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Research Paper

Characterization of the Heavy Metals in the Aquifer of Matori Industrial Estate Lagos Nigeria

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ABSTRACT
This study investigated the heavy metals content of the groundwatersin Matori Industrial Estate Lagos for its suitabilityfor human consumption. The research areaMatori industrial estate was mapped out into 5 research zones and water samples were collected from 5 dugout wells and taps in each zone bulked and composites taken for analysis. The analytical standard adopted was USEPA 5020 and the analytical instrument for determination deployed was GFAAS model A300. The mean result obtained were: Pb; 0.05±0.17mg/l Cr; 0.27±0.05 mg/l; Cd, 0.06±0.02mg/l, As 0.24±0.28mg/l and Hg; 0.02±0.00. The mean results obtained were subjected to test of significance with ANOVA deploying SPSS model 21. Thep-value is 0.41 thus rejecting H_o. The study recommends that the groundwater in Matori industrial estate should not be utilized for domestic purposes; the industries operating in Matori Industrial Estate should adopt world best practices in their operations. They should stopfurther seepage of contaminants into the aquifers by carryingout effluents treatment before disposal, and they should carryingout remediation of already impacted aquifers.The monitoring Agency (NESREA)is enjoined to increase their surveillance on operating industries to ensure compliance to guidelines by the industries.

Keywords: *industries operation, groundwater, heavy metals seepage, human health.*

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I. Introduction

Water is a natural compound that is composed of oxygen and hydrogen as chemical elements and exists in liquid, solid and gaseous form. Water is the major constituents of the Earth's hydrosphere (Firmi et al., 2015; Ogwu et al., 2022, Yuhu et al., 2022). It is a universal solvent and at room temperature it is tasteless and odourless (Ogwu et al., 2022, Epinoza& Quinones, 2005; Prabu, 2009). Water freezes at below zero degree Celsius into ice and boils at above 100 degree Celsius turning into gaseous state (Kane et al., 2012, Ghazizadeh et al., 2006; Pandey & Pandey, 2009). It has a vapour pressure of 0.2psi absolute pressure of -14.5 gauge (Eaton &Franson, 2005, Ahmad et al., 2010, Brenner & Hoekstra, 2012). Water molecules have very strong affinity and easily cling to each other through the force of adhesion (Obasohan&Equavoen, 2008; Fipps, 2003). Water is a shape shifter (Vang et al., 2010; Kosari&Vanae, 2007), and it descends from the cloud as rain forming streams, lakes, seas and ocean (Burton, 2002, Long, et al., 2013). Water is the fulcrum of all economic and social developments (Varaghe et al., 2020, Ogwu et al., 2021, Chin, 2019) and it is the constituent of all living matter (Luis, 2019, Ruez, 2010). Water is pivotal in manufacturing,for good health, indispensible in agriculture for growing crops and raising of animals and vital in the management of environment especially the redox reactions (Ogwu et al., 2021, Xiao, 2010, Duruibeet al. 2007). It modulates temperature, lubricate joints, protects sensitive tissues such as the spinal cord (Ahand&Ishaku, 2019, Zank, et al., 2015, Eggleton, 2004, Long, 2020), water helps in clearing wastes in human body through bowel movement, urination, perspiration and breathing (Ogwu et al., 2020, Turdi et al., 2016, Bird, 2016). It helps the kidney to function optimally and ensures healthy stool and ward-off constipation (Jung, 2008, Sarmiento et al, 2008), prevents fatigue and keeps all organs of the body healthy (Edaminrshron et al., 2003; Liu et al., 2013, Fu et al., 2007).

Water makes up 70 percent of the earth (Tang, 2016; Hu, 2016),the ocean holds 96 percent of the earth's water (Mishra et al., 2021, Chen, 2016). Earths fresh water constitutes only 3 percent and 98 percent of the earth available fresh water exists as ground water in aquifers (Ogwu et al., 2020, Zheng et al., 2011, Cheng, 2019). The groundwater is man's major source of domestic water (Hu et al., 2019). Portable water should be odourless, colourless and tasteless and free from pollution (Gao, 2019, United States Environmental Protectoin Agency, 2004, Tong et al., 2021).

Groundwater pollution is now a globalconcern as it is threatening global health (Githaige et al., 2021, Wang et al., 2017). Contamination of earth's groundwater occur through industrial effluents seepage (Huang et al., 2015, Mao, 2019), agricultural inputs such as herbicides, insecticides and fertilizers seepage (Zhang et al., 2015), feacal coliform from sewers, sediments and chemicals perculation into the aquifers (Bellinger, 2015, Wei, 2018) seepage of heavy metals such as Pb, Cd, Cr, Hg, as industrial process wastes discharged into the production environment (Kinuthia, 2020).

Heavy metals in drinking water results in cancer, muscular weakness, nervous disorder cardiovascular complications, kidney dysfunction, birth defects and death (Appiah-Opong et al. 2021, Ogwu et al., 2020, Ogwu et al., 2020). The focus of this study is the determination of the heavy metals content of the groundwaters of Matori industrial estate Lagos, Nigeria.

