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# Assessment Of Heavy Metals Concentration Levels In Portable Drinking Water Around Crude Oil Exploration Sites In Obi, Nasarawa State, Nigeria

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**Abstract:** In this study, the heavy metal analysis concentrations in portable drinking water around crude oil exploration sites in Obi, Nasarawa State, Nigeria were assessed. Sixty water samples (twenty each from a well, borehole, and stream) were collected, prepared, and analyzed for heavy metal concentration using microplasma atomic emission spectrometry analysis. The hazard parameters such as chronic daily intake, hazard quotient, hazard index, and incremental life cancer risk were calculated for heavy metal concentration analysis. The results of heavy metals in the collected water samples from the study area were determined. The minimum (maximum) values of the combined concentration of Cd, Cr, As, Pb, and Ni in all the water sources are 0.00011 mg/L (0.00377 mg/L), 0.01001 mg/L (0.05101 mg/L), 0.00003 mg/L (0.00906 mg/L), 0.00014 mg/L (0.10100 mg/L), and 0.01002 mg/L (0.01002 mg/L), respectively. The mean concentration of heavy metals is 0.000951418 mg/L, 0.028627167 mg/L, 0.003285667 mg/L, 0.005518 mg/L, and 0.039830667 mg/L, for Cd, Cr, As, Pb, and Ni, respectively. The mean concentration is in the order; of Pb>Ni>As>Cr>Cd. The chronic daily intake (CDI) for child (adult) are 6.08E-5 mg/kg/day (2.61E-5 mg/kg/day) for Cd, 1.83E-3 mg/kg/day (7.84E-4 mg/kg/day) for Cr, 2.10E-4 mg/kg/day (9.00E-5 mg/kg/day) for As, 3.53E-4 mg/kg/day (1.51E-4 mg/kg/day), and 2.55E-3 mg/kg/day (1.09E-3 mg/kg/day). The hazard quotient (HQ) for the child (adult) is 0.121643 (0.052133) for Cd, 6.100457 (2.614353) for Cr, 0.700142 (0.300061) for As, 0.097986 (0.041994), and 0.127313 (0.054563) for Ni. Both values of Cd for children and adults are below 1.0, indicating that the risk of adverse health effects from cadmium exposure is low for both children and adults. Both values for children and adults of Cr significantly exceed 1.0, indicating a high potential health risk from chromium exposure for both children and adults. The ILCR data for the water samples from the crude oil exploration site in Obi, Nasarawa State, indicate significant cancer risks, particularly due to chromium, nickel, and cadmium. The cumulative ILCR of 0.0334 far exceeds typical safety thresholds, underscoring the urgent need for remediation and preventive measures to protect public health.

**Keywords:** Heavy metals, microplasma atomic emission spectrometry analysis, chronic daily intake, hazard index, and incremental life cancer risk.

## 1 Introduction

The availability of clean and safe drinking water is a fundamental necessity for human health and environmental sustainability. However, this critical resource is increasingly compromised by industrial and anthropogenic activities, particularly crude oil exploration and extraction. These activities can introduce a variety of contaminants into surrounding ecosystems, including heavy metals, which pose significant health hazards when present in water sources consumed by humans [1, 2]. Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), and mercury (Hg) are particularly hazardous due to their toxicity, persistence in the environment, and ability to bioaccumulate in living organisms [2, 3]. Even at trace levels, prolonged exposure to these metals can result in serious health complications, including organ damage, neurological disorders, and increased risks of cancer [2, 4-6].

Nigeria has long been recognized as a major player in the

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global oil and gas industry, with most of its crude oil exploration activities concentrated in the Niger Delta region. However, the discovery of new petroleum reserves has led to the expansion of oil exploration into other parts of the country, including Nasarawa State. Obi Local Government Area (LGA) in Nasarawa has recently emerged as a site of interest for crude oil exploration, raising concerns about its potential environmental and public health implications. Oil exploration and drilling operations often involve the use of various chemical additives, drilling muds, and production processes that can contribute to groundwater and surface water contamination.

The improper disposal of industrial waste, oil spills, and leaching from exploration sites can introduce hazardous pollutants into nearby water sources, making it imperative to assess the extent of contamination in drinking water supplies [4, 6- 8].

Given the significant role of water in sustaining human life and economic activities, understanding the quality of potable drinking water in oil exploration regions is crucial.

This study focuses on evaluating the concentration levels of selected heavy metals in drinking water sources located near crude oil exploration sites in Obi, Nasarawa State, Nigeria. The research aims to identify potential health risks associated with heavy metal contamination, determine whether the detected concentrations exceed permissible limits set by regulatory bodies such as the World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ), and recommend appropriate mitigation measures. The findings of this study will provide valuable data for environmental monitoring, contribute to public health policy discussions, and inform future regulations aimed at ensuring safe drinking water in oil-producing communities.

## 2 Materials and Method

### *2.1 Study Area*

The Nigerian National Petroleum Company Limited has announced the discovery of oil in Nasarawa State, saying it will spud the first oil well in March 2023. It said the discovery was in continuation of its oil exploration activities in the country's inland basins. The discovery of crude oil in commercial quantities in Obi Local Government Area of Nasarawa State has revived the hope of the ailing national economy and proven that the North could further contribute to the betterment of the nation's economy. The study area of this study is the proposed oil drilling site in Obi Local Government Area, Nasarawa State, Nigeria as shown in Figure 1. The area lies within, longitude 8°27'N and latitude 8°46'E.

It covers an area under 967 square kilometers and a population below 148,874 at the 2006 census. Obi local government in Nasarawa State shares common boundaries with Lafia Local Government to the East, Jenkwe Local Government to the West as well as Keana Local Government to the Southwest. The average temperature is 32$^0$C, the soil varies from loam to sandy loam which is good for crop production and there are also sufficient grazing areas for livestock production. The area has two climatic seasons which include the wet and dry seasons.

The wet climatic season begins in late April to late December or early November and the dry wind spell with Harm at an starts from early December to late March. The major towns in the Local Government Area include Adudu, Agwatashi, Obi, Tudun Adabu, Daddare, and Riri Respectively. It is estimated that about 75% of the entire population of women in the area are farmers (NADP, 2007). The crops cultivated include yam, maize, cassava, millet, cowpea, etc.

**Fig. 1.** Map of Nigeria showing Nasarawa State.

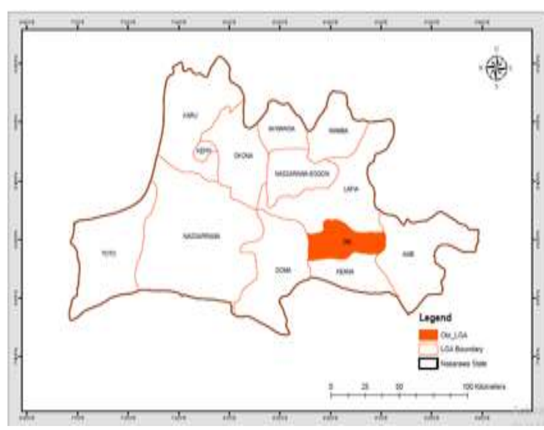

**Fig. 2.** Map of Nasarawa State showing the study area.

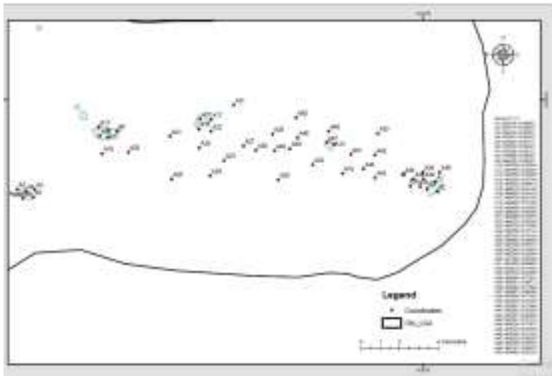


**Fig.3.** Map of study area showing sampling locations.

## 2.2 Population of Samples

The population of the study covers all the streams, boreholes, and wells around the proposed crude oil drilling sites in Obi, Nasarawa State, Nigeria. To obtain representative water samples and to ensure that all water samples have equal chances of selection, a simple random sampling technique was adopted to collect sixty (60) water samples from the study area.

## 2.3 Method of Sample Collection

The plastic containers were first washed and rinsed with distilled water to avