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Evaluation of hazard quotient (HQ) of toxic and heavy metal concentration in air sediments across selected cities in Nigeria

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Abstract

This study evaluates Hazard Quotient (HQ) from toxic and heavy metal concentration across selected cities in Nigeria. The gravitational sedimentation method was used to collect air sediments to extract toxic and heavy metals contained in air particulates. Funnel shaped collectors which were securely attached to clean empty containers were exposed in open spaces at designated locations within the city, for a period of nine months (January to September 2023), covering the two major seasons in Nigeria. Airborne particles were allowed to settle naturally in the container along with rainwater. Samples from various sub-locations within the city were put together for spectroscopic analyses. This procedure was repeated in six cities covering various geographical and climatic regions in Nigeria. The cities include Benin (S1), Kano (S2), Abuja (S3), Lagos (S4), Enugu (S5), and Calabar (S6). The average concentration of toxic and carcinogenic elements reveals that; lead (Pb) at 5.66, nickel (Ni) at 4.58, magnesium (Mn) at 4.43, Cadmium (Cd) at 1.83, Iron (Fe) at 1.31 and chromium (Cr) at 1.06. Conversely, elements such as; (NH_3) :0.042, (Al):0.36, (Co):0.02, (Cu):0.11, (Zn):0.01, (K):0.86, (NO_2^-):0.32, (NO_3^-):0.042, (F):0.12 and (Na):0.18 have HQs below 1, indicating safe exposure levels. Cadmium (Cd) displays the highest HQ in Kano (S2) at 2.33, suggesting significant health risks, which may include cancer and kidney failure. Nickel has highest HQ recorded in Edo State, Benin (S1) at 5.5, linked to bronchitis, asthma, and skin irritation. Manganese (Mn) has the highest HQ in Enugu (S5) at 16, with potential for lung inflammation, liver damage, and cognitive impairment. Lead (Pb) shows the highest HQ in Kano (S2) and Calabar (S6) at 8, associated with kidney damage and developmental issues. Chromium (Cr) exhibits the highest HQ in Kano (S2) at 1.3, potentially causing lung cancer and bronchitis. Potassium (K) exceeds an HQ of 1 only in Kano (S2) at 1.05, posing risks of hyperkalemia and kidney issues. This study highlights the critical need for monitoring and mitigating exposure to elements with high HQs to protect public health in these urban areas.

Keywords: Particulate matter; Sources of PM; Effects of PM; Health; Life expectancy; Hazard quotient; $PM_{2.5}$, Air pollution; Heavy metals. Toxic elements

1. Introduction

Recent findings highlight the severe impact of air pollution on global health. The Special Report by the Health Effects Institute (HEI) on the State of Global Air (SOGA, 2020) ranks air pollution as the fourth leading cause of premature death, responsible for about twelve percent of global fatalities. In the Niger Delta Area of Nigeria, a study conducted by Udo and Ewona, supported by TET Fund, has revealed significant levels of pollution in the region. To assess air quality, the gravity settling method was employed for collecting air samples, as detailed by Ewona et al. (2021); Ewona et al. (2022), (Udo et al. 2018b; 2018c; 2020b; 2020c).

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The World Health Organization (WHO, 2021) has determined that exposure to air pollution results in millions of deaths and lost years of healthy life, annually. Cardiovascular diseases are the leading cause of death globally. An estimated 17.9 million people died from cardiovascular disease in 2019, representing 32% of all global deaths. And 85% of those casualties were attributed to heart attack and stroke.

Air pollution is currently reported as the greatest environmental threat to human health. Air pollution has the potential to cause Noncommunicable diseases (NCDs). Noncommunicable diseases (NCDs) are now the primary causes of death and disability globally. NCDs are diseases that cannot be transmitted directly from one person to another. These include Parkinson's disease, strokes, heart diseases, cancer, diabetes, chronic kidney disease, and osteoarthritis. NCDs encompass a wide range of diseases affecting the cardiovascular, neurological, respiratory, and other organ systems. Air pollution increases the incidence and severity of cardiovascular and respiratory diseases and lung cancer, with growing evidence of its effects on other organs (Ewona et al. 2024; Ewona et al. 2013).

Air pollution originates from numerous sources, both natural and man-made, with combustion being the primary contributor. Fossil fuels and biomass combustion for energy generation is regarded as a major source of pollution, which can come from both indoor and outdoor sources.

Indoor sources of air pollutants include heating with polluted fuels like coal, wood, or dung, unvented heating, cooking stoves, cooking gas, tobacco smoke, and combustion for religious and cultural practices. Other sources include the use of incense and kerosene lamps for religious purposes, house renovations, cleaning products like detergents and insecticides, and the operation of electrical devices such as printers.

Outdoor sources include transportation, power generation, construction activities, industries, biomass burning, and the long-range atmospheric transport of pollutants from distant sources. Pollutants can be emitted directly as primary pollutants or formed in the air as secondary pollutants through complex physiochemical processes, such as sulfates, nitrates, and organic carbon.

Airborne pollutants such as particulate matter (PM), measured as $PM_{2.5}$ and PM_{10}, and gaseous pollutants including ammonia (NH_3), carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and organic air pollutants, have significant adverse effects on human health and the environment.

There is a need to investigate and identify sources of soot and ways to mitigate its impact, along with public health campaigns to communicate the health risks of particulate matter from soot. Particulate matter pollution poses a serious health concern, especially at elevated concentrations. Its size determines its atmospheric persistence and deposition in the human respiratory system. Burning solid fuels such as coal and biomass is a significant source of anthropogenic particulate matter.

Chlorine gas is a well-known harmful gas, with even small amounts causing severe health issues such as pulmonary edema, pneumonitis, emphysema, bronchitis, and irritation of the eyes, throat, and nose. Particulate matter is a major driver of climate change and a source of health toxicity. In the upper atmosphere, it modifies the earth's radiation budget and cloud formation, while in the lower atmosphere, it affects visibility and alters biogeochemical cycles. Most critical effects are observed in ambient air, where particulate matter degrades human health (Mukherjee and Agrawal, 2017).

1.1. Sources of Emission and Exposure

Air pollution arises from numerous discharge sources, both natural and man-made, due to industrialization. According to the WHO, the combustion process to generate energy is the largest contributor to air pollution, including the burning of fossil fuels in unvented heating and cooking stoves, tobacco combustion, and for cultural or religious practices.

To reduce greenhouse gas emissions, improving public transportation systems and encouraging non-motorized means of transportation, such as biking, walking, and horse-drawn vehicles, are essential. Planting trees along major roads to trap and absorb pollutants, and discouraging the use of older vehicles, which emit more pollutants, are also important measures (Tunde et al., 2022, Ekah, et al. 2023).

Below is a table representing air quality guidelines (AQG) for PM and ozone, designed to protect public health, including the most vulnerable populations such as children, the elderly, and those with preexisting health conditions. These guidelines are periodically reviewed and updated based on the latest scientific evidence.