The heavy metals investigated are As, Pb, Cd, Cr and Hg.

The study was guided by the following research questions:

1. What are the concentration of As, Pb, Cd, Cr and Hg in the groundwaters of Matori Industrial estate?
2. Are the concentrations of the heavy metals in the groundwater of Matoriwithin the maximum permissible concentration for such metals in drinking water as stipulated by World Health Organization 2014 and USEPA 2008.
3. Can the groundwater in Matori Industrial estate be used as portable water

The study was guided by a hypothesis as follows:

Ho: There is no significant difference between the concentrations of the heavy metals investigated and WHOmaximum permissible concentration (MPC) for heavy metals in water

Map of Matori

Source: Map Data, (2023)

Study Area

Matori Industrial estate Lagos is one of the thirteen industrial estate in Lagos state. It lies within the geographical coordinates of longitude 2°.420"E to 3°.420'E and latitude 6.220N to 6°.420'N. It is located in Mushin local government which has a population of 633543 (National Population Commission, 2006) and plays host to varying industries such as industrial metalling and packaging industries Ltd, industrial metalizing and packaging Ltd, Xerox HS formerly Rank Xerox, Plastic Fabrication Company Ltd, Onward Paper mills Ltd amongst others.

The ground water in Matori Industrial estate is the recipient of the waste discharges from the operations of these industries.

II. Materials and Methods

The research area MatoriIndsutrialestate was mapped out into 5 research stations (Abdulfatai, 2021). These are Industrial Metalling and Packaging Ltd research zone, Industrial Metallizing and Packaging Ltd, Small Scale Industries cluster zone, Plastic Fabrication Company And Papa Ajaoresearch zones. From each of the 5research zones water samples were collected from 5 boreholes and dugout wells with plastic sample collection bottles, bulked and composites drawn and fixed with nitric acid to ward off oxidation. The samples were stored in ice cool boxes with which they were taken to the laboratory for analysis.

Analysis of the samples

The analysis of the samples were carried out in the water pollution laboratory of the Nigeria Institute of oceanography and Marine Research, Victoria Island, Lagos.

200 ml of each sample was first concentrated at 80°C on a sandy oven till the volume gets to 50ml. 4ml concentrated H_2SO_4 (98%)mercc.) was added into each of the samples and digestion carried out deploying digestible apparatus for 4 minutes. 12mll of hydrogen peroxide(30% merc) was added and heated till oxidation was completed. It was then allowed to cool and then diluted with distilled deionized water to a determined volume of 50ml. The individual metals investigated were then determined with Graphite Furnace Atomic Absorption Spectroscopy (GFAAS model A300.

III. Result

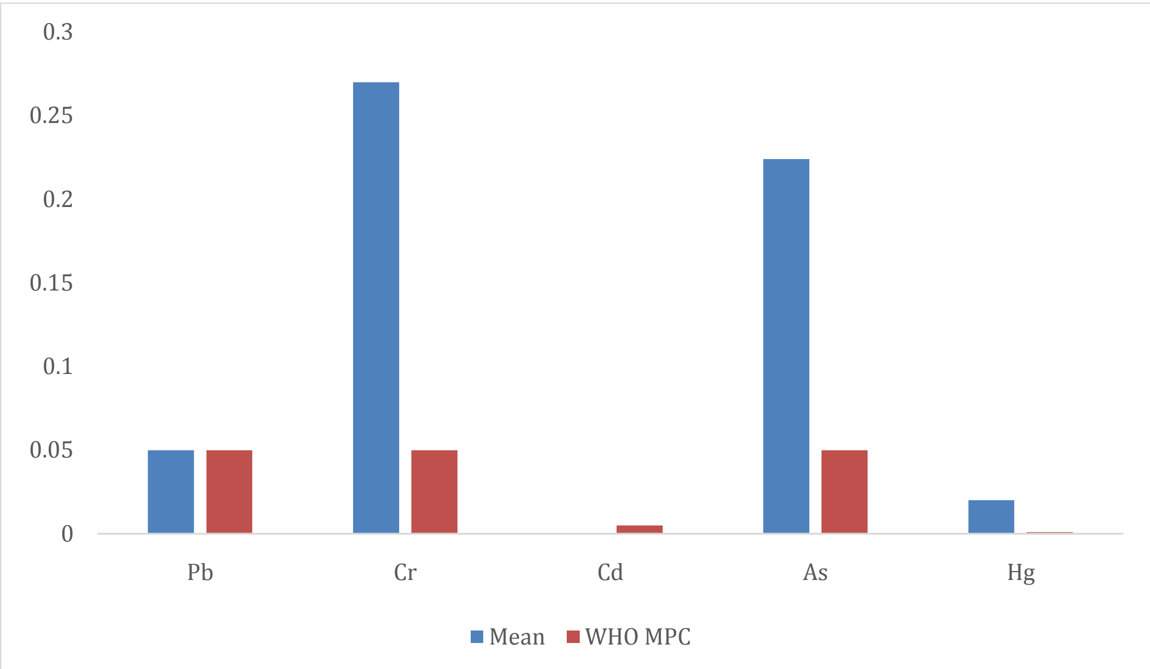
The results of the heavy metals in the ground waters of Matoriindustrial estate are as in Table 1.

Table 1: Heavy metals content of the groundwater in Matori Industrial estate and WHO MPC in mg/l

Parameters	Industrial metal company	Metalling and packaging	Small scale industry	Plastic fabrication	Papa Ajao	$\bar{x}$	SD	WHO MPC
Pb	0.44	0.33	0.64	0.77	0.55	0.05	0.17	0.05
Cr	0.34	0.22	0.24	0.25	0.32	0.27	0.03	0.05
Cd	0.08	0.07	0.03	0.03	0.07	0.0	0.01	0.005
As	0.75	0.12	0.09	0.16	0.10	0.224	0.20	0.05
Hg	0.02	0.01	0.01	0.03	0.02	0.02	0.00	0.001

Heavy metals content of the groundwater of Matori Industrial estate were presented in graph as in Figure 2.

Figure 2: Graph presentation of the heavy metals content of groundwater in Matori industrial estate and WHO in mg/l



The mean concentration of the heavy metals in the groundwater of Matorriwere subjected to the test of significance with analysis of variance (ANOVA) deploying Special Package for Social Science (SPSS) model 21. The P-value is 0.41 thus rejecting Ho.

IV. Discussion of Findings

The analysis of the groundwatersin Matori Industrial Estate presented varying concentrations of the heavy metals investigated.

The value of Pb the analysis revealed ranged from 0.44 mg/l in industrial metaling company to 0.77 mg/l in Plastic Fabrication Company zone with mean concentration of 0.55 mg/l. The WHO maximum permissible concentration for Pb in portable water is 0.05 mg/l. The concentration of Pb in Matori industrial estate groundwater is higher than the acceptable level. Similar report of high concentration of Pb in drinking water was in (Adjei-Kyereme et al., 2015, Amfo-Out, 2012). The health effects of elevated Pb in drinking water include damage to the brain, organs, inference with the blood and death (Apauet al., 2014). Abdominal pains, memory loss, loss of appetite (American Public Health Association, 2005).

The concentration of Cr in the groundwater of Matori Industrial estate the analysis revealed was between 0.22 mg/l in Industrial Metaling to 0.34 mg/l in Industrial metalizing and packaging with a mean concentration of 0.27 mg/l. The WHO maximum allowable concentration for Cr in drinking water is 0.05 mg/l. The concentration of Cr is higher than the recommended. Increased Cr in drinking water was reported in (Bhattadharya et al., 2007, Balakrishman et al., 2016). Cr in human system above the recommended threshold results in allergic dermatitis (skin rash) and liver damage (Boakeng et al., 2015), kidney damage, respiratory cancer, pulmonary congestion and nose irritation (Cluamsthit et al., 2020).

The analysis of the groundwater in Matori Industrial estate also revealed that the concentration of Cd was between 0.03 in in small scale industries and Plastic Fabrication area to 0.08 mg/l in Industrial Metaling Company with a mean concentration of 0.06 mg/l. The recommended concentration of Cd in drinking water by the monitoring agency WHO is 0.005 mg/l. The elevated content of Cd in the area is the effect of poor effluent management by the industries operating in the area. Similar report was in (Duruibe et al., 2007, Guarg et al., 2008). The presence of Cd in water above the maximum acceptable limit leads to varying health complications such as decreased bone density, kidney failure (Gyamti et al., 2012), Shortness of breath, diarrhea, vomiting and swelling of the pharynx (Ite et al., 2005, Hsu, et al., 2002).

Groundwater analysis of Matori Industrial estate also presented a rang of concentration of As which is between 0.10 mg/l in Papa Ajao zone to 0.75 mg/l in industrial metaling company with mean concentration of 0.24 mg/l. The recommended limit for Asin drinking water is 0.05 by WHO. High content of As in drinking water was in the reports of (Akin et al., 2002, Koffi et al., 2014).Presence of As in the human system above the level recommended will lead to health complications and these include cancer and skin lesions, cardiovascular diseases and diabetes (Manikannanet al., 2011, Krishana&Govil, 2004).

The result of the analysis of the groundwater in Matori industrial estate equally revealed that the concentrations of Hg in the aquifer is between 0.01 mg/l in industrial metalling and small scale industries to 0.03 mg/l in Plastic Fabrication with a mean concentration of 0.02 mg/l. The WHO maximum allowable concentration for Hg in drinking water is 0.001. The elevated content of Hg is the industrial zone is the concomitant effect of poor effluent treatment and disposal. Similar report of increased Hg in aquifer environment was in (Maskonni et al., 2020, Milivojevic, 2016). The health effects of Hg in human body include effect on the nervous system, kidneys, eyes and skin (Mohameds&Zahir, 2013, Mukherjee et al., 2006).

V. Conclusion and Recommendations

Anthropogenic activities have in most cases resulted in unwanted degradation of the environment. Industriesestablishment is a welcome development as it is the hallmark of economic growth withresultant positive effect of improved standard of living for the citizens,however this should be carried out with ethics and mantra of sustainable development in the tenets and codes of operation.

The result of the analysis of the groundwater of Matori Industrial estate revealed increased concentration of all the variables considered making the groundwater unsuitable for human consumption which is anathema to the lives of the citizens dwelling and utilizing the groundwater as portable water.

Against this backdrop, therefore it is recommended that the industries operating in Matori Industrial Estate should:

1. carryout proper treatment before the disposal of their discharges
2. remediationof the groundwater should be carried.
3. adhere strictly to the established standards in operations.

REFERENCES

[1]. Abdulfatai, M. N. (2021). Sample and Samples Preparation in Analytical Chemistry. Lagos: Oja Books Ltd.

[2]. Adjei-Kyereme Y, Donkor AK, Golow AA, Yeboah PO, Pwamang J. (2015). Mercuury concentrations in water and sediments in rivers impacted by artisanal gold mining in the Asutif District, Ghana. Res J Chem Environ Sci 3(1):40–48

[3]. Affandi FA, Ishak MY. 2019. Impacts of suspended sediment and metal pollution from mining activities on riverine fish populationa review. Environ SciPollut Res Int. 26(17):16939–51. https://doi.org/10. 1007/s11356-019-05137-7 PMID: 31028621

[4]. Ahmad M. K., Islam S., Rahman S., Haque M. R., and Islam M. M. 2010 "Heavy metals in water, sediment and some fishes of buriganga river, Bangladesh," International Journal of Environmental Research, vol. 4, no. 2, pp. 321–332.

[5]. Amfo-Otu R, Omari S, Boakye-Dede E (2012). Assessment of physicochemical quality of groundwater sources in Ga East municipality of Ghana. Environ Nat Resour Res 2(3):19–24. https://doi.org/ 10.5539/enrr.v2n3p19

[6]. Apau J, Acheampong A, Bepule V (2014). Physicochemical and microbial parameters of water from hand-dug wells from Nyamebekyere, A Surburb of Obuasi, Ghana. Int J SciTechnol 3(6):347–351

[7]. APHA (2005). American Public Health Association. Standard methods for the examination of water and wastewater, 21st edn. APHAAWWA-WEF, Washington

[8]. Appiah-Opong, R., Ofori, A., Ofosuhene, M., Ofori-attah, E., Nunoo, F., Tuffour, I., Gordon, C., Arhinful, D., Nyarko, A.K., &Fosu-Mensah, B.Y. (2021). Heavy metals concentration and pollution index (HPI) in drinking water along the southwest coast of Ghana. *Applied Water Science, 11*. DOI:10.1007/s13201-021-01386-5

[9]. Balakrishnan A, Ramu A (2016). Evaluation of heavy metal pollution index (HPI) of ground water in and around the coastal area of Gulf of Mannar biosphere and Palk Strait. J AdvChemSci 2(3):331–333

[10]. Banzi, F.P., Msaki, P., & Mohammed, N.K. (2015). Assessment of Heavy Metal Concentration in Water around the Proposed Mkuju River Uranium Project in Tanzania. *Tanzania Journal of Science, 41*, 8-18.

[11]. Bellinger EG, Sigee DC, Bellinger EG, Sigee DC.2015. Freshwater Algae: Identification, Enumeration and Use as Bioindicators, 2nd Edition.

[12]. Bhattacharya P, Welch AH, Stollenwerk KG, McLaughlin MJ, Bundschuh J, Panaullah G (2007). Arsenic in the environment: biology and chemistry. Sci Total Environ 379(2–3):109–120. https://doi. org/10.1016/j.scitotenv.2007.02.037

[13]. Bird G. 2016. The influence of the scale of mining activity and mine site remediation on the contamination legacy of historical metal mining activity. Environ SciPollut Res Int.23(23):23456–66. https://doi. org/10.1007/s11356-016-7400-z PMID: 27613630

[14]. Boateng TK, Opoku F, Acquaah SO, Akoto O (2015). Pollution evaluation, sources and risk assessment of heavy metals in hand-dug wells from Ejisu-Juaben Municipality. Ghana Environ Syst Res 4:18

[15]. Brenner A. and Hoekstra E. J., 2012 "Drinking water quality standards and regulations," in Best Practice Guide on Metals Removal from Drinking Water by Treatment, p. 1.

[16]. Burton G. A. 2002 "Sediment quality criteria in use around the world," Limnology, vol. 3, no. 2, pp. 65–76.

[17]. Byrne P, Wood PJ, Reid I. 2012. The Impairment of River Systems by Metal Mine Contamination: A Review Including Remediation Options. Crit Rev Environ Sci Technol.42(19):2017–77. https://doi.org/10. 1080/10643389.2011.574103

[18]. Chen H, Teng Y, Lu S, Wang Y, Wang J. 2015. Contamination features and health risk of soil heavy metals in China. Sci Total Environ. 512:143–53. https://doi.org/10.1016/j.scitotenv.2015.01.025 PMID: 25617996

[19]. Chen M, Li F, Tao M, Hu L, Shi Y, Liu Y. 2019. Distribution and ecological risks of heavy metals in river sediments and overlying water in typical mining areas of China. Mar Pollut Bull.; 146:893–9. https:// doi.org/10.1016/j.marpolbul.2019.07.029 PMID: 31426233

[20]. Cheng H, Li M, Zhao C, Li K, Peng M, Qin A, et al. 2014. Overview of trace metals in the urban soil of 31 metropolises in China. J GeochemExplor.; 139:31–52. https://doi.org/10.1016/j.gexplo.2013.08. 012

[21]. Chiamsathit C, Supunnika A, Thammarakcharoen S (2020). Heavy metal pollution index for assessment of seasonal groundwater supply quality in hillside area, Kalasin. ThailAppl Water Sci 10:142. https://doi.org/10.1007/s13201-020-01230-2

[22]. Dan SF, Umoh UU, Osabor VN (2014). Seasonal variation of enrichment and contamination of heavy metals in the surface water of Qua Iboe River Estuary and adjoining creeks, South-South Nigeria. J Oceanogr Mar Sci 5(6):45–54.

[23]. Duruibe JO, Ogwuegbu MOC, Egwurugwu JN (2007). Heavy metal pollution and human biotoxicefects. Int J PhysSci 2(5):112–118.

[24]. Duruibe JO, Ogwuegbu MOC, Egwurugwu JN. 2007. Heavy metal pollution and human biotoxic effects. International Journal of the Physical Sciences.2(5):112–8.

[25]. Eaton A. D. and Franson M. A. H, 2005. Standard Methods for the Examination of Water & Waste Water, American Public Health Association.

[26]. Eggleton J, Thomas KV. 2004. A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. Environ Int.30(7):973–80. https://doi.org/10.1016/j.envint. 2004.03.001 PMID: 15196845

[27]. Espinoza-Quinones F. R., Zacarkim C. E., S. M. Palacio et ˜ al., 2005. "Removal of heavy metal from polluted river water using aquatic macrophytesSalvinia sp.," Brazilian Journal of Physics, vol. 35, no. 3, pp. 744–746.

[28]. Fipps G. 2003 "Irrigation water quality standards and salinity management strategies," http://repository.tamu.edu/handle/ 1969.1/87829.

[29]. Fu S-m, Zhou Y-z, Zhang C-b, Yang X-q, Ding J, Zhao Y-y. 2007. Environmental response to manganese contamination of Dabaoshan mine in environmental system of lower reaches. ActaScientiarumNaturaliumUniversitatisSunyatseni.46(2):92–6. INSPEC:9714222.

[30]. Gao B, Gao L, Gao J, Xu D, Wang Q, Sun K. 2019. Simultaneous evaluations of occurrence and probabilistic human health risk associated with trace elements in typical drinking water sources from major river basins in China. Sci Total Environ. 666:139–46. https://doi.org/10.1016/j.scitotenv.2019.02.148 PMID: 30798224

[31]. Gao S, Wang Z, Wu Q, Zeng J. 2020. Multivariate statistical evaluation of dissolved heavy metals and a water quality assessment in the Lake Aha watershed, Southwest China. Peerj.8. https://doi.org/10. 7717/peerj.9660

[32]. Garg D, Kaur R, Chand D, Mehla SK, Singh RV (2008). Analysis of water quality of bharatpur area in post-monsoon season, January 2007. J Chem 1(4):743–750

[33]. Ghazizadeh N., Shariat M., and Jafarzadeh N. "The effect of Masjedsoleiman sewage on water quality of Tembi River and water quality management guidelines presented it," in Proceedings of the 7th International River engineering Conference, , Eds., ShahidChamran University, Ahwaz, Iran, 2006.

[34]. Githaiga KB, Njuguna SM, Gituru RW, Yan X. 2021. Water quality assessment, multivariate analysis and human health risks of heavy metals in eight major lakes in Kenya. J Environ Manag.; 297. https:// doi.org/10.1016/j.jenvman.2021.113410 PMID: 34346396

[35]. Gyamf ET, Ackah M, Anim AK, Hanson JK, Kpattah L (2012). Chemical analysis of potable water samples from selected suburbs of Accra, Ghana. IntAcadEcol Environ Sci 2(2):118–127

[36]. Hammarstrom JM, Seal RR, Meier AL, Jackson JC. 2003. Weathering of sulfidic shale and copper mine waste: secondary minerals and metal cycling in Great Smoky Mountains National Park, Tennessee, and North Carolina, USA. Environ Geol.45(1):35–57. https://doi.org/10.1007/s00254-003- 0856-4

[37]. He ZL, Yang XE, Stofella PJ (2005). Trace elements in agroecosystems and impacts on the environment. J Trace Elem Med Biol 19(2–3):125–140

