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RESEARCH ARTICLE

Effects of Mining Industry Operations on Fresh Water Quality in Zamfara State, Nigeria: A Review

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ABSTRACT

The Planet Earth is 71% water, but fresh water for our basic survival needs is only 3%. Of this figure, only 0.5% is available for human use; the remaining 2.5% exists in glaciers, ice, and snow. As a result, many people (about 1.1 billion) live in areas where access to fresh water is a pressing issue. The competitive struggle to earn a livelihood amidst unsafe mining practices releases tons of poisonous chemicals from mineral processing, especially gold ore in Zamfara State. These harmful substances are deposited on soil surfaces, drinking water, edible plant leaves, and fruits. The United Nations' World Water Development Report revealed that industrial water consumption accounts for 22% of global fresh water withdrawal but varies between high- and low-income countries; and by 2025, industries will account for 24% of global fresh water withdrawal. Mining industries' waste (both solid and liquid) has been identified as a source of fresh water pollution, releasing toxic heavy metals, organic solvents, sludge, and other harmful elements. In developing countries (Zamfara inclusive), 70% of these wastes are discharge (untreated) into rivers, streams, and land, causing serious reduction in the quality and availability of fresh water for domestic use. This paper aims to review the effects of mining industry operations on fresh water quality in Zamfara State, Nigeria.

Keywords: *Mining; Industry; Freshwater; Water quality; Effect; Zamfara State*

1. INTRODUCTION

Water resources constitute one of the vital assets that contribute to socio-economic development and poverty eradication and have great economic potential for tourism, agriculture and industries (Nsubuga et al, 2014). Despite covering most parts of the Earth, accessibility to water resources, especially freshwater to meet basic human needs of sanitation and food production, remains a pressing issue. Food and agricultural production account for 70% of water withdrawal, while other industries such as energy, mining, and manufacturing account for 19% (Ritchie and Roser, 2017). Given these figures, it will be impossible to significantly address water security without recognizing the role of mining industries in hydrological cycle disruption (Ceres, 2022). Industrialization and rapid population growth, notably in developing countries, coupled with technological advancement, increased demand for industrial goods and services, present a significant threat to water (freshwater inclusive) as well as a threat to sustainability, prompting the need to carefully handle and protect the resource (United Nations, 2014).

Industrial operations (food production, mining and manufacturing) are the single largest user and influencer of freshwater resources globally, causing systematic impacts on water quality, quantity and environmental changes. Scientific research output revealed that a series of mining operations are putting considerable pressure on freshwater through changes in water availability, water quality, and ecosystem alteration. This evidence underscores that mining industries are a critical part of the global hydrological system along with natural processes and human use (Ceres, 2022).

Zamfara State has a lot of untapped mineral resources. The natives extract these minerals crudely with so many mining mills scattered all over the State (Ogabiela et al, 2011). The uncontrolled and illegal mining activities have left a lot of environmental hazards, an enormous amount of waste, and different types of pollutants in the mining communities (Udiba et al, 2012). Due to this, water sources and solid minerals will inevitably interact in Zamfara mining sites; hence, the rivers' and lakes' water is used in flotation to separate the precious stones after crushing (Von et al, 2011). Most communities in Zamfara State use surface and ground water directly without undergoing any water treatment for drinking, domestic purposes, and irrigation (Yahaya et al., 2020). The economic benefit of mineral exploration has increased artisanal mining activities in Zamfara State, and the competitive struggle to earn a livelihood amidst unsafe mining practices releases tons of poisonous chemicals from mineral processing, especially gold ore. It was reported that approximately 163 persons lost their lives to soil- and water-related contamination in some villages of Anka local government (Ogelekaa & Alaminiokumab, 2020). This literature review aims to identify, analyze, and summarize key findings in the literature related to the effect of mining industry operations on fresh water quality in Zamfara State by integrating findings from various studies and research that have been conducted in the state. This will provide a deeper understanding of how mining industries' operations are impacting freshwater quality in the state, as well as providing valuable guidance for miners and policymakers for effective management of solid mineral resources and sustainable mining in the state.