2. Literature review

Ekah et al. (2024a) evaluated the concentration of toxic elements and environmental pollutants in Lagos State, Nigeria, focusing on airborne particles and rainwater contamination using gravitational settling method. Airborne particles were collected over a nine-month period, from January to September 2023, using funnels and clean containers placed at various sub-locations within the state. The collected sediments were analyzed in a laboratory using spectroscopic techniques. The following compounds were examined: arsenic (As), cadmium (Cd), manganese (Mn), ammonia (NH_3), chromium (Cr), mercury (Hg), chloride (Cl), aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), zinc (Zn), potassium (K), nitrite (NO_2^-), nitrate NO_3^-, and fluoride (F). In addition, salinity and conductivity of the rainwater samples were analyzed. The sediments were collected and averaged across the sub-locations, and generalized for the entire state, with a geoaccumulation index computed to assess contamination levels. The study found that pollutants such as cadmium (Cd), chromium (Cr), aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), zinc (Zn), potassium (K), nitrite (NO_2^-), nitrate (NO_3^-), and fluoride (F) reflected a clean or natural environment (Class 0) in terms of contamination. However, salinity levels were found to be a concern, indicating moderate to heavy contamination, which could affect environmental and ecological health. Nickel (Ni), manganese (Mn), and lead (Pb) were classified as Class 2, indicating moderate contamination.

Ekah, et al. (2024b) analyzed the following compounds; arsenic (As), cadmium (Cd), manganese (Mn), ammonia (NH_3), chromium (Cr), mercury (Hg), chloride (Cl), aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), zinc (Zn), potassium (K), nitrite (NO_2^-), nitrate (NO_3^-), and fluoride (F). Results revealed that Lead (Pb) exhibited the highest CF (5.66), indicating considerable contamination, followed by Nickel (Ni) (CF = 4.58) and Manganese (Mn) (CF = 4.43). Cadmium (Cd) and Chromium (Cr) demonstrated moderate contamination, with CF values of (1.83 and 1.06), respectively. The EF results suggest moderate enrichment for Pb (4.339), Ni (3.51), and Mn (3.396), pointing to significant anthropogenic contributions, while Cd (1.276) reflected minimal enrichment, indicating a blend of natural and human sources. Ecological risk assessment revealed that Lead (Pb) posed a very high ecological risk (Er = 254.7), reflecting its toxicity and substantial environmental impact. Cadmium (Cd) presented a considerable risk (Er = 54.9).

The study at the University of Cross River State, Calabar, Nigeria, involved collecting dust samples from six indoor halls across four campuses, analyzing them for heavy metals such as; zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), chromium (Cr), cadmium (Cd), nickel (Ni), and lead (Pb) using standard laboratory techniques. The results revealed significant contaminations, particularly with cadmium. (Ewona et al. 2024; Ewona et al. 2013).

Ewona & Okoli (2018) examined the trends in life expectancy in Nigeria from various demographic perspectives. The study analyzed data from the World Bank and WHO, revealing that life expectancy has increased over the last two decades but remains lower than the global average. The authors recommend strengthening health policies and community-based health initiatives to address the underlying causes of low life expectancy and improve access to healthcare services.

Raquel et al. (2016) examined the global mortality burden linked to anthropogenic ozone and $PM_{2.5}$ using a global chemical transport model. Their simulations for 2005 estimated that 2.23 million deaths annually can be attributed to anthropogenic $PM_{2.5}$, with the highest mortality rates in East Asia. They found that residential and commercial sectors contributed significantly to these deaths globally and suggested targeted air pollution control strategies for different regions.

Ewona (2020) explored how various socioeconomic factors influence life expectancy among rural populations in Nigeria. The study utilized surveys and interviews, finding that access to education and healthcare resources is crucial in determining health outcomes. The research results indicated that areas with improved education and healthcare services showed higher life expectancy. The author recommends targeted interventions to enhance these factors, including community health initiatives and educational outreach programs.

Elisaveta et al. (2013) provide an overview of PM pollution in Africa, outlining published monitoring studies, identifying major themes, highlighting data gaps, and discussing strategies to address particulate air pollution in fast-growing cities.

Frank et al. (2020) discussed the need to safeguard human health from particulate matter (PM) pollution generated by four contrasting sources: household biomass combustion, wildfires, desert dust storms, and urban air pollution in rapidly growing megacities. The article highlighted measures to protect populations in these urban areas and addresses the economic and behavioral challenges associated with sustainable energy use. Key areas of focus include locations affected by high concentrations of airborne particles, the importance of effective communication through public awareness campaigns, and empowering communities to enhance their health and air quality.

Ewona & Olaniyan (2021) examined the critical link between healthcare access and life expectancy in developing countries, focusing on Nigeria. The paper utilized statistical analysis of healthcare access data, revealing significant barriers, such as economic constraints and geographical challenges, that hinder access to quality healthcare services. The authors advocate for policy reforms aimed at improving healthcare infrastructure and accessibility, along with the implementation of mobile health services and to enhance overall health outcomes and life expectancy in underserved regions.

Ala'a (2021) evaluated $PM_{2.5}$ and PM_{10} concentration levels in Karbala, Iraq, over a 20-day period from June 1, 2015, to July 20, 2015. The observed concentrations exceeded WHO recommendations, with $PM_{2.5}$ levels above the guideline by 16% and PM_{10} by 12%. The study suggested that reducing $PM_{2.5}$ density to as low as 3 μg/m^3 could significantly decrease risks associated with long-term exposure to pollutants which might lead to lung cancer and cardiopulmonary mortality.

Ewona & Chukwu (2019) investigated the critical determinants of life expectancy in Nigeria, focusing on socioeconomic variables, environmental conditions, and healthcare access. The results indicated that higher income levels and education are significantly correlated with increased life expectancy. The authors suggest enhancing educational programs and improving economic conditions as effective methods to strengthen health outcomes and reduce disparities.

The review emphasized the critical role of air quality in urban development in Africa, linking it to rapid urbanization, social issues, health impacts, climate change, policy, and innovation. The high pollution levels, driven by low vehicle quality and fuel standards, reliance on solid fuels for cooking and other activities including waste burning, pose severe health threats (Asmamaw et al., 2021).

$PM_{2.5}$ level was assessed in Nairobi identified seven monitoring sites based on land use types, employing low-cost sensors and cyclone samplers for measurement. Results revealed that $PM_{2.5}$ concentrations peaked in industrial areas (111.87 μg/m^3) and were lowest in forested areas (21.25 μg/m^3). The study found daily variations in $PM_{2.5}$ levels correlated with human activities and atmospheric conditions, suggesting varying exposure risks among residents of different land use types (Caroline et al., 2021).

Airborne particulate matter presents a significant global environmental concern due to its detrimental effects on health and the environment. Many developing nations are establishing standards for PM to address its impacts. This review critically evaluates how PM affects visual air quality, human health, and damage to materials, vegetation, soil, and water bodies (Jimoda, 2012).

Gurusamy et al. (2021) studied the impact of Saharan dust events on PM concentrations in Mexico, comparing data from Saharan dust days to non-Saharan dust days. Their findings indicated that PM10 and $PM_{2.5}$ levels increased significantly during dust events, correlating with COVID-19 case numbers and emphasizing the need for improved air quality measures post-pandemic.

In Korea, sand dust is a source of PM, raising concerns about its health effects. Studies have shown that PM can enter the respiratory system through various mechanisms, leading to oxidative stress, inflammation, and increased risks for respiratory and cardiovascular diseases, including lung cancer. Effective management strategies are necessary to mitigate PM exposure and its health implications (Jun 2016).

Ambient air pollution, including PM and gaseous pollutants, is a major environmental risk factor affecting health. PM comprises a mixture of small particles and droplets, containing various components like acids, metals, and soil. Studies have linked PM inhalation to numerous health issues, including asthma, lung cancer, and cardiovascular diseases (An-Soo, 2014).

In Bosnia and Herzegovina, ambient $PM_{2.5}$ pollution accounts for a substantial proportion of deaths, with estimates suggesting that reducing PM could significantly increase life expectancy in affected cities (Vlatka et al., 2020).

The study examined the determinants of life expectancy in the world's most polluted countries, and it was found that environmental degradation poses a threat to health, while health expenditure, clean water access, and improved sanitation positively influence life expectancy. The results highlighted various causal relationships between carbon emissions and life expectancy (Mohammad et al., 2022).

Lastly, a review of global healthcare data revealed significant correlations between causes of death, healthcare quality, and socio-economic factors. This study analyzed global trends in mortality causes and their regional disparities, suggesting that socio-economic conditions impact health outcomes (Simona-Andree et al., 2021).

3. Materials and methods

3.1. Materials

- Materials used for the research include field data.
- Software used for statistical analysis includes Origin and MS excel.
- Funnels, writing markers, Petri dish, sellotapes, empty plastic containers used for field work.

3.2. Method

Funnels were securely attached to clean, empty containers, which were placed outdoors for a duration of nine months, from January to September 2023 at different sample locations. The different sample locations were grouped as single locations across different geographical locations in Nigeria. The locations include; Edo state (Benin) (S_1), Kano (S_2), Abuja (S_3), Lagos (S_4), Enugu (S_5), and Calabar (S_6). Samples were collected using the gravitational settling method, allowing airborne particles to settle naturally into the container along with rainwater. Subsequently, the samples were treated and moved to air quality control laboratory for spectroscopic analysis.

The analysis focused on the following elements: arsenic (As), cadmium (Cd), manganese (Mn), ammonia (NH_3), chromium (Cr), mercury (Hg), chloride (Cl), aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), zinc (Zn), potassium (K), nitrite (NO_2^-), nitrate (NO_3^-), and fluoride (F).

3.2.1. Determination of hazard quotient

The Hazard Quotient (HQ) is a numerical value used to assess the risk posed by exposure to a hazardous substance. It is a dimensionless ratio that compares the potential exposure to a substance with the level at which no adverse effects are expected. HQ is commonly used in environmental health and risk assessments to evaluate the potential non-carcinogenic health effects of chemicals.

3.2.2. Interpretation of Hazard Quotient

- **HQ < 1**: Indicates that the exposure level is less than the reference dose, suggesting that adverse health effects are unlikely.
- **HQ = 1**: Indicates that the exposure level is equal to the reference dose, which is considered a threshold level where no adverse health effects are expected.
- **HQ > 1**: Indicates that the exposure level exceeds the reference dose, suggesting a potential for adverse health effects and the need for further investigation or mitigation.

This can be determined by the relationship;

$$\mathbf{HQ} = \frac{Air\ concentration\ exposure\ measured\ at\ the\ field\ \ EC}{Reference\ concentration\ as\ recommended\ by\ regulatory\ bodies\ \ (RFC)}$$

Where;
HQ = Hazard Quotient is dimensionless
EC = Exposure air concentration (μg/m^3)
RfC = Reference concentration (μg/m^3)

3.2.3. Hazard Quotient finds applications in the following areas

- **Environmental Risk Assessment**: HQ is used to evaluate the risk of non-carcinogenic effects from exposure to environmental contaminants, such as heavy metals in soil, water, or air.
- **Human Health Risk Assessment**: HQ helps determine the risk associated with exposure to chemicals in consumer products, occupational settings, or contaminated sites.
- **Regulatory Standards**: HQ is used by regulatory agencies to establish safety standards and guidelines for allowable exposure levels to various substances.

4. Results of analysis

Hazard Quotient HQ for locations S_1 to S_6 was computed and the results were obtained and analyzed as shown below. Locations for the study include; S_1 (Edo state, Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River) and the total averaged HQ for the entire locations were displayed as well. Results of the tabulated values are shown on the figures from figure 1 to figure 16.

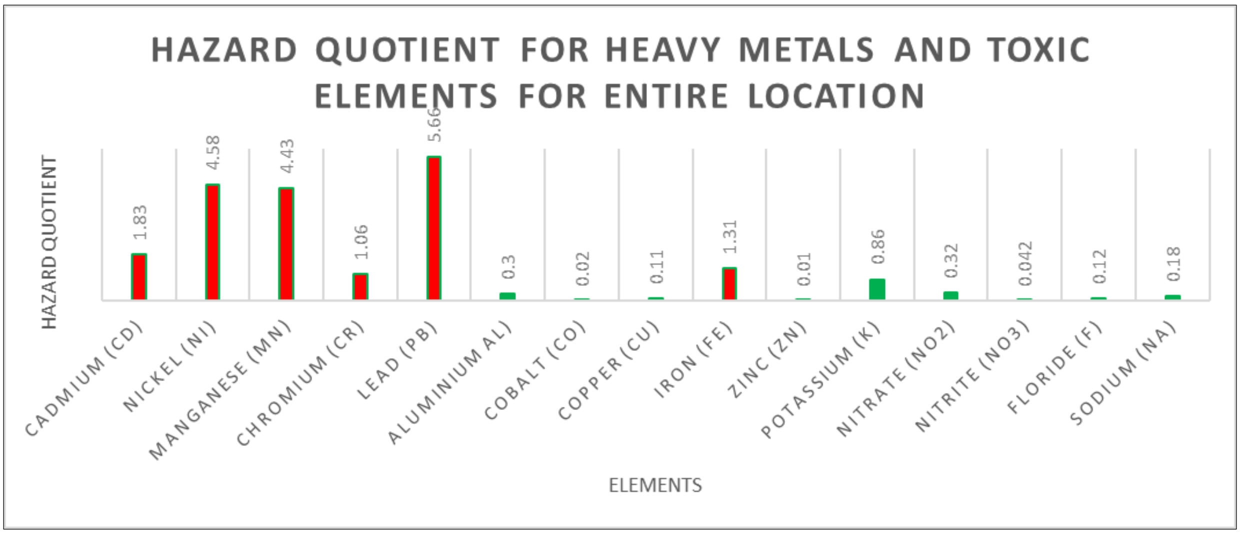

Figure 1 Hazard quotient for heavy metals and toxic elements for all studied locations

Figure 1 shows the HQ for air samples across; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 (Calabar). The result displays hazard quotient (HQ) of the following elements Cd: 1.83, Ni: 4.58, Mn 4.43, Cr 1.06, Pb 5.66, and Fe 1.31. The following elements; Ni, Mn, Pb, Cd and Cr had **HQ > 1**: Indicates that the exposure level exceeds the reference dose, suggesting a potential for adverse health effects and the need for further investigation or mitigation.

The HQ gives a clearer explanation of the magnitude of the level of concentration of the emitted elements and heavy metals. Excessive exposure to the following elements might expose residents to adverse health effects. The figure also shows that the following elements; NH_3:0.042, Al:0.36, Co:0.02, Cu:0.11, Zn:0.01, K:0.86, NO_2^-:0.32, NO_3^-:0.042, F: 0.12 and Na:0.18 had HQ less than 1, indicating a safe exposure level for human consumption.

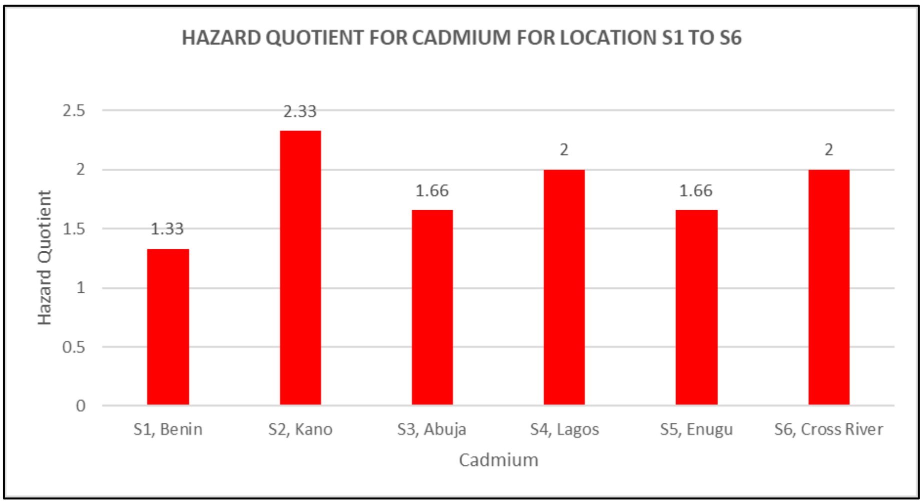

Figure 2 Hazard quotient for cadmium for location S1 to S6

Figure 2 represents HQ for cadmium for S_1 Benin (Edo state), S_2 Kano, S_3 Abuja, S_4 Lagos, S_5 Enugu and S_6 Calabar (Cross River). Results show that HQ > 1, suggesting a potential for adverse effects and the need for further investigation and mitigation. S_2 Kano had the highest HQ with numerical value of 2.33 followed by S_4 Lagos and S_6 Cross River with HQ of 2.0. Other cities Like S_3 Abuja, S_5 Enugu and S_1 Benin had HQ of 1.66, 1.66 and 1.33 respectively. Cadmium is a highly toxic chemical element and could be one of the leading causes of cancer and kidney failure when consumed in excess. The red colour bars is an indication that hazard quotient HQ of the element is greater than 1.

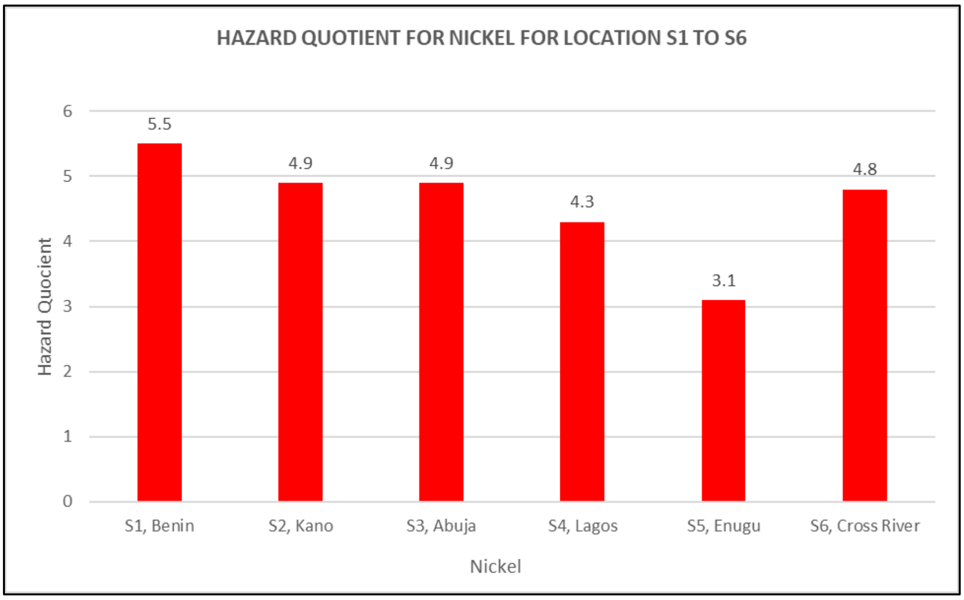

Figure 3 Hazard quotient for nickel for location S1 to S6

Figure 3 represents HQ for nickel, at; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). Result shows that HQ > 1. This indicates the potential for detrimental effects on human wellbeing. HQ of nickel was highest at S_1 Benin (Edo state) with a numerical value of 5.5, followed by S_2, Kano and S_3 Abuja with numerical value 4.9 each. Other locations like S_6, Calabar (Cross River), S_4 Lagos and S_5 Enugu had HQ value of 4.8, 4.3 and 3.1. The bar is repented with red colour indicating injurious reactions to man. Excessive exposure to nickel might result in bronchitis, asthma, or skin irritation.

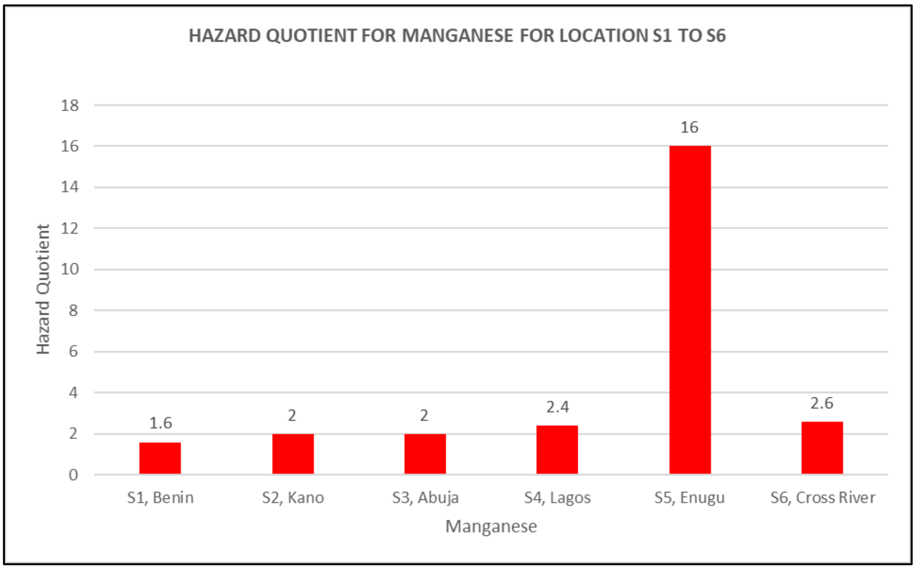

Figure 4 Hazard quotient for manganese for location S1 to S6

Figure 4 represents HQ for manganese across S_1, Edo State, Benin, S_2 (Kano), S_3 (Abuja), S_4 (Lagos), S_5 (Enugu), And S_6 Cross River. S_5, Enugu had the highest HQ of 16. Other locations like S_6, Calabar, S_4 Lagos, S_3 Abuja, S_2 Kano and S_1 Benin had HQ of 2.6, 2.4, 2.0, 2.0, 1.6 respectively. The HQ bar chart was made red indicating that HQ >1 which could be unfriendly to humans. Exorbitant exposure to manganese might result in lung inflammation, liver damage, neurological symptoms and cognitive impairment.

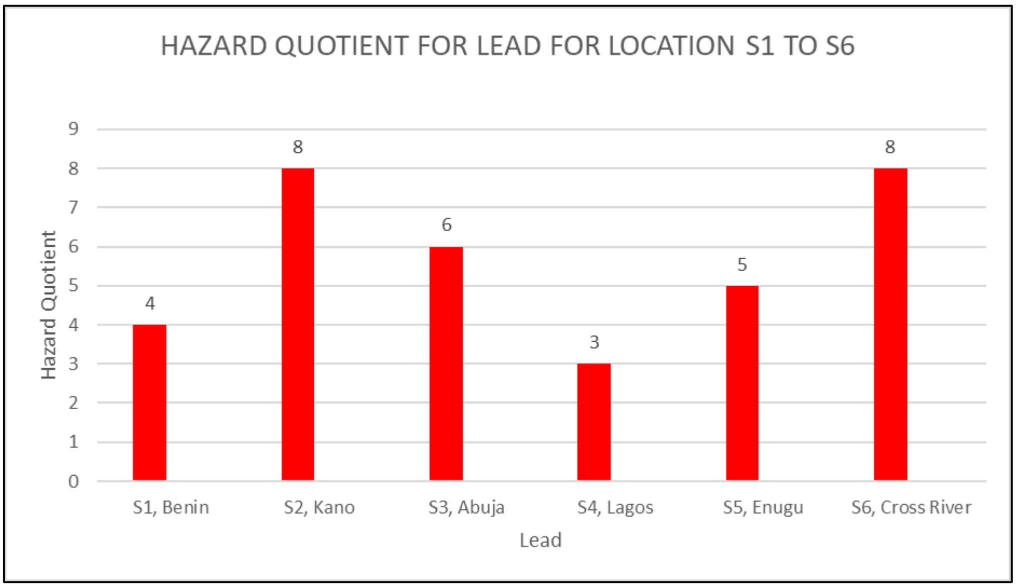

Figure 5 Hazard quotient for lead for location S1 to S6

Figure 5 illustrates HQ for lead as a heavy metal at; S_1 (Benin) Edo State, S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 (Calabar, Cross River). Result detects that all the locations in consideration had HQ > 1. HQ was greatest at S_2 Kano and S_6 Cross River with numerical values of 8 then followed by S_3 Abuja and S_5 Enugu with HQ of 6 and 5. Other locations such as S_1 (Benin) Edo State and S_4 Lagos State had HQ of 4 and 3 individually. HQ obtained for lead indicates deleterious effects like kidney damage and hypertension in adults and developmental issues and learning disabilities in children.

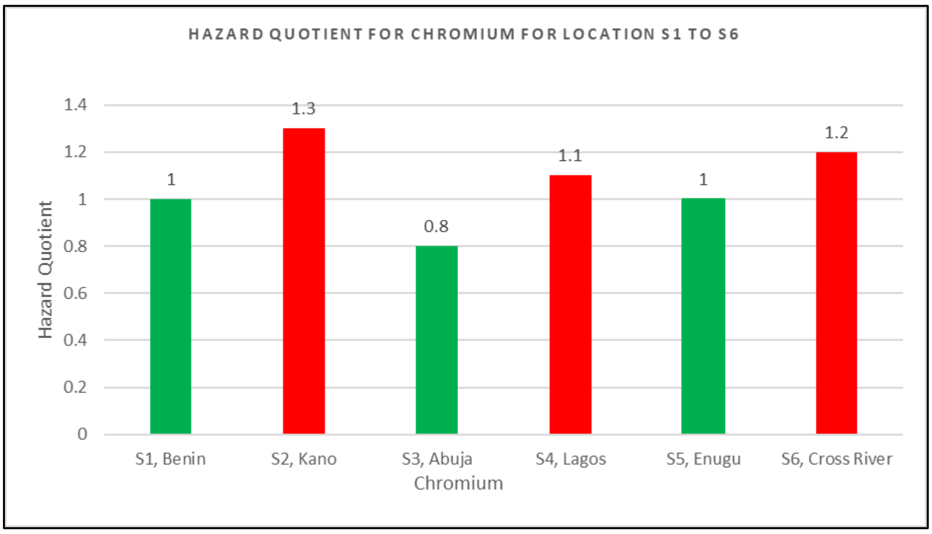

Figure 6 Hazard quotient for chromium for location S1 to S6

Figure 6 depicts HQ for chromium element at S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). Observation shows that S_2 Kano, Lagos S_4 and S_6 Cross River had HQ of 1.3, 1.2, and 1.1 respectively beyond the threshold limit while S_1 Benin, S_2 Abuja, S_5 Enugu had HQ <1 indicating that the exposure level of chromium is less than the reference dose, suggesting that adverse health effects are unlikely. Those living at locations with excessive exposure to chromium may be exposed to non-communicable diseases such as lung cancer, ulcer, bronchitis (inflammation of tubes which carries air to the lungs).

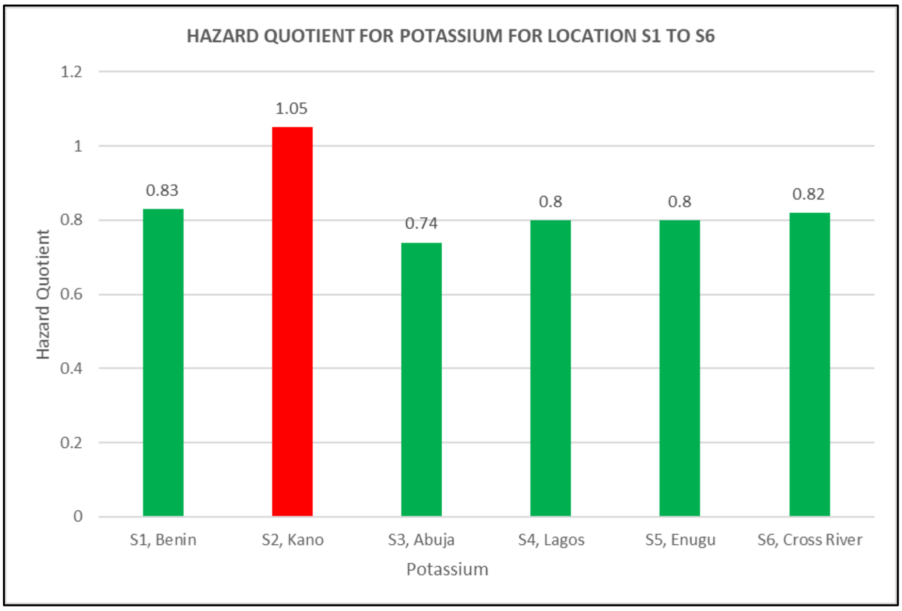

Figure 7 Hazard quotient for potassium for location S1 to S6

Figure 7 describes HQ for potassium for S_1 Edo, Benin, S_2 Kano, S_3 Abuja, S_4 Lagos, S_5 Enugu and S_6 Calabar (Cross River). Result demonstrates that HQ <1 for S_1, S_3, S_4, S_5 and S_6 which is below the reference dose while HQ> 1 for Kano S_2 with the value of 1.05. Result further reveals that residents living in Kano may be exposed to risk of hyperkalemia (medical condition which may lead to muscle weakness, fatigue, irregular heartbeats), nausea and vomiting, paralysis, kidney issues.

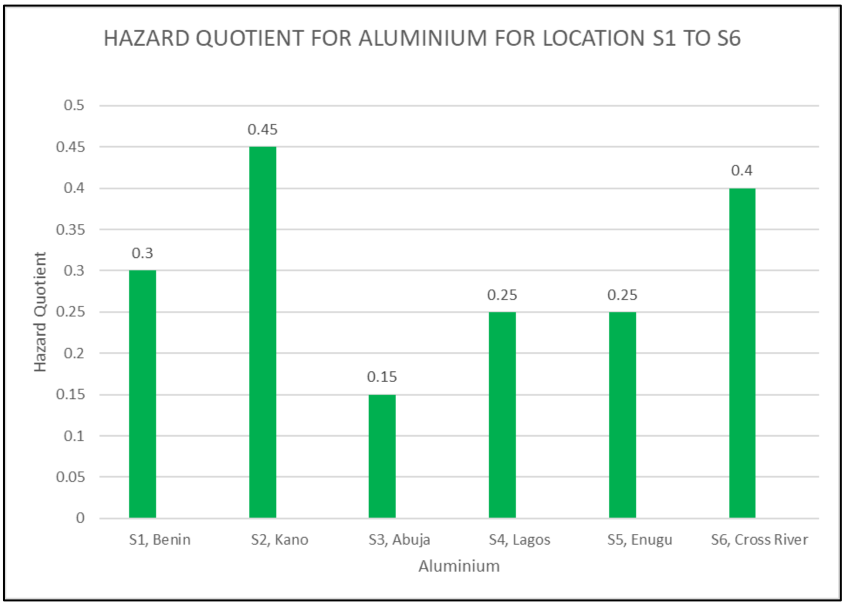

Figure 8 Hazard quotient for aluminium for location S1 to S6

Figure 8 delineates HQ for aluminum for S_1 Edo State, Benin, S_2 Kano, S_3 Abuja, S_4 Lagos, S_5 Enugu, And S_6 Calabar (Cross River). An HQ < 1 indicates that the exposure levels within the considered locations are less than reference dose, suggesting that adverse effects are unlikely.

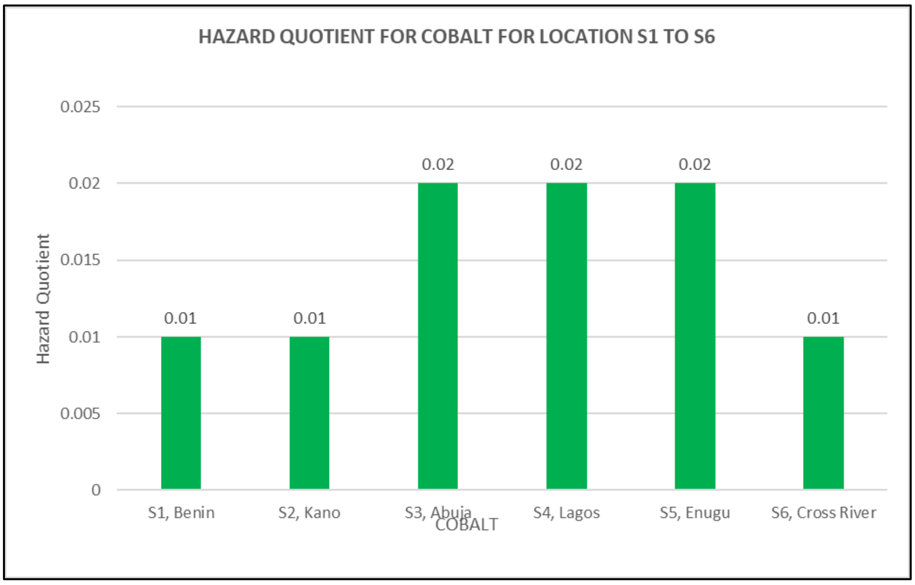

Figure 9 Hazard quotient for cobalt for location s1 to s6

Figure 9 depicts HQ for cobalt for S_1, Benin, S_2 Kano, S_3 Abuja, S_4 Lagos, S_5 Enugu and S_6 Calabar (Cross River). Results show that HQ ranged between 0.01 to 0.02. The HQ for the above listed locations was below the reference dose, suggesting that detrimental effects is implausible.

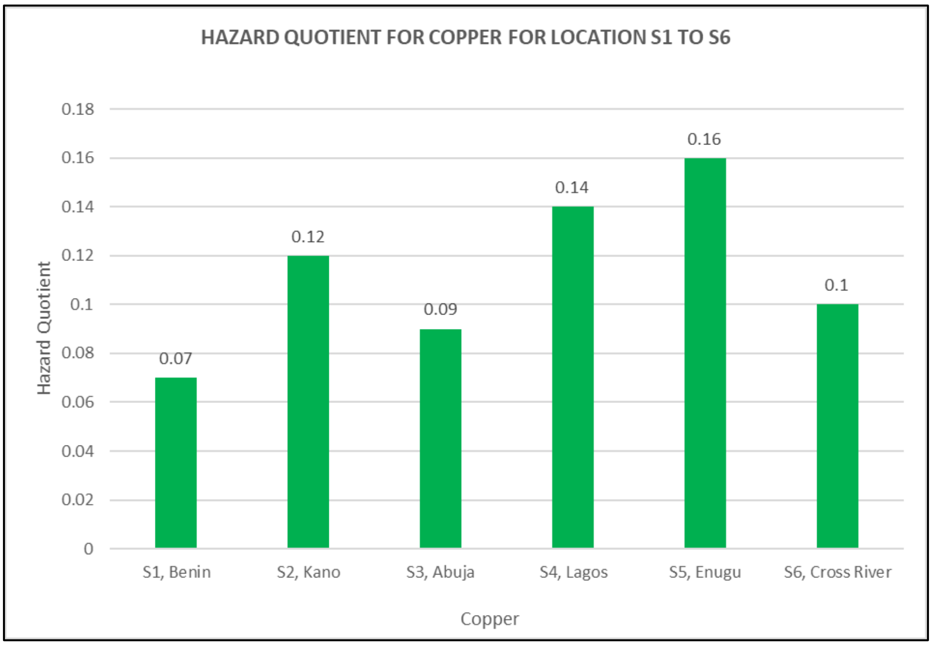

Figure 10 Hazard quotient for copper for location s1 to s6

Figure 10 represents HQ for copper element for locations; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). The HQ for the following locations was below the reference dose. HQ ranges between 0.16 to 0.07.

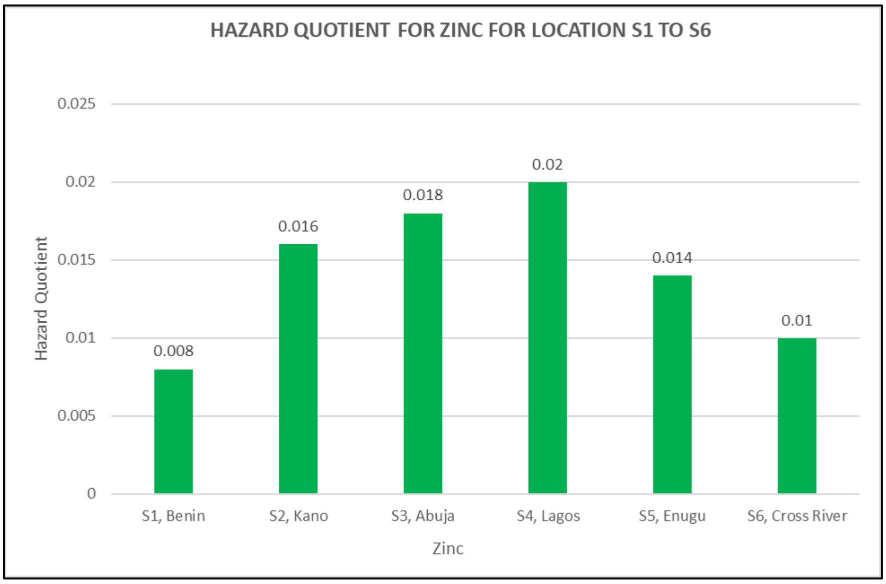

Figure 11 Hazard quotient for zinc for location S1 to S6

Figure 11 signifies HQ for zinc element for; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). Results show that HQ <1 and was within the reference dose. HQ ranges between 0.02 to 0.008.

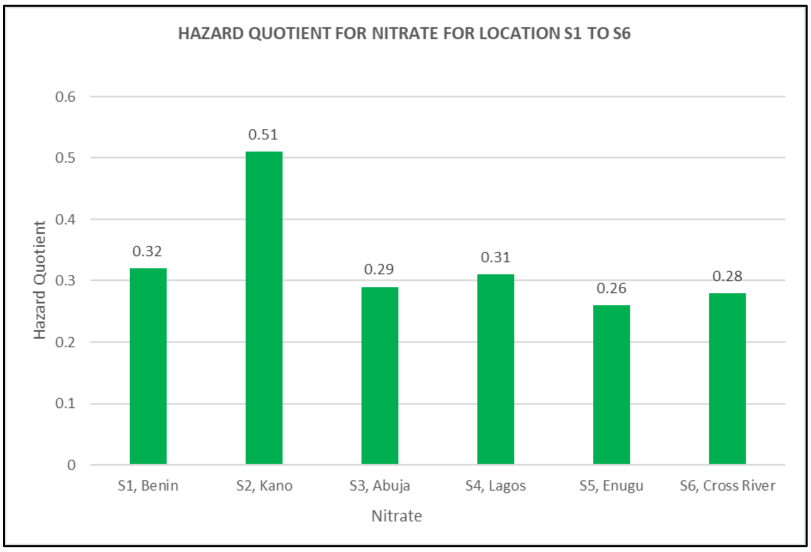

Figure 12 hazard quotient for nitrate for location S1 TO S6

The figure illustrates HQ for nitrite for; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). The results reveal that HQ for cadmium was below the reference dose for the locations S_1 to S_6. Results also show the HQ range between 0.51 to 0.26.

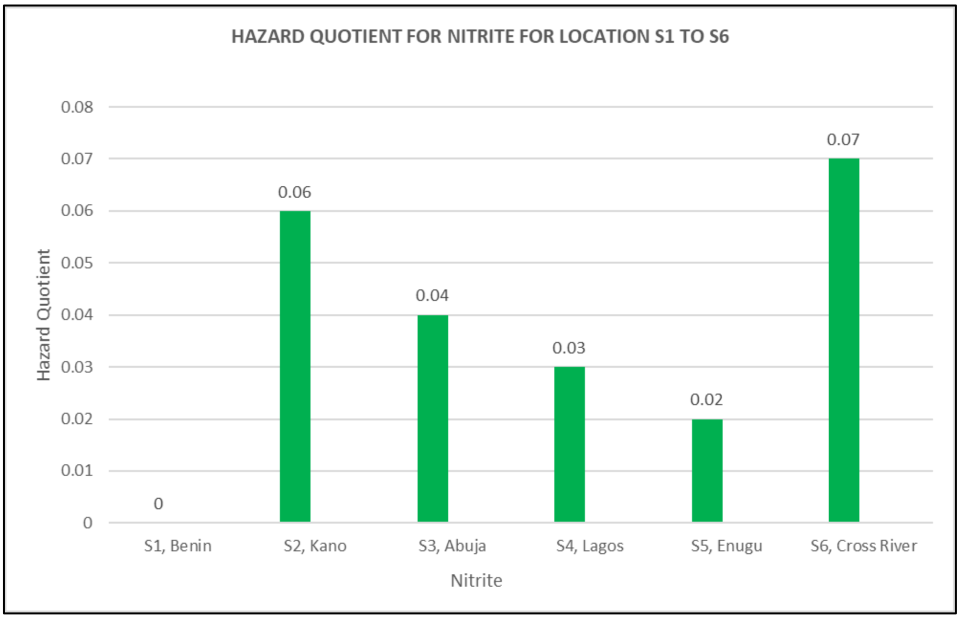

Figure 13 Hazard quotient for nitrite for location s1 to s6

Figure 13 stipulates that the HQ for nitrite within the following locations; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River) were below the reference dose. HQ for cadmium ranged between 0.07 to 0.02.

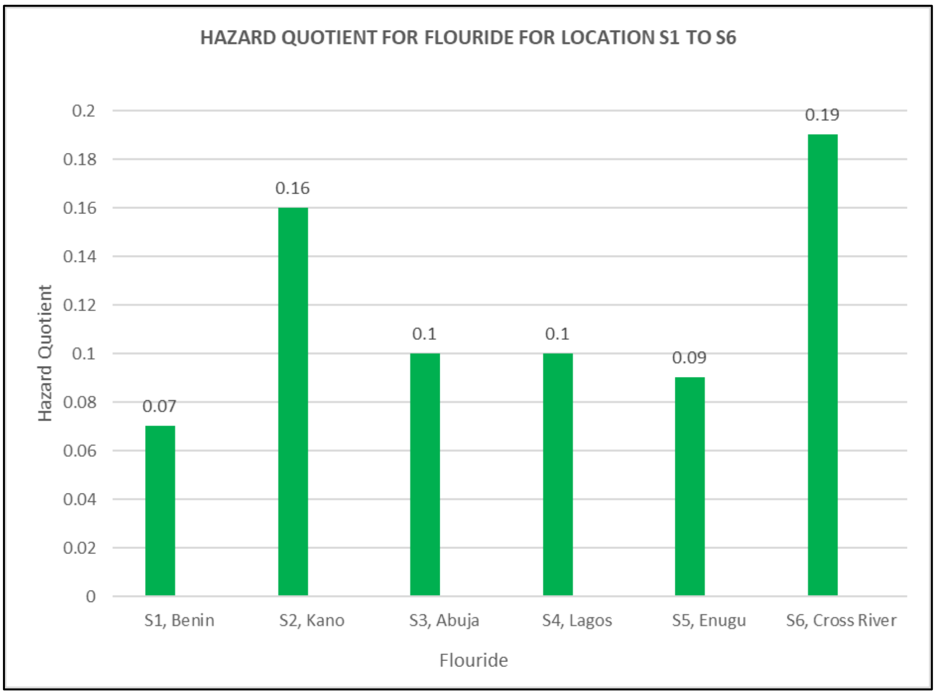

Figure 14 Hazard quotient for flouride for location s1 to s6

The figure reveals HQ for fluoride within the following locations; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). Results shows that HQ for fluoride < 1, which is below the reference dose. The HQ for fluoride ranges between 0.07 to 0.19.

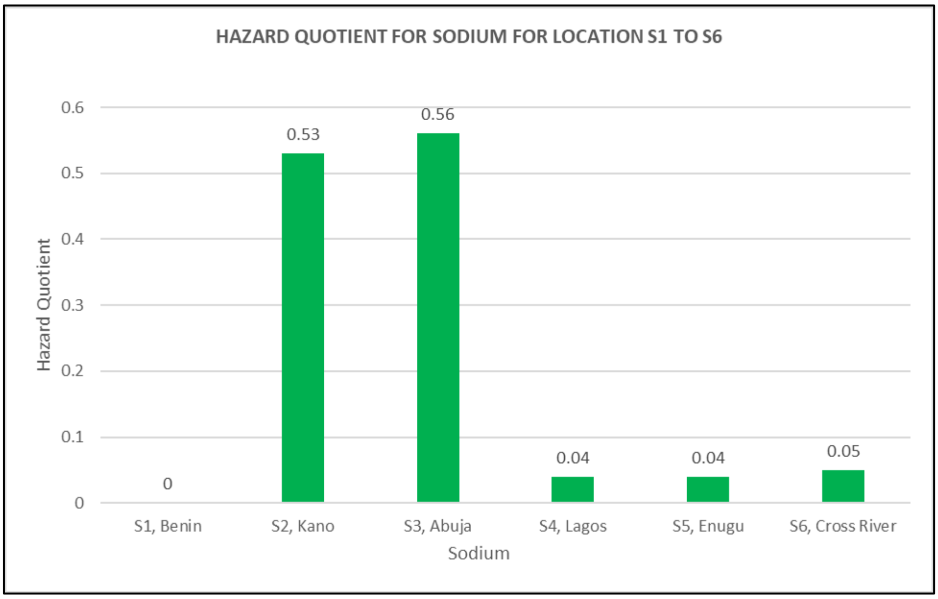

Figure 15 Hazard quotient for sodium for location s1 to s6

Figure 15 depicts HQ for sodium for cities; S_1 (Benin), S_2 (Kano), S_3 (Abuja), S_4 (Lagos) S_5 (Enugu), S_6 Calabar (Cross River). Results reveals that for sodium, HQ < 1 which is below the reference dose. HQ for sodium ranges between 0.56 to 0.04.

5. Discussion

The study identified hazardous quotients (HQ) for various elements across Nigerian cities, with is displayed as follows; nickel (Ni) with a value of 4.58, magnesium (Mn): 4.43, lead (Pb):3.66, chlorine (Cl):1.83, and chromium (Cr): 1.06. In contrast, elements such as Ar, NH_3, Hg, Cl, Al, Co, Cu, Zn, K, NO_2^-, NO_3^-, F, and Na had HQs below 1, indicating safe exposure levels. Cadmium (Cd) showed the highest HQ in Kano (S_2) at 2.33, with potential health risks including cancer and kidney failure. Nickel's highest HQ in Benin (S_1) was at 5.5, linked to bronchitis, asthma, and skin irritation. Manganese (Mn) had the highest HQ in Enugu (S_5) at 16, with risks of lung inflammation, liver damage, and cognitive impairment. Lead (Pb) had the highest HQ in Kano (S_2) and Calabar (S_6) at 8, associated with kidney damage and developmental issues. Salinity's highest HQ was in Abuja (S_3) at 32.74, affecting water quality and health. Chromium (Cr) had the highest HQ in Kano (S_2) at 1.3, potentially causing lung cancer and bronchitis. Potassium (K) had an HQ above 1 only in Kano (S_2) at 1.05, with risks of hyperkalemia and kidney issues. Elements with HQs below 1, such as aluminum, cobalt, copper, zinc, nitrite, fluoride, sodium, and conductivity, were deemed safe for exposure. This analysis underscores the need for urgent attention to elements with high HQs to protect public health in Nigerian cities.

6. Conclusion

This study examines the Hazard Quotients (HQ) of toxic elements and heavy metals in six Nigerian locations: Edo State, Benin; Kano; Abuja; Lagos; Enugu; and Cross River. The highest HQs were found for nickel (Ni), magnesium (Mn), lead (Pb), chlorine (Cl), and chromium (Cr), indicating significant health risks. Conversely, elements like aluminum, cobalt, copper, zinc, nitrite, fluoride, sodium had HQs below 1, suggesting safe exposure levels. The study underscores the urgent need to monitor and mitigate high HQ elements to safeguard public health in these cities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Funding Declaration

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Consent to participate and publish

I, **Professor Igwe O. Ewona** hereby give my consent to be one of a Co-author of "EVALUATION OF HAZARD QUOTIENT (HQ) OF TOXIC AND HEAVY METAL CONCENTRATION IN AIR SEDIMENTS ACROSS SELECTED CITIES IN NIGERIA" having made useful contributions to the article. There is no ethical issue since this does not have to do with human or animal products or specimens.

I, **B. J. Ekah**, consent to being involved in the research titled "**EVALUATION OF HAZARDQUOTIENT (HQ) OF TOXIC AND HEAVY METAL CONCENTRATION IN AIR SEDIMENTS ACROSS SELECTED CITIES IN NIGERIA**" I fully understand the purpose of the research and confirm that my participation was voluntary. I contributed to the study ethically and in an informed manner.

I, **U. J. Akwagiobe**, willingly agree to participate in the study titled "**EVALUATION OF HAZARD QUOTIENT (HQ) OF TOXIC AND HEAVY METAL CONCENTRATION IN AIR SEDIMENTS ACROSS SELECTED CITIES IN NIGERIA**". I was made aware of all aspects of the research and chose to take part voluntarily. My participation was ethical, and I played an active role in the research process.

I, **Prof. S. O. Udo** hereby affirm my consent to participate in the research titled "**EVALUATION OF HAZARD QUOTIENT (HQ) OF TOXIC AND HEAVY METAL CONCENTRATION IN AIR SEDIMENTS ACROSS SELECTED CITIES IN NIGERIA**".I was provided with the necessary information about the study, and I partook in the research voluntarily. My involvement was ethical and meaningful.

I, **Prof. B. Rabiu**, acknowledge that I gave my informed consent to participate in the research titled **"EVALUATION OF HAZARD QUOTIENT (HQ) OF TOXIC AND HEAVY METAL CONCENTRATION IN AIR SEDIMENTS ACROSS SELECTED CITIES IN NIGERIA**". I understand the research's nature and agree to be part of it voluntarily. My participation was conducted ethically, and I contributed fully to the study.

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