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Impact of metals and nutrients pollution on the socio-cultural disposition of humans: A case study of Aleto River, Rivers State, Nigeria

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A R T I C L E I N F O

Article type:
Research article
Article history:
Received August 2023
Accepted November 2023
January 2024 Issue
Keywords:
Trace metals
Nutrient load
Water quality parameters
Monitoring
Aleto River

A B S T R A C T

This study evaluates the effect of trace metals and nutrient loads on the inhabitants of Aleto using Aleto rivers in Eleme, Rivers State, Nigeria. Aleto River serves as the point of industrial effluent discharge while Agbonchia River was used as the control point. Physico-chemical properties were analyzed in the samples such as pH, phosphate, sulphate, nitrate, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), chloride and dissolved oxygen (DO). The trace metal components were analyzed using a flame atomic absorption spectrophotometer (FAAS). The physicochemical characteristics revealed range value of chloride, biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen were above World Health Organization permissible limits for upstream and downstream points, while temperature, electrical conductivity, phosphate, sulphate, and nitrate were within the maximum allowable limit of World Health Organization. The result shows the presence of all the heavy metals (lead, manganese and cadmium) in the river except nickel. The pH values ranged from 6.30-9.00 showing a result on the upstream to be alkaline while the downstream to be slightly acidic. This indicates that the river is unfit for both human and aquatic species thereby affecting the socio-cultural heritage of the people within the locality. The findings highlight the urgent need for government regulations to ensure clean water and sanitation in alignment with Sustainable Development Goal 6.

Capsule Summary: The impact of trace metals and nutrient loads on the Aleto River due to industrial effluent discharge, revealed elevated levels of pollutants beyond WHO limits, which need government regulations to ensure clean water.

Cite This Article As: B. Akpene, L. C. Anyika and C. Obi. Impact of metals and nutrients pollution on the socio-cultural disposition of humans: a case study of Aleto River, Rivers State, Nigeria. Chemistry International 10(1) (2024) 22-28.
https://doi.org/10.5281/zenodo.11001037

INTRODUCTION

Water is essential for life and also utilized for domestic, agricultural production, industrial activities, and many other uses as in the case of Aleto town. Water is a basic amenity to humanity on the planet Earth. However, Fakayode (2005) observed that water is managed poorly in many parts of the world despite it being important for life. Water is a good solvent, and due to this characteristic, it will always dissolve and contain mineral constituents and other substances that it leaches out on contact. The contamination of water in a particular area is always directly related to the degree of contamination of its environment (Nirankar et al., 2022). Consequently, impurities from surface run-off, sewage discharges, and industrial effluents are collected by rivers and streams in their course of flow (Aziz et al., 2015; Alves et al., 2023).

Rivers and streams are important sources and channels for the movement and transportation of anthropogenic metals of the ocean (Binner et al., 2023). Water pollution from anthropogenic activities has been documented in many parts of the world (Slywia et al., 2023). Many rivers, lakes, wetlands, ground waters, and oceans suffer a great loss of degradation from various human activities. These activities have effects on water quality, changing both its physiochemical and biological parameters thereby making it unsuitable not only for domestic use but also for other purposes. Water pollution also has effects on habitats, causing species migration for species that cannot adapt, while exterminating others due to impacts that affect their reproductive abilities.

Metals refer to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of such elements include; mercury (Hg), cadmium (Cd), manganese (Mn), nickel (Ni), etc. They are natural components of the earth's crust and cannot be degraded or destroyed. To a lesser extent, they enter our bodies via food, drinking water and air. Trace elements (e.g., copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations, the consumption of trace metals in contaminated water can lead to poisoning and eventual death (Bharatraj and Yathapu, 2018). This is because they tend to bioaccumulate in the body (Nnaji et al., 2023).

Nutrient load means the total amount of a nutrient such as nitrogen or phosphorus entering the water domain during a given time such as discharges, point source discharges, or the air (Leyun et al., 2021). The proper balance of nutrients in an aquatic ecosystem is vital for aquatic life, health and environmental safety (Quadra and Brovini, 2023). Controlling nitrogen and phosphorus which often occur in excess in bodies of water surrounded by fertilized vegetation, accumulated organic materials, and abundant human activity is particularly important. This is often because fertilizers and excess organic materials contain excess nitrogen and phosphorous to increase a plant's growth potential. This can cause algae blooms or eutrophication which is large masses of algae that use up the excess nutrients. These large masses of algae block surface light from reaching other vegetation below the surface making the aquatic species uninhabitable (Dai *et al*., 2023)

New challenges in environmental protection and conservation that have resulted from global changes bring the need for baseline data to evaluate the potential impact of pollutants on ecosystems (Ukaogo *et al.,* 2020). In the recent past, microbial quality of water for potable uses was of concern and often given priority due to the immediate and potentially devastating consequences of waterborne infectious diseases (Ukaogo et al., 2020). Currently, however, increased concern has shifted over to the effect of heavy metals in water bodies. This is because the public has now become aware of the marked toxic effects of heavy metal pollution and its environmental problem owing to their persistent and accumulative properties (Briffa et al., 2020; Camilo et al., 2021)

Moreover, agrochemicals introduced in the soil as soil nutrients to improve fertility contain metals that in most cases exceed the limits set for land application and their continuous use can exacerbate their accumulation in agricultural soils (Asit et al., 2020; Saravanan et al., 2022). Hence, the use of agrochemicals such as pesticides and fertilizers may result in undesirable accumulation of trace elements like Cd, Cu, Pb and Zn (Quinteros et al., 2017; Attilio et al., 2020; Naccarato et al., 2020). In addition, the use of composts and bio-solids has been shown to increase cadmium, copper, and zinc in soils while phosphate-containing fertilizers have been found to enhance the leaching of cadmium from soil (Smith, 2009; Wang et al., 2021; Abdellah et al., 2022).

Eleme Local Government Area houses several companies, a seaport, and most especially refinery situated close to the river. Aleto River could be suffering from the effects of the discharges from these companies into its waters hence, the motivation for the study. Aleto River is a river that flows into Imo River and is located in Eleme Local Government Area and situated between latitude 50.04^{o} and 60.00^{o} North of the equator and longitude 60.38^{o} and 55.99^{o} East of the Greenwich Meridian (Figure 1). The Imo River section of the river flows through Oyigbo and discharges into the Agbonchia River. The other end of the river is linked to the Akpajo and Okirika Rivers.

Among other activities, Aleto River supports farming, fishing, domestic, and recreational activities of the local communities around it. Any dilapidation of this river through pollution will have very crucial negative impacts in the livelihoods of local communities and hence, affect their socio-cultural dispositions. Therefore, this study aimed to evaluate the effects of trace metals and nutrient loads in the water sample from the Aleto River.

MATERIAL AND METHODS

Description of the study area

Eleme Local Government Area, Rivers State, Nigeria can be found between the coordinates 7E and 8E, 4N and 5N on the South-Eastern map of Nigeria. It is bound on the Northern side by Obio/Akpor and Oyigbo, in the Southern side by Okrika and Ogu/Obolo, on the East by Tai and on the West by Okrika and Port Harcourt Local Government Areas. The upper reaches of the stream which experience high tide is fresh water while the lower reaches consisting of saltwater experience low tide.

Sample collection and preparation

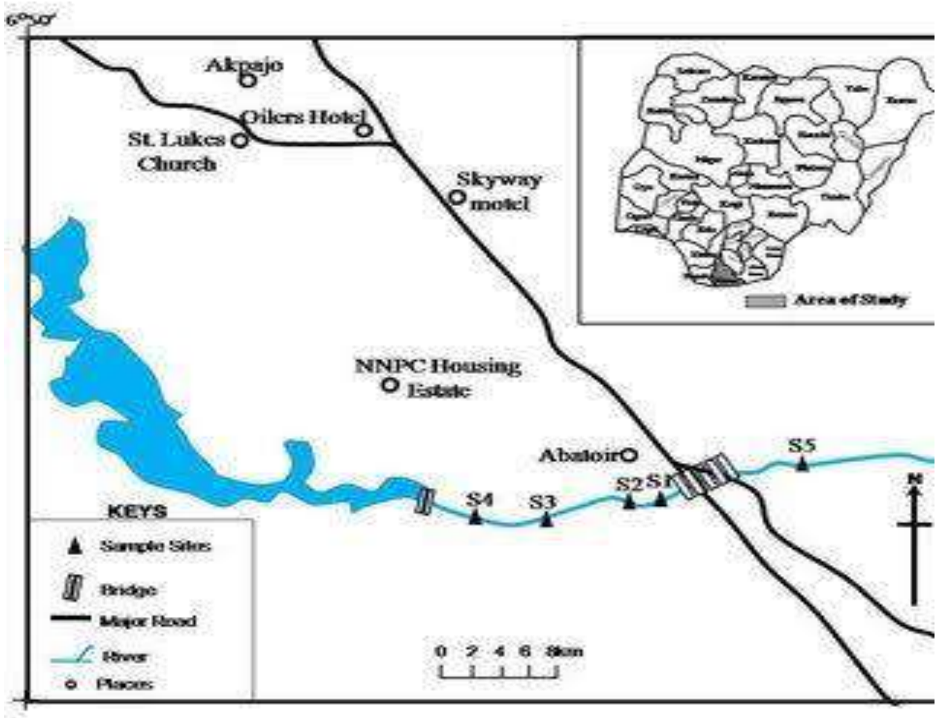

Fig. 1: Map showing study area.

Sample collection was limited to surface water. The water samples were collected from Aleto river (upstream and downstream) and Agbonchia River (control) both in Eleme Local Government Area, Rivers State in July, 2022. The samples were collected randomly and manually from the study sites, into pre-cleaned 1 L plastic containers. The samples for dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected using DO and BOD bottles of 50-100 mL. The sensitive water parameters like temperature and pH were analyzed in situ, whereas, samples for the estimation of biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nitrate (as in NO_3^-), phosphate, chloride and sulphate, lead, manganese, nickel and cadmium were brought to the laboratory for analysis.

pH

The pH meter was calibrated with buffer standards and afterwards the meter was turned on and electrode was then dipped into the sample in the beaker, stirred and the reading was taken.

Temperature

The thermometer was first cleaned before it was dipped into the sample in the beaker and after 5-7 times, the reading was taken. The analysis was run three (3) times before the final reading was taken.

Conductivity measurement

Conductivity was first carried out using the conductivity cell to determine the number of ions present in the river sample and also to be able to determine the number of ions that could conduct electricity in the water sample.

Chloride

Potassium chromate was used as a reagent while silver nitrate ($AgNO_3$) as a titrant. Water (20 mL) was first used as the blank titrant and then $AgNO_3$ into the distilled water sample in the beaker gave the entire solution a non-fading red tinge meaning an end point has been reached. The water sample (10 mL) was then refilled to the zero level with $AgNO_3$ as the titrant and dropped into the water sample in a steady sequence while stirring gently. Using the titrated blank as a guide, the sample was titrated until the colour matched that of the blank. Then the number of millimeters used to cover the colour range on the pipette scale was recorded as titer value. Chloride was calculated using Eq. 1, mg/L chloride as NaCl.

$$\text{NaCl}\ (\text{Cl}^-) = \frac{\text{Litre value (mL)} - \text{indicator reading (mL)}}{\text{Volume of water sample used}} \times 100 \qquad (1)$$

Phosphate

Two cell bottles were used in determining the proportion of ions in the sample. First a 10 mL of de-ionized water was added in a cell bottle as the blank, then another 10 mL sample was filled in the bottle with the water sample and phthalate-phosphate reagent powder pillow was added.

Using a spectrophotometer at 470 nm, the blank was first run before the water sample.

Sulphate

Two cell bottles were used in determining the proportion of ions in the sample. A 10 mL of de-ionized water was added in a cell bottle as the blank, and another 10 mL sample with sulphate reagent powder. Using a spectrophotometer at 420 nm, a milky precipitate indicates the presence of sulphate.

Nitrate

A stock solution containing 5 mg/L of nitrite were transferred into a 10 mL calibrated flask. 1 mL of 0.5% sulfanilic acid and 1 mL of 2 mol/L hydrochloric acid solution were added and the solution was shaken thoroughly for 5 min to allow the diazotization reaction to go to completion. Then, 1 mL of 0.5% methyl anthranilate and 2 mL of 2 mol/L sodium hydroxide solution were added to form an azo dye and the mixtures were diluted to 10 mL using water. After dilution to 10 mL with water, the absorbance of the red-colored dye was measured at 493 nm against the corresponding reagent blank and the calibration graph was constructed.

Trace metals analysis

The heavy metals were analyzed by Flame Atomic Absorption Spectroscopy (FAAS) (Model 2380) as described by Baird & Bridgewater, (2017).

BOD, COD and DO analysis

BOD and COD were determined by standard methods (Baird and Bridgewater, 2017). Dissolved Oxygen was analyzed by titrimetric method (Baird and Bridgewater, 2017).

RESULTS AND DISCUSSION

The temperature of water samples was in the range of 23.0 -29.0°C. The temperature values were however slightly lower than 29.27-29.87°C recorded by Osinbajo et al. (2011). The values of temperature obtained from all the studied sites were within WHO maximum value (Table 1).

The pH values ranged between 6.30-9.00 indicating the samples were slightly alkaline. The pH of the control sample was found to be 7.00 which is neutral. Similar results were obtained by Gbarakoro et al. (2020), but lower than 9.88 and 9.87 values documented by Osinbajo et al. (2011). The slight variation in the pH can be attributed to industrial effluents received by the river and it could be a treat to the downstream users since the river is used by inhabitants in the area.

Electrical Conductivity (EC) of Aleto River ranged from 5400.00 μs/cm–5600.00 μs/cm and EC showed higher values in upstream, downstream, and the control (Agbonchia river). The higher amount of EC could be attributed to high number of dissolved solids in ionized form as cations and anions. The EC in all the samples was noticeably higher than the WHO permissible limit and in line with the values recorded by Otokunefor and Obiukwu (2005).

The nitrate was generally higher than the phosphate, however, the values fell within the maximum permissible limits by WHO. The nitrate values were very close to 4.87 mg/L and 3.97 mg/L reported by Sorsa et al. (2015) for the two sites (upstream and downstream) but below the ones documented by Gbarakoro et al. (2014). The nitrate concentrations in the river could be due to dumping of effluents and run-offs from agricultural lands. The concentration of the phosphate ranged from 0.60-1.90 mg/L. The levels were within the WHO permissible limit, the low phosphate level could be as a result of the geology of the area. This is in line with similar work carried out by Adeyemo et al. (2008).

The chloride level recorded for Aleto River was in the range of 1798.00 mg/L-2043.00 mg/L. All values were higher than that of the control sample (74.00 mg/L) and WHO maximum allowable limits. The high presence of chloride in the downstream could be attributed to the discharge of household waste which might contain a large number of chlorides (Osinbajo et al., 2011).

In Aleto river, the COD and BOD_5 parameters as represented in Table 1 were not in agreement with the standard data as stipulated by WHO (5 mg/L). The COD ranged between 50.00-100.00 mg/L while high BOD_5 ranged between 12.00-23.00 mg/L for the water samples which is in agreement with Gbarakoro et al. (2020) indicating that organic and inorganic matters were present in the water, this could be an indication of organic pollution since run-off from catchment areas washed fertilizers from agricultural lands into the river. However, the values obtained were lower in the control though slightly close to the WHO limit for BOD_5 (6.00 mg/L) and slightly away for COD (30.00 mg/L) showing that Agbonchia River was not distorted by organic pollution arising from the discharges from these companies. Generally, COD displays higher values than the BOD_5 in the river. Fenta et al. (2015) report that elevated levels of BOD_5 and COD lower the DO contents in the river.

The level of dissolved oxygen (DO) in water samples in Table 1 was found to be in the range of 12.00-15.00 mg/L. The DO in the sample was found to be lower than the control (18.00 mg/L), but far above WHO permissible limits and the values obtained by Wakawa et al. (2008). Therefore, DO results recorded an indication of microbial contamination or corrosion of chemical substances in the aquifer (Olumuyiwa et al., 2012). The results of the metals analyses in Table 1 showed that the two sites and the control were polluted with trace metal except nickel which fell within WHO permissible limit and followed the order lead > manganese > cadmium > nickel in all the study sites.

Table 1: Physicochemical parameters of Aleto River

S/N	Parameter	Sample A (Upstream)	Sample B (Downstream)	Agbonchia River	WHO Limit (Adeyemo et al., 2008)
1.	Temperature (^{o}C)	29.00 ± 0.00	23.70 ± 0.01	24.30 ± 0.00	15-30
2.	pH	9.00 ± 0.01	6.30 ± 0.01	7.00 ± 0.00	6.5-8.5
3.	EC (μs/cm)	5400 ± 0.01	5600.00 ± 0.01	5500.00 ± 0.01	400
4.	(BOD_5) (mg/L)	12.00 ± 0.00	23.00 ± 0.00	6.00 ± 0.00	5
5.	(COD) (mg/L)	50.00 ± 0.01	100.00 ± 0.01	30.00 ± 0.01	5
6.	(DO) (mg/L)	12.00 ± 0.00	15.00 ± 0.00	18.00 ± 0.00	6.0
7.	Nitrate (mg/L)	4.85 ± 0.00	2.95 ± 0.00	2.01 ± 0.00	50 (NO_3^-)
8.	Phosphate (mg/L)	0.60 ± 0.00	1.90 ± 0.00	<0.01 ± 0.00	2
9.	Chloride	1798.00 ± 0.01	2043.00 ± 0.01	74.00 ± 0.01	600
10.	Sulphate, (mg/L)	14.00 ± 0.00	16. 00 ± 0.00	80.00 ± 0.00	250
11.	Lead (mg/L)	0.36 ± 0.01	0.39 ± 0.00	0.11 ± 0.00	0.01
12.	Manganese (mg/L)	0.07 ± 0.00	0.08 ± 0.01	0.26 ± 0.01	0.02
13.	Nickel (mg/L)	< 0.001 ± 0.00	< 0.001 ± 0.00	< 0.01 ± 0.00	5.0
14.	Cadmium (mg/L)	0.06 ± 0.01	0.05 ± 0.01	0.22 ± 0.01	0.05

However, the results obtained were generally lower than the values documented by Aliyu et al. (2015) who worked on the same trace metals. The result revealed that lead, manganese, and cadmium were far above the WHO allowable concentration, then the other metal (nickel) had values below the maximum allowable limits recommended by WHO and above the values reported by Rout et al. (2003). The results indicated that the river was polluted with trace metals. These pollutants could be as a result of urban agricultural and industrial effluents and other anthropogenic sources which were discharged into the river.

CONCLUSIONS

This study has shown that the upstream has low levels of samples analyzed while the downstream has high values. The physicochemical parameters such as electrical conductivity, biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen were above the WHO permissible limit. This suggests that the effluent discharged from nearby companies (Indorama petrol chemical company) and abattoirs into Aleto River could be responsible for the deterioration of the river as it affects both human and aquatic dwellers, thereby causing undue stress on the river. Therefore, the river should be monitored regularly to keep a record of any changed condition of the quality of the river, to avert any outbreak of health disorders. This study recommends that abattoir activities at the bank of the stream should be discouraged.

DECLARATION OF COMPETING INTEREST

The authors declare no competing financial interest.

REFERENCES

Abubakar, A. J., Yusuf, S., Shehu, K., 2015. Heavy Metals Pollution on Surface Water Sources in Kaduna Metropolis, Nigeria Science World Journal 10(2), 1-5.

Adesuyi, A. A., Nnodu, V. C., Njoku, K. L., Jolaoso, A., 2015. Nitrate and Phosphate Pollution in Surface Water of Nwaja Creek, Port Harcourt, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Sciences 3(5), 14-20.

Adeyemo, O., Adedokun, O., Yusuf, R., Abeleye, E., 2008. Seasonal changes in physico-chemical parameters and nutrient load of river sediments in Ibadan city, Nigeria. Global Nest the International Journal 10, 326-336.

Aliyu, J., Saleh, Y., Kabiru, S., 2015. Heavy metals pollution on surface water sources in Kaduna metropolis, Nigeria. Science World Journal 10, 1-5.

Alves, R. N., Mariz, C. F., de Melo Alves, M. K. et al., 2023. Zebrafish as a biological model for assessing water quality along tropical hydrographic river basins in Northeast Brazilian Ecotoxicology 32, 908–925.

Asit, M., Binoy, S., Sanchita, M., Meththika, V., Ashok, K. P., Madhab, C. M., 2020. Chapter 7 - Impact of agrochemicals on soil health, Editor(s): Majeti, N. V. P., Agrochemicals Detection, Treatment and Remediation, Butterworth-Heinemann, pp. 161-187.

Attilio, N., Antonella, T., Francesco, C., Rosangela, E., Nicola, P., Francesca, S., et al., 2020. Agrochemical treatments as a source of heavy metals and rare earth elements in agricultural soils and bioaccumulation in ground beetles. Science of The Total Environment 749, 141438.

Aziz, T., Maqsood, M. A., Kanwal, S., Hussain, S., Ahmad, H. R., Sabir, M., 2015. Fertilizers and Environment: Issues and Challenges. In: Hakeem, K. (eds) Crop Production and Global Environmental Issues. Springer, Cham. https://doi.org/10.1007/978-3-319-23162-4_21.

Baird, R., Bridgewater, L., 2017. *Standard methods for the examination of water and wastewater.* 23rd edition. Washington, D.C.: American Public Health Association.

Bharatraj, D. K., Yathapu, S. R., 2018. Nutrition-pollution interaction: An emerging research area. Indian Journal of Medical Research 148(6), 697-704.

Binner, H., Sullivan, T., Jansen, M. A. K., McNamara, M. E., 2023. Metals in urban soils of Europe: A systematic review. Science of The Total Environment 854, 158734.

Camilo, Z-L., Daniela, N-B., Freddy, F., Ezequiel, Z-L., Ming, N., Frank, A., Victor, H. G., 2021. Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods. Environmental Technology and Innovation 22, 101504.

Dai, M., Zhao, Y., Chai, F., Chen, M., Chen, N., Chen, Y., Zhang, Z., 2023. Persistent eutrophication and hypoxia in the coastal ocean. Cambridge Prisms: Coastal Futures, 1, E19. doi:10.1017/cft.2023.7.

Fakayode, S. O., 2005. Impact assessment of industrial effluent on water quality of the receiving Alaro River in Ibadan, Nigeria. African Journal of Environmental Assessment and Management 10, 1-13.

Fenta, A. A., Kifle, A., Gebreyohannes, T. et al., 2015. Spatial analysis of groundwater potential using remote sensing and GIS-based multi-criteria evaluation in Raya Valley, Northern Ethiopia. Hydrogeology Journal 23, 195–206.

Gbarakoro, S. L., Gbarakoro, T. N., Eebu, W. L., 2020. Impact of Industrial Effluent Discharge on the Physico-chemical Properties of Aleto Stream, Eleme, Rivers State, Nigeria. Annual Research and Review in Biology 35(1), 79-89.

Jessica, B., E., Sinagra, R. B., 2020. Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon 6(9), e04691.

Kapoor, D., Singh, M. P., 2021. Chapter 10 - Heavy metal contamination in water and its possible sources, Editor(s): Kumar, V., Sharma, A., Cerdà, A, Heavy Metals in the Environment, Elsevier, pp. 179-189.

Khan, M., Omer, T., Ellahi, A., Rahman, Z. U., Niaz, R., Lone, S. A., 2023. Monitoring and assessment of heavy metal contamination in surface water of selected rivers. Geocarto International 38, 1.

Leyun, W., Jia, X., Hui, N., Xilai, Z., 2021. Effects of different fertilizer applications on nitrogen leaching losses and the response in soil microbial community structure. Environmental Technology and Innovation 23, 101608.

Marchuk, S., Tait, S., Sinha, P., Harris, P., Antille, D. L., McCabe, B. K., 2023. Biosolids-derived fertilizers: A review of challenges and opportunities, Science of The Total Environment 875, 162555.

Naccarato, A., Tassone, A., Cavaliere, F., Elliani, R., Pirrone, N., Sprovieri, F., *et al*., 2020. Agrochemical treatments as a source of heavy metals and rare earth elements in agricultural soils and bioaccumulation in ground beetles. Science Total Environment 20(749), 141438.

Nirankar, S., Twinkle, P., Samarjeet, S. S., Arun, L. S., Harish, K. S., Susheel, K. M., 2022. Challenges of water contamination in urban areas, Eds., Arun, L. S., Sughosh, M., Abhishek, K. B., Eugenia, V-J. Current Directions in Water Scarcity Research 6, 173-202.

Njoku, V. O., Obi, C., Obodo, G. A., 2007. Heavy metals concentrations in some surface and ground waters in Imo State, Nigeria. International Journal of Natural and Applied Sciences 3(2), 157-159.

Nnaji, N. D., Onyeaka, H., Miri, T., Ugwa, C., 2023. Bioaccumulation for heavy metal removal: A review. Springer Nature Journal of Applied Sciences 5, 125.

Olumuyiwa, I. O., Fred, A. O. O., George, M. O., 2012. Groundwater: Characteristics, qualities, pollutions and treatments: An overview. International Journal of Water Resources and Environmental Engineering 4(6), 162-170.

Osinbajo, O, Daso, A. P., Gbadebo, A. M., 2011. The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria. African Journal of Biotechnology 10(4), 696-702.

Otokunefor, T. V., Obiukwu, C., 2005. Impact of Refinery Effluent on Physico-chemical Properties of Water Body in the Niger Delta. Applied Ecology and Environmental Research 3(1), 61-72.

Quadra, G. R., Brovini, E. M., 2023. Nutrient Pollution. In: Brinkmann, R., (eds). The Palgrave Handbook of Global Sustainability. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-01949-4_60.

Quinteros, E., Ribó, A., Mejía, R. et al., 2017. Heavy metals and pesticide exposure from agricultural activities and former agrochemical factory in a Salvadoran rural community. Environmental Science and Pollution Research 24, 1662–1676.

Rosen, V., Chen, Y., 2018. Effects of compost application on soil vulnerability to heavy metal pollution. Environmental Science and Pollution Research 25, 35221–35231.

Rout, S. K., Pradhan, S., Trivedi, R. K., Das, B. K., 2003. Impact Assessment of the Surroundings on Water Quality of Kulia Beel. Journal of Environment and Ecology 21, 54-58.

Saravanan, A., Senthil, K. P., Jeevanantham, S., Anubha, M., Jayashree, S., 2022. Degradation of toxic agrochemicals and pharmaceutical pollutants: Effective and alternative approaches toward photocatalysis. Environmental Pollution 298, 118844.

Smith, S. R., 2009. A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Environmental International 35(1), 142-156.

Sylwia, B., Anna, B., Edward, R., Przemysław, N., Mirosław, M. 2023. Trace of negative changes in environment recorded in cores of trees growing near busy city roads in Poznań, Poland – dendromonitoring of urban pollution. Ecological Indicators 149, 110198.

Ukaogo, P. O., Ewuzie, U., Onwuka, C. V., 2020. Chapter 21 - Environmental pollution: causes, effects, and the remedies, Editor(s): Chowdhary, P., Raj, A., Verma, D., Akhter, Y., Microorganisms for Sustainable Environment and Health, Elsevier, pp. 419-429.

Wakawa, R. J., Uzairu, A., Kagbu, J. A., Balarabe, M. L., 2008. Impact assessment of effluent discharge on physicochemical parameters and some heavy metal concentrations in surface water of River Challawa Kano, Nigeria. African Journal of Pure and Applied Chemistry 2(10), 100-106.

Yousif, A. Y. A., Zhao-Ji, S., Yu-Sen, L., Wen-Tao, H., Xi, Y., Rui-Long, W., 2022. Effects of different additives and aerobic composting factors on heavy metal bioavailability reduction and compost parameters: A meta-analysis. Environmental Pollution 307, 119549.

Zhang, X., Zhang, Y., Shi, P., Bi, Z., Shan, Z., Ren, L., 2021. The deep challenge of nitrate pollution in river water of China. Science of The Total Environment 770, 144674.

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