2. MATERIALS AND METHODS

The study employed a rapid systematic review approach to review the effects of mining industry operations on water quality in Zamfara State from 2015 to 2025. Data were gathered through a comprehensive search of academic peer-reviewed papers in databases (such as Google Scholar, ResearchGate), government reports, and credible news archives. Keywords included 'water quality', 'mining activities', 'water resources', and 'Zamfara State '. Papers and reports were filtered for relevance to impacts of mining activities on water quality. The selected data were synthesized thematically to understand how mining industry operations are impacting freshwater quality in the state.

3. RESULTS AND DISCUSSION

Global Fresh Water Crisis

The world's water resources are in excess of 43,750km^3 per annum, which is distributed across the globe according to the physical features and climatic variables (FAO, 2003). Water crises are one of the greatest challenges to the human population and global economy. Today, nearly two billion people live in areas at risk from severe water scarcity, and climate change will only make the situation worse since its impacts will most immediately and acutely be felt through water. More than ever, the world needs healthy freshwater resources (WWF, 2020). If there is going to be a 3rd World War, then it's almost at our doorstep, and it is definitely going to be about water; to curb this, we need to take action (Kofi Annan; Cited in Yeleliere *et al*, 2018).

Freshwater scarcity has been cited as the major crisis of the 21st century (Srinivasan et al, 2012). As world population continues to grow, fresh water has become a globally scarce resource. As a result, the world is now facing a global water crisis that is being exacerbated by climate change. Population growth, industrialization, urbanization, and climate change have collectively contributed to a rapidly accelerating global water crisis. Today, nearly four billion people are affected by water scarcity, and predictions suggest this number will only rise as global water demand is projected to increase 55% by 2050. It is predicted that by 2030, there will be a 40% gap between global fresh water supply and demand (WGBC, 2023).

It is estimated that four billion people, i.e., almost two-thirds of the world's population, experience severe water scarcity for at least one month each year. And over two billion people live in countries where water supply is inadequate. Half of the world's population could be living in areas facing water scarcity by as early as 2025. Some 700 million people could be displaced by intense water scarcity by 2030 (WHO/UNICEF, 2021).

Studies consistently predict that some regions of the world, such as India, northern China, north and sub-Saharan Africa, the Middle East, and parts of Eastern Europe, will face water crises. And these predictions of water crises pose several problems (Vörösmarty et al., 2010). Africa is the continent where the impact of water scarcity is the highest. In ten African countries, half of their populations do not have access to potable water. Out of the 771 million people still lacking basic drinking water service in 2020, half lived in Sub-Saharan Africa (WHO/UNICEF, 2021); and there is a widening gap in water supply between urban and rural dwellers (Adams et al., 2019). The environmental impacts of the water crisis are equally alarming. Multiple, cumulative and compounding problems with water supply and quality are converging globally. Increasing population growth and industrial activities are already competing with nature for finite water resources. Several rivers do not make it to the sea, and there is widespread surface and groundwater contamination that makes valuable water supplies unfit for other uses. A growing number of contaminants, such as endocrine-altering substances, will demand higher wastewater treatment standards and more exhaustive monitoring of water contaminants (Bigas, 2012).

Mining Industry and Water Consumption

The mining sector is a large industrial water user that is growing rapidly all over the world. The usage of water in the mining industry shares many of the characteristics of other industrial water consumers, but it has some distinctive features. For example, mining projects cannot freely choose where to operate since mining is limited to locations abundant in geologically concentrated minerals and economically and technically feasible. Consequently, mining companies often operate in sensitive or challenging environments facing the full spectrum of ecological and hydrological contexts, e.g., in arid regions (Le et al, 2020). Exploration for minerals, which are needed to manufacture solar panels, electric cars, and other clean technologies, is increasing because of high demand for green energy. Due to the fact that essential minerals are used in laptops, smartphones, and other consumer electronics, this increases the demand already present from the tech industry. Without a doubt, more mineral mining will be required around the world, but there are concerns involved, such as the possibility of depleting water resources and quality (Lakshman, 2024).

Significant volumes of water are needed for the majority of key mineral mining techniques today in order to separate minerals, cool equipment, and manage dust. Water in surrounding towns may become contaminated by mining and processing waste, which includes leftover chemicals and minerals (Lakshman, 2024). Mining, manufacturing, and energy industries together use approximately 19% of the world's freshwater withdrawals (Ritchie and Roser, 2017). It is projected that there will be a 24% increase in industry and energy's water demand by 2050 (Burek et al., 2016). A regional distribution shows that industrial water withdrawal averages 17% of total water use in high-income countries but only 2% in low-income countries (Ritchie and Roser, 2017). It has been estimated that two-thirds of all water consumption is involved in corporate supply chains. Supporting this estimate, companies in seven major sectors (food, textile, energy, industry, chemicals, pharmaceuticals and mining) are affecting more than 70% of the world's freshwater use and pollution (CDP, 2018).

Mining Activities in Zamfara State

Zamfara State is blessed with solid minerals and basement complex rocks (intrusive & extrusive) from which the local people strive to earn a living. The Zamfara solid mineral deposits occur in alluvial, eluvial, and schist belts. The most important occurrences are found in Maru, Bukkuyum, and Anka areas. Minerals commonly mined include gold, limestone, and gypsum (Salisu *et al,* 2016). Both the solid mineral and stone mining activities are at small-scale levels, but more attention is shifted to solid minerals, especially gold ore, because of its huge revenue to the state, high return on investment, and value of gold ore in the global market (Aondowase & Ugba, 2021). The mining industry in Zamfara State is not organized, and authorities do not have accurate data about the number of mining fields operating in the state. This made it difficult for the government to effectively curtail, monitor, and enforce the ensuing environmental violations/pollution arising from mining activities (Salati and Mustapha, 2016). There are many mining enclaves (both gold and stone) scattered within the state in Anka, Bukkuyum, Bungudu, Bakura, Gusau, Maradun, Talata-Mafara and Tsafe Local Government Areas, with the majority found around Anka and Bukkuyum for gold; and the Gusau, Tsafe and Maru LGAs axis for stone. In many of these mining enclaves, miners use manual tools and crude gold extraction and processing techniques (Aondowase & Ugba, 2021). Despite its obvious dangers, the artisanal mining (AM) method dominated the mining landscape of the state (Hilson, 2016), and there is indiscriminate use of toxic chemicals (notably mercury) (Anka et al., 2020; Chalker, 2018). Ineffective regulation of the sector and low adherence to mining standards in the industry have further aggravated the already existing environmental challenges facing the state (Anka *et al*., 2020; Chalker, 2018).

Effects of Mining Industry Activities on Fresh Water Quality in Zamfara State

The quality and availability of freshwater are some of the most critical sustainability concerns of the 21st century (Yahaya et al., 2022 & Udiba et al., 2019). CDRT (2023) opined that Zamfara State is endowed with various invaluable mineral resources, as a result of which numerous mining enterprises have been exploiting them, the activities of which have caused serious contamination of the environment and water resources. The mining industry operations in the State have been linked to lead poisoning, water pollution, and soil contamination (Dooyum et al., 2015). The state's fresh water is currently under serious threat by a combination of factors such as over-extraction, microbiological and chemical contamination as a result of increased activities of illegal miners (Mathew & Ndububa, 2023). The density of mining sites and the concentration of activities in the state have been unprecedented in recent years. Soil and water surfaces across the state have been the most affected parts of the environment, caused by the intensity and exposure of mineral extraction and the deposits of heavy metals and other toxic debris into the environment. The exposure of these toxic materials to water has caused serious degradation of water quality and has resulted in serious health concern on human population and ecological systems for over a decade (Nawaz et al. 2023 & Udiba et al. 2019). Recently, the increased number of people going into mining activities has led to the rising level of lead concentration in both ground and surface water spaces in the state.

Moses et al. (2019) examined the physicochemical properties of water (pH, temperature, conductivity, total dissolved solids, total suspended solids, alkalinity, dissolved oxygen, chloride, turbidity, hardness, sulphate, chemical oxygen demand and biochemical oxygen) of the three major dams and rivers in Zamfara State using standard analytical methods. It was discovered that total bacterial counts obtained during the wet season (3.6 x 106 to 8.9 x 106) were generally higher than those obtained in the dry season (2.4 x105 to 7.9 x 105). The microbial values recorded in the dam, which ranged from (2.4 x105 to 7.4 x 106) and rivers (5.2 x105 to 8.9 x 106) water bodies represent high bacterial load compared to the recommended standards for drinking water. The results of the physicochemical parameters revealed significant variations and non-uniform distribution from one season to another for the two years of study. The pH, temperature, EC, TDS, alkalinity, BOD, and SO_4, etc., have values that fall below the standard limit for drinking water, with the exception of turbidity (88.67 mg/l), which has a value higher than the recommended standard limit. Analysis of variance revealed that there was a significant difference ($P < 0.05$) between the parameters based on locations and seasons.

In their investigation on physicochemical parameters of ground and surface water, randomly collected from mining sites, Dareta et al. (2016) found that the mean temperature of the groundwater was 28.34 ± 0.6°C for the well, 30.06 ± 0.48°C for the stream, and 30.19 ± 0.29°C for the borehole, indicating all the mean temperature values were above the WHO permissible value of 25°C. The average pH values were found to be 6.69 ± 0.33 for the well, 6.66 ± 0.41 for the borehole, and 6.60±1.04 for the stream, and concluded that the pH values for the three water sources were within the pH range set by the WHO and NSDWQ for domestic water. They, however, discovered that the mean electrical conductivity (µs/cm) was 631.00 ± 141.13 for well, 660.70 ± 236.41 for borehole, and 326.00 ± 51.44 for stream, respectively. All the mean values were higher than the WHO set value of 500 but lower than the NSDWQ set value of 1000

Ahmad et al. (2016) analyzed heavy metals in water around Gidan Saru mining site, in Zamfara State, their findings revealed that the levels of Lead, Nickel, manganese, Zinc, Iron, Copper and Cadmium in the water samples of hand dug wells and bore hole were above both the Nigeria Standard Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) Maximum Permissible Limits. Assessment of impacts of Artisanal Mining on Some Heavy Metals Concentration in Surface Water in Kutcheri area (Zamfara East axis) shows that there is minimal level presence of metals when compared with World Health Organization limits, and that can be attributed to less concentration of mining activities in the zone (Rasheed & Amuda, 2014).

The effect of mining operations on water quality lingers for years even when the operations have stopped. Odey et al (2022) recently evaluated the safety and potential health implications of water from post-remediated lead-polluted areas of Zamfara State and found that in groundwater (boreholes and wells), the mean temperature and conductivity were still higher than the World Health Organization (WHO) safety levels for drinking water. The values of total dissolved solids (TDS) and pH were within the recommended limits. In surface water (streams), the physical parameters were not higher than the WHO safety limits, but the concentrations of lead (Pb), cadmium (Cd), and chromium (Cr) were above the drinking water guidelines. The estimated average daily intake (EADI) and the target hazard quotient (THQ) for all the water sources in both adult and children consumer populations exceeded the reference dose by the US Environmental Protection Agency (US-EPA). They concluded that there is an increased hazard for the human populations that still source their drinking water from the borehole, well, and stream of remediated villages.

4. CONCLUSION

The mining industry operations in Zamfara State have severely impacted the water quality, posing substantial health risks to the local communities. From the majority of the reviewed literature, results indicated higher figures of water quality parameters above the recommended standard by the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO). It is essential to implement sustainable mining practices, ensure proper waste management practices, provide clean water sources for the local communities, and conduct regular monitoring and testing of water quality to ensure that it meets international standards.

5. COMPETING INTEREST

None to declare

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