[38]. Hsu P, Leon Y (2002). Antioxidant nutrients and lead toxicity. Toxicology 180:33–44
[39]. Hu H, Wei Y. 2006. Chinese freshwater algae:systems,ecology and classification. Beijing: Science Press.
[40]. Huang X, Sillanpaa M, Gjessing ET, Peraniemi S, Vogt RD. 2010. Environmental impact of mining activities on the surface water quality in Tibet: Gyama valley. Sci Total Environ. 408(19):4177–84. https:// doi.org/10.1016/j.scitotenv.2010.05.015 PMID: 20542540
[41]. Humood AN 2013. Assessment and management of heavy metal pollution in the marine environment of the Arabian Gulf: A review Marine Poll. Bull. 72(1) 6-13.
[42]. IAEA 2010. Best practice in environmental management of uranium mining IAEA Nuclear Energy Series No. NF-T-1.2.
[43]. Jie QIN, Wen Z, Peng Z. 2011. The environment mercury pollution toxicity effect to the alga and their influencing factors. J Biol. 28(3):74–6,83. CSCD:4241764
[44]. Jung MC. 2008. Contamination by Cd, Cu, Pb, and Zn in mine wastes from abandoned metal mines classified as mineralization types in Korea. Environ Geochem Health.; 30(3):205–17. https://doi.org/10. 1007/s10653-007-9109-x PMID: 17687627
[45]. Kane S., Lazo P., and Vlora A. 2012. "Assessment of heavy metals in some dumps of copper mining and plants in Mirdita Area, Albania," in Proceedings of the 5th International Scientific Conference on Water, Climate and Environment. Eds., Ohrid, Macedonia
[46]. Kim MJ, Nriagu J, Haack S (2002). Arsenic species and chemistry in groundwater of southeast Michigan. Environ Pollut 120(2):379–390
[47]. Kinuthia, G.K., Ngure, V., Beti, D, Lugalia R, Wangila A, and Kamau L. (2020). Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: community health implication. *Sci Rep* **10**, 8434. https://doi.org/10.1038/s41598-020-65359-5
[48]. Koffi KM, Coulibaly S, Atse BC, Paul E (2014). Survey of heavy metals concentrations in water and sediments of the estuary Bietri Bay. Ebrie Lagoon, Cote D 'Ivoire 1(3):1–10
[49]. Kosari S. and Vanae M. 2007 "Survey of the source and amount of pollutants concentration of heavy metal in Tembi River and Bohlol Lake," in Proceedings of the 1st Conference on Geological and Environmental and Medical, , Eds., Tehran, Iran.
[50]. Lefcort H, Vancura J, Lider EL. 2010. 75 years after mining ends stream insect diversity is still affected by heavy metals. Ecotoxicology. 19(8):1416–25. https://doi.org/10.1007/s10646-010-0526-8 PMID: 20680454
[51]. Liu G, Tao L, Liu X, Hou J, Wang A, Li R. 2013. Heavy metal speciation and pollution of agricultural soils along Jishui River in non-ferrous metal mine area in Jiangxi Province, China. J GeochemExplor. 2013; 132:156–63. https://doi.org/10.1016/j.gexplo.06.017
[52]. Long E. R., Dutch M., Partridge V., Weakland S., and Welch K. 2013 "Revision of sediment quality triad indicators in Puget Sound (Washington, USA): I. A sediment chemistry Index and targets for mixtures of toxicants," Integrated Environmental Assessment and Management, vol. 9, no. 1, pp. 31–49.
[53]. Long J, Luo K. 2020. Elements in surface and well water from the central North China Plain: Enrichment patterns, origins, and health risk assessment. Environ Pollut.258. https://doi.org/10.1016/j.envpol. 2019.113725 PMID: 31838383
[54]. Luis AT, Antonio Grande J, Duraes N, Miguel Davila J, Santisteban M, Almeida SFP, et al. 2019. Biogeochemical characterization of surface waters in the Aljustrel mining area (South Portugal). Environ Geochem Health.; 41(5):1909–21. https://doi.org/10.1007/s10653-019-00249-y PMID: 30701355
[55]. Luo, Y., Rao, J., &Jia, Q. (2022). Heavy metal pollution and environmental risks in the water of Rongna River caused by natural AMD around Tiegelongnan copper deposit, Northern Tibet, China. *PloS one*, *17*(4), e0266700. https://doi.org/10.1371/journal.pone.0266700
[56]. Manikannan R, Asokan S, Ali AHMS (2011). Seasonal variations of physico-chemical properties of the Great Swamp, Point Calimere Wildlife Sanctuary, South-east coast of India. Afr J Environ SciTechnol 5(9):673–681
[57]. Mao G, Zhao Y, Zhang F, Liu J, Huang X. 2019. Spatiotemporal variability of heavy metals and identification of potential source tracers in the surface water of the Lhasa River basin. Environ SciPollut Res Int.26(8):7442–52. https://doi.org/10.1007/s11356-019-04188-0 PMID: 30694435
[58]. Maskooni EK, Naseri-Rad M, Berndtsson R, Nakagawa K (2020). Use of heavy metal content and modifed water quality index to assess groundwater quality in a semiarid area. Water 12:1115
[59]. Milivojević J, Krstić D, Šmit B, Djekić V (2016). Assessment of heavy metal contamination and calculation of its pollution index for Uglješnica River, Serbia. Bull Environ ContamToxicol 97(5):737–774
[60]. Mishra S, Kumar A, Shukla P. 2021. Estimation of heavy metal contamination in the Hindon River, India: an environmetric approach. Applied Water Science.11(1). https://doi.org/10.1007/s13201-020- 01331-y
[61]. Mohamed HM, Zahir HA (2013). Vedaranyam study of groundwater quality at Dindigul Town, Tamilnadu, India. International Research Jounrnal of Environment Science 2(1):68–73
[62]. Mohammed NK. andMazunga MS. 2013. Natural Radioactivity in Soil and Water from Likuyu Village in the Neighborhood of Mkuju Uranium Deposit International Journal of Analytical Chemistry Volume 2013, Article ID 501856, 4 pages http://dx.doi.org/10.1155/2013/501856
[63]. Mukherjee A, Sengupta MK, Hossain MK, Ahamed S, Das B, Nayak B, Lodh D, Rahman MM, Chakraborti D (2006). Arsenic contamination in groundwater : a global perspective with emphasis on the Asian Scenario. J Health PopulNutr 24(2):142–163
[64]. Obasohan E. E. and Eguavoen O. I., 2008 "Seasonal variations of bioaccumulation of heavy metals in a freshwater fish (Erpetoichthyscalabaricus) from Ogba River, Benin City, Nigeria," Indian Journal of Animal Research, vol. 42, no. 3, pp. 171–179.
[65]. Ogwu C, Imobighe M, Okofu S, Attamah F (2022), Speciation of heavy metals in fish species in the wetlands of oil-bearing communities of the Niger Delta; IJB, V21, N2, August, P169-178. https://innspub.net/speciation-of-heavy-metals-in-fish-species-in-the-wetlands-of-oil-bearing-communities-of-the-niger-delta/
[66]. Ogwu C. (2021). Heavy metals loadings of *Telfairiaoccidentalis*(Fluted pumpkin) grown in Ekpan (Host community of Warri Refinery and Petrochemical) Nigeria. Quest Journals: *Journal of Research in Agriculture and Animal Science.* 8(1), 16-20
[67]. Ogwu C.,Azonuche J E and Okumebo V. O. (2021). Heavy metals content of *Telfairiaoccidentalis*(fluted pumpkin; order: Violales, Family: Cucurbitacea) grown in Ebedei (An oil and gas bearing community) Niger Delta, Nigeria. Quest Journals: *Journal of Research in Humanities and Social Science.* 9(4), 74-78
[68]. Ogwu C.,Azonuche J. E and Okeke, M. (2020). Heavy metals contamination status of *Telfairia*occidentalis (Fluted pumpkin) grown in Uzere oil rich community, Niger Delta. Quest Journal*: Journal of Research in Agriculture and Animal Science.* 7(7), 12-17
[69]. Ogwu C.,Azonuche J., and Achuba F (2021). Heavy metals quantification of Telfairiaoccidentalis (Fluted pumpkin, Order: Violales, family: Cucurbitaceae) grown in Niger Delta oil producing areas. International Journal of Biosciences. 13(2) 170-179.
[70]. OgwuChukwudi, Ideh Victor, Imobighe Mabel (2022), Bioaccumulation of heavy metals in some pelagic and benthic fish species in selected wetlands in oil-bearing communities of the Niger Delta; International Journal of Biosciences. 20 (6), Pp. 128-139.

https://innspub.net/bioaccumulation-of-heavy-metals-in-some-pelagic-and-benthic-fish-species-in-selected-wetlands-in-oil-bearing-communities-of-the-niger-delta/

[71]. Pandey J. and Pandey U., 2009 "Accumulation of heavy metals in dietary vegetables and cultivated soil horizon in organic farming system in relation to atmospheric deposition in a seasonally dry tropical region of India," Environmental Monitoring and Assessment, vol. 148, no. 1–4, pp. 61–74.

[72]. Qu B, Zhang Y, Kang S, Sillanpaa M. 2019. Water quality in the Tibetan Plateau: Major ions and trace elements in rivers of the "Water Tower of Asia". Sci Total Environ.649:571–81. https://doi.org/10. 1016/j.scitotenv.2018.08.316 PMID: 30176468

[73]. Ruiz Canovas C, Riera J, Carrero S, Olias M. 2018. Dissolved and particulate metal fluxes in an AMD-affected stream under different hydrological conditions: The Odiel River (SW Spain). CATENA.; 165:414– 24. https://doi.org/10.1016/j.catena.2018.02.020

[74]. Saeed Shanbehzadeh, MarziehVahidDastjerdi, Akbar Hassanzadeh, Toba Kiyanizadeh, (2014). "Heavy Metals in Water and Sediment: A Case Study of Tembi River", Journal of Environmental and Public Health, vol. 2014, Article ID 858720, 5 pages,.https://doi.org/10.1155/2014/858720

[75]. Sarmiento AM, Miguel Nieto J, Olias M, Canovas CR. 2008. Hydrochemical characteristics and seasonal influence on the pollution by acid mine drainage in the Odiel river Basin (SW Spain). ApplGeochem. 2009; 24(4):697–714. https://doi.org/10.1016/j.apgeochem.12.025

[76]. Tang J, Song Y, Wang Q, Lin B, Yang C, Guo N, et al. 2016. Geological Characteristics and Exploration Model of the Tiegelongnan Cu (Au-Ag) Deposit: The First Ten Million Tons Metal Resources of a Porphyry-epithermal Deposit in Tibet. ActaGeoscientiaSinica. 37(6):663–90. CSCD:5868665.

[77]. Tong S, Li H, Tudi M, Yuan X, Yang L. 2021. Comparison of characteristics, water quality and health risk assessment of trace elements in surface water and groundwater in China. Ecotoxicol Environ Saf.; 219. https://doi.org/10.1016/j.ecoenv.2021.112283 PMID: 34015707

[78]. Turdi M, Yang L. 2016. Trace Elements Contamination and Human Health Risk Assessment in Drinking Water from the Agricultural and Pastoral Areas of Bay County, Xinjiang, China. Int J Environ Res Public Health. 13(10). https://doi.org/10.3390/ijerph13100938 PMID: 27669274

[79]. USEPA. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Washington DC, USA: Office of Superfund Remediation and Technology Innovation U.S. Environmental Protection Agency.

[80]. Wang J, Liu G, Liu H, Lam PKS. 2017. Multivariate statistical evaluation of dissolved trace elements and a water quality assessment in the middle reaches of Huaihe River, Anhui, China. Sci Total Environ. 583:421–31. https://doi.org/10.1016/j.scitotenv.2017.01.088 PMID: 28126280

[81]. Wang Y., Chen P., Cui R., Si W., Zhang Y., and Ji W. 2010 "Heavy metal concentrations in water, sediment, and tissues of two fish species (Triplohysapappenheimi, Gobiohwanghensis) from the Lanzhou section of the Yellow River, China," Environmental Monitoring and Assessment, vol. 165, no. 1–4, pp. 97–102.

[82]. Wei W, Ma R, Sun Z, Zhou A, Bu J, Long X, et al. 2018. Effects of Mining Activities on the Release of Heavy Metals (HMs) in a Typical Mountain Headwater Region, the Qinghai-Tibet Plateau in China. Int J Environ Res Public Health.; 15(9). https://doi.org/10.3390/ijerph15091987 PMID: 30213099

[83]. Wogu M. D. and Okaka C. E., 2011 "Pollution studies on Nigerian rivers: heavy metals in surface water of warri river, Delta State," Journal of Biodiversity and Environmental Sciences, vol. 1, no. 3, pp. 7–12.

[84]. Wu J, Lu J, Zhang C, Zhang Y, Lin Y, Xu J. 2020. Pollution, sources, and risks of heavy metals in coastal waters of China. Human and Ecological Risk Assessment. 26(8):2011–26. https://doi.org/10. 1080/10807039.2019.1634466

[85]. Xiao HY, Zhou WB, Zeng FP, Wu DS. 2010. Water chemistry and heavy metal distribution in an AMD highly contaminated river. Environmental Earth Sciences. 59(5):1023–31. https://doi.org/10.1007/ s12665-009-0094-5

[86]. Xiao J, Wang L, Deng L, Jin Z. 2019. Characteristics, sources, water quality and health risk assessment of trace elements in river water and well water in the Chinese Loess Plateau. Sci Total Environ.; 650:2004–12. https://doi.org/10.1016/j.scitotenv.2018.09.322 PMID: 30290343

[87]. Yaraghi N, Ronkanen A-K, Haghighi AT, Aminikhah M, Kujala K, Klove B. 2020. Impacts of gold mine effluent on water quality in a pristine sub-Arctic river. Journal of Hydrology. 589. https://doi.org/10.1016/j. jhydrol.2020.125170

[88]. Zeng J, Han G, Yang K. 2020. Assessment and sources of heavy metals in suspended particulate matter in a tropical catchment, northeast Thailand. Journal of Cleaner Production. 265. https://doi.org/10. 1016/j.jclepro.2020.121487 PMID: 32831484

[89]. Zeng X, Liu Y, You S, Zeng G, Tan X, Hu X, et al. 2015. Spatial distribution, health risk assessment and statistical source identification of the trace elements in surface water from the Xiangjiang River, China. Environ SciPollut Res Int.; 22(12):9400–12. https://doi.org/10.1007/s11356-014-4064-4 PMID: 25874418

[90]. Zhang C, Qiao Q, Piper JDA, Huang B. 2011. Assessment of heavy metal pollution from a Fe-smelting plant in urban river sediments using environmental magnetic and geochemical methods. Environ Pollut.; 159(10):3057–70. https://doi.org/10.1016/j.envpol.2011.04.006 PMID: 21561693.

[91]. Zhang Y, Li F, Li J, Liu Q, Tu C, Suzuki Y, et al. 2015. Spatial Distribution, Potential Sources, and Risk Assessment of Trace Metals of Groundwater in the North China Plain. Human and Ecological Risk Assessment. 21(3):726–43. https://doi.org/10.1080/10807039.2014.921533