluents contain acidic waste, heavy metals, and organic contaminants, which significantly contribute to the contamination of water bodies. As a result of variations in the nature of raw materials, by-products, and the effectiveness of the operation system, polluted water discharged from steel production industries varied greatly in physicochemical indices and heavy metal concentrations.

Surface water contamination may lead to a high concentration of physicochemical elements that could upset the environment[6]. Industrial wastes have been reported to cause changes in ecosystem values, pH, conductivity, and trace metals. Biochemical processes in water systems have been shown to be influenced by physicochemical factors like temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), turbidity, and nutrient loads[1].

Calcium and magnesium make up most of what is known as water hardness. Technically, other multivalent cations (of valence greater than $^{+1}$) are considered part of the hardness.

Total Dissolved Solids and Turbidity levels are related to the presence of suspended organic materials which also promote the growth of microorganisms[7].

The pH value is a significant determinant of the quality of water that indicates the presence of alkali or acid in the samples of the water. It also affects chemical reactions, such as metal toxicity and solubility[8].

Electrical conductivity (E.C.) is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water[9]. The conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Therefore, wastewater treatment is an essential requirement in today's society in order to decrease pollution and save natural resources.

The aim of this study was to evaluate the toxicological and environmental impacts of a copper and steel factory wastes on the physicochemical and microbial qualities of the liquid effluent, water and soil samples around a copper and steel factory in Nnewi, Anambra State Nigeria.

Materials and methods

Study Area:

This study was carried out in Nnewi Industrial area of Nnewi North LGA, Anambra State, Nigeria. The study area, Nnewi, lies between Longitudes $6^{o}\ 91^{1}$ E and $6^{o}\ 55^{1}$ E and Latitudes $6^{o}\ 16^{1}$N and $6^{o}\ 10^{1}$ N.

Statistical analysis:

The data were presented as mean ± SD and the mean values of the test groups were compared with Control groups and WHO permissible limits by t-test and ANOVA using Statistical package for social sciences (SPSS) (Version 22) software. A $P<0.05$ was considered as significant.

Results

Table 1 presents the result of physicochemical analysis of samples from factory sand and waste water, factory boreholes, neighborhood borehole and control samples. The results in Table 1 revealed that pH of group 1 was significantly higher than the WHO permissible limit (group 8) and control (group 5). The pH values of groups 2, 3 and 4 were within the WHO permissible limit (group 8) but significantly higher when compared with the control (group 6). The EC values of groups 2, 3 and 4 were significantly lower than the WHO permissible limit; values of groups 3 and 4 were also significantly lower than the control (group 6).

The TDS values of groups 2, 3 and 4 were significantly lower than WHO limit while values of groups 3 and 4 were also significantly lower when compared to the control (group 6). Also, the TH values of groups 2, 3 and 4, were significantly lower than WHO permissible limit; values of groups 3 and 4 were also significantly lower when compared to the control (group 6).

The values of turbidity in groups 2, 3 and 4 when compared to WHO permissible Limit was insignificant while groups 3 and 4 were significantly higher when compared to the control (group 6).

Table 2 presents the result of the physical characteristics of samples from factory sand and waste water, factory boreholes, neighborhood boreholes and control samples. The results in table 2 showed that the colour of groups 1 and 5 were brown, they were odorless but contained particles. Group 2 had a cloudy look, was odorless but contained visible particles. Groups 3, 4 and 6 were seen to be colorless, odorless and not containing particles.

The results of the microbial analysis on samples from factory sand and liquid effluent, factory boreholes, neighborhood boreholes and control samples are presented in Table 3.The results revealed that *Coliform specie* was seen in groups 1 and 5 suggesting their presence in both sand samples and sand control samples. E. coli was present in all groups except group 2, which is the effluent discharge from the factory.

The table also showed that in groups 2, 4 and 6, there was presence of *Klebsiella spp. Streptococci spp.* was seen in only group 4, while *Staph spp*. was not seen in any of the groups.

Table 1: Results of Physicochemical Analysis of Samples from Factory Soil and Liquid Effluent, Factory Boreholes, Neighborhood Borehole and Control Samples.

Physicochemical properties	pH	Electrical Conductivity (uS).	Total Dissolved Solids(mg/L)	Total Hardness (mg/L)	Turbidity (NTU)
Factory Soil N=6	7.21®0.06	NA	NA	NA	NA
Factory Effluent N=6	6.60®0.11	41.4®4.9	20.65®2.46	15.00®0.63	5.00®0.00
Factory Boreholes N=6	7.00®0.00	37.95®11.34	16.50®1.64	17.00®0.06	5.35®0.05
Neighborhood Boreholes N=12	6.85®0.05	33.06®6.17	14.65®5.53	18.00®0.63	3.98®2.11
Soil Control N=6	6.93®0.00	NA	NA	NA	NA
Water Control N=6	6.52®0.00	64.34®7.12	40.36®0.00	41.58®0.09	1.67®0.00
WHO Sand Limit	6.0-9.5	NA	NA	NA	NA
WHO water Limit	6.5-8.5	1000	500	75.0	5.00

Values are presented as Mean ± SD, $P<0.05$.

NA: Not Applicable; for quantities that cannot be determined.

Table 2: Result of the Physical Characteristics of Samples from Factory Soil and Liquid Effluent, Factory Boreholes, Neighborhood Boreholes and Control Samples.

Groups	Sampling Sites	Colour	Odour	Presence Of Particles
1	A	Brown	Odourless	+++
	B	Brown	Odourless	+++
2	C	Cloudy	Odourless	+++
	D	Cloudy	Odourless	+
3	E	Colourless	Odourless	-
	F	Colourless	Odourless	-
	G	Colourless	Odourless	-
4	H	Colourless	Odourless	-
	I	Colourless	Odourless	-
	J	Colourless	Odourless	-
5	P	Brown	Odourless	+++
	Q	Brown	Odourless	+++
6	R	Colourless	Odourless	-
	S	Colourless	Odourless	-

Table 3: Result of Microbial Analysis on Samples from Factory Soil and Liquid Effluent, Factory Boreholes, Neighborhood Boreholes and Control Samples.

Groups	Sampling sites	*E. Coli* spp.	*Strept.* spp.	*Coliform* spp.	*Klebsiella* spp.	*Staph.* spp.
1	A	-	-	++	-	-
	B	+++	-	-	-	-
2	C	-	-	-	++	-
	D	-	-	-	+++	-
3	E	+++	-	-	-	-
	F	-	-	-	-	-
	G	++	++	-	-	-
	H	+++	+++	-	-	-
4	I	++	++	-	-	-
	J	-	-	-	++	-
	P	-	-	++	-	-
5	Q	++	-	-	-	-
6	R	-	-	-	++	-
	S	++	-	-	-	-

key **-:** Not seen, +: Scanty Growth, ++: Moderate Growth, +++: Heavy Growth

Discussion

The physicochemical and physical effects of the industrial wastes of a copper and steel factory was evaluated in this study. The presence of anions and cations such as sodium, calcium, sulphate, nitrate, phosphate, chloride and bicarbonate as well as physicochemical parameters such as electrical conductivity (EC), total dissolved solids (TDS), total hardness, pH, turbidity and selected common microorganisms in the liquid effluent, factory and neighborhood borehole water and soil samples from the factory were measured, recorded, analyzed and compared with the control samples and the WHO maximum permissible limits for water and soil.

In this study, all the cations and anions concentrations except phosphate concentration in all the borehole water, soil, and factory effluent samples were found to be significantly lower than the WHO set permissible limits. This result agrees with the previous findings in different parts of Nigeria like the West and South East Nigeria [15-22]. Phosphate, chloride and sulphate levels were higher in the factory soil samples and effluent discharge when compared to the control groups.

This could be as a result of the additives such as stabilizers and plasticers used by the factory in their processes. Sodium causes scale formation and corrosion in boilers while in human excess sodium ion causes hypertension, congenial diseases, kidney and nervous disorders[23].

Phosphates in the environment, food or water are not toxic to people or animals unless they are present in very high concentration or amount. High levels of phosphate are deleterious to animals and humans on consumption. It can cause increase in plasma phosphorus level and decrease in serum calcium. The resulting hypocalcaemia stimulates secretion of parathyroid hormone, which in turn increases the rate of bone resorption[24]. High nitrate concentration has been linked to methemoglobinemia and formation of carcinogenic and mutagenic nitrous amine in gastrointestinal tracts of human being[25]. Chloride, phosphate and sulphate anions are acidic and when ingested in high concentrations, change the acid-base equilibrium, creating more acidic conditions, a process that can lead to acidosis[15].

Results of the physicochemical analysis of samples in this study showed that the neighborhood borehole water and factory effluent and water were slightly acidic and neutral respectively but fell within the WHO set permissible limit for industrial and agricultural water. This slight acidity can be attributed to the significantly lower number of cations and anions found in the samples. However, the pH of the factory soil sample is slightly basic and can be attributed to the rich organic and inorganic matters found in it. Although pH usually has no direct impact on water consumers, it is one of the most

important water quality parameters that should be carefully monitored to avoid leaching of metals in the water, sour taste and skin irritations. The pH affects the solubility of most metals in water and is an important factor affecting the productivity of aquatic ecosystems[26].

Electrical conductivity, Total dissolved solid and Total hardness are all interrelated as an increase in the total concentration of dissolved ions in the water will cause an increase in the aforementioned parameters within the samples. Ekenta *et al*. [27] stated that electrical conductivity (EC) reflects the total concentration of soluble salts in water.

Total Dissolved Solids (TDS) comprise mainly of inorganic salts and some small number of organic substances that are dissolved in water and affect water quality [28-29], while total hardness is dictated by the amount of minerals such as calcium and magnesium deposited in the water. In this study, the EC, TDS, and TH in either the factory effluent or water samples were significantly lower than the WHO set permissible limits. These results agree with the findings of [27, 30-31] but disagree with the findings of Dessie *et al.*[32], who found higher values of EC, TDS, TH in industrial waste water due to differences in quantity and nature of chemicals used. Turbidity is the reduction of transparency of water due to the presence of particulate matters such as clay, silt, organic matter, or microscopic organisms. The result of this study indicates that there is high turbidity in all the effluent and water samples of the factory.

This shows pollution and possibility of bacterial growth [33]. It is in line with the result of the physical characteristics of the samples. Borehole water samples are colourless, odourless and has no particles while the effluent discharge are cloudy, odourless and has moderate particles. The FAO[34] reported that elevated colour concentration might suggest coloured organic substances and the presence of metals such as Fe, Mn and Cu.

Results from the microbial analysis of soil, water and effluent discharge samples showed the presence of varying growth ratio of pathogenic organisms such as *E. coli spp*., *Streptococcus spp., Coliform spp.,* and *Klebsiella spp.*, in the different samples while *Staphylococcus spp.* was not detected in all the samples.

These pathogenic organisms should not be found in drinking and industrial water but are usually present in surface water, soil and faeces of humans and animals. Though not all coliform bacteria can cause illness in humans, the presence of any microbe is a possible health concern. The result is in line with the findings of Akoji [35] who reported 25% *Enterobacter aerogenes*, 40% *E. coli* and 35% of different coliforms in borehole water in Abuja and Sojobi [17] who found *Enterobacter aerogenes* and *E. coli* in borehole water in North Central of Nigeria.

Conclusion:

The results from this study showed that the industrial wastes from the factory may have polluted the borehole water, thereby making it unsafe for both drinking and domestic use.

References

1. Gemeda FT, Guta DD, Wakjira FS, Girma G. Physicochemical characterization of effluents from industries in Sabata town of Ethiopia. Heliyon. 2020; **6**(8): e04624.
2. Adesakin T A, Oyewale AT, Umar B A, Mohammed A N, Aduwo I A, Ahmed P Z, *et al*. Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. Heliyon, 2020; **6**: e04773.
3. Adam A, Saffaj N, Mamouni R, Ait Baih M. Characterization of industrial wastewater physico-chemical properties. International Journal on Technical and Physical Problems of Engineering. 2022; **40**(1): 219-227.
4. Adebayo KI, Nyong VE, Oyetade PO, Amah G. Physicochemical Properties of groundwater in parts of Irun Akoko, Ondo State, Nigeria. Global Journal of Geological Sciences. 2021; **19**: 85-91
5. Peni S, Listyani A. Physical and chemical properties of groundwater in Banjararum Area and its vicinity, West Progo. Kurvatek. 2019; **4**(2):111-116
6. Lawal JA, Odebunmi EO, Adekola FA. Physicochemical analysis and heavy metal content of effluent discharge from a steel processing plant in Ilorin, Kwara State, Nigeria. Centrepoint Journal. 2022; 26(1):67-78.
7. Igbinosa EO, Uyi OO, Odjadjare E E, Ajuzie C U, Orhue P O, Adewole E M. Assessment of physicochemical qualities, heavy metal concentrations and bacterial pathogens in Shanomi Creek in the Niger Delta, Nigeria. African Journal of Environmental Science and Technology. 2012; **6**(11): 419-424.
8. Kadir HA, Okoyomon OO, Zango ZU, Saidu U, Nura SA. Physicochemical composition and heavy metal determination of selected industrial effluents of Ibadan City, Nigeria. Open Journals of Environmental Research. 2021; **2**(2): 58 – 66.
9. Environmental Protection Agency (EPA). Conductivity. In water: Monitoring and Assessment. 2012; pp5- 9 Retrieved from http://www.epa.gov/type/rsl/monitoring/vms59.cfm
10. American Public Health Association. 1998. Standard methods for the examination of water and wastewater. 20th Edition, Washington Dc. rainforest landscape. Journal of Geography and Regional Planning 1998; **3,** 177-184.
11. Cheesbrough M. Medical laboratory manual for tropical countries Volume 11. Second edition, University Press, Cambridge, Great Britain, 2000; pp 377.
12. Rahmanian N, Sitihajarbt A, Homayoonfard M, Ali NJ, Rehan M, Sadef Y, *et al*. Analysis of Physiochemical parameters to evaluate the drinking water quality in the state of Perak Malaysia. Journal of Chemistry. 2015; Article ID 716125. Retrieved from: https://doi.org/10.1155/2015/716125
13. American Public Health Association. Standard Methods for the Examination of Water and Wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington. DC. 2005.
14. Mazdoor KSS, Jawaharlal N. Methods of sampling and test (physical and chemical) for water and wastewater, Turbidity. Environmental Protection and Waste Management, 2002; **10**:1.
15. Isiuku BO, Enyoh C E. Pollution and health risks assessment of nitrate and phosphate concentrations in water bodies in South Eastern, Nigeria. Environmental Advances, 2020; **2**:1–7.
16. Sojobi AO, Owamah HI, Dahunsi SO. Comparative study of household water treatment in a rural community in Kwara State Nigeria. Nigerian Journal of Technology. 2014; **33** (1): 134–140.

17. Sojobi AO. Evaluation of groundwater quality in a rural community in North Central of Nigeria. Environmental Monitoring and Assessment. 2016; 188:192.

18. Ishaku JM, Kaigama U, Onyeka NR. Assessment of groundwater quality using factor analysis in Mararaba-mubi area, Northeastern Nigeria. Journal of Earth Sciences and Geotechnical Engineering. 2011; **1**(1): 9–33.

19. Nwankwoala HO, Amadi AN, Oborie E, Ushie FA. Hydrochemical factors and correlation analysis in groundwater quality in Yenagoa, Bayelsa State, Nigeria. Applied Ecology and Environmental Sciences. 2014; 2(4):100–105.

20. Viswanath NC, Kumar PGD, Ammad K K. Statistical analysis of quality of water in various water shed for Kozhikode City, Kerala, India. Aquatic Procedia, 2015; **4**:1078–1085.

21. Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB. Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. International Journal of Environmental Research and Public Health. 2007; **4**(4):307-318.

22. Devic G, Djordjevic D, Sakan S. Natural and anthropogenic factors affecting the groundwater in Serbia. Science of the Total Environment. 2014; **468**(46):933–942.

23. Ramesh K, Elango L. Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. Environmental Monitoring Assessment. 2011; pp 10-15 Retrieved from: https://doi.org/10.1007/s10661-011-2231-3.

24. Edeogu CO. Nitrate, sulphate, phosphate and chloride status of staple food crops, soils and water as indicator of environmental base anion pollution load in Ebonyi State, Nigeria. Journal of Biological Sciences. 2007; **7**(5):745-751.

25. Umer IM, Abduljabar PA, Newar AH. (2018). Assessment of ground water pollution by heavy metals and anions in Kwashe industrial area, Duhok City, Kurdistan Region Iraq. International Conference on Materials Engineering and Science. 2018; **454**(1):1-8

26. Aniyikaiye T E, Oluseyi T, Odiyo JO, Edokpayi J N. Physico-chemical analysis of wastewater discharge from selected paint industries in Lagos, Nigeria. International Journal of Environmental Research and Public Health. 2019; **16**(7):1235.

27. Ekenta OE, Okoro BU, Ezeabasili ACC. Hydrogeological characteristics and groundwater quality analysis for selected boreholes in Ogbaru Local Government Area, Anambra State, Nigeria. American Scientific Research Journal for Engineering, Technology and Sciences. 2015; **14**(2):198-210.

28. Kumar A, Cabral-Pinto M, Kumar A, Kumar M, Dinis PA. Estimation of risk to the eco-environment and human health using heavy metals in the Uttarakhand Himalaya, India. Applied Sciences. 2020; 10:7078. Retrieved from: https://doi.org/10.3390/app10207078

29. Lanjwani MF, Khuhawar MY, Khuhawar TMJ. Groundwater quality assessment of Shahdadkot, Qubo Saeed Khan and Sijawal Junejo Talukas of District Qambar Shahdadkot, Sindh. Applied Water Science, 2020; **10**:26.

30. Sokpuwu IA. Groundwater quality assessment in Ebubu Community, Eleme, Rivers State, Nigeria. Journal of Environmental Analytical Chemistry. 2017; **4**(4):1-6.

31. Igwe O, Chukwurah UO. Integrated physicochemical and hydrogeochemical assessment to groundwater quality in Obosi and Onitsha provinces, South-eastern Nigeria. Environmental Earth Sciences. 2018; **77**:263

32. Dessie B, Tessema B, Asegide E, Tibebe D, Alamirew T, Walsh C, Zeleke G. Physicochemical characterization and heavy metals analysis from industrial discharges in Upper Awash River Basin, Ethiopia. Toxicology Reports. 2022; 8(9):1297-1307.
33. Awomeso JA, Taiwo AM, Morawo OA, Moyosore JO. Possible abstraction sites along Oshun River-Lower course in Ogun and Lagos State, Nigeria for sustainable production of quality potable water. Journal of Science and Technology. 2011; **31** (3):58-67.
34. Food and Agricultural Organization. Water quality monitoring, standards and treatment. In: Fishery Harbour Manual on the Prevention of Pollution-Bay of Bengal Programme. FAO repository document. 2012. Retrieved From: http://www.fao.org/docrep/x5624e/x5624e05.htm. Accessed 18/08/14.
35. Akoji JN. Evaluation of Groundwater Quality in Some Rural Areas of the Federal Capital Territory, Abuja, Nigeria. Nigerian Research Journal of Chemical Sciences, 2019; **7**:197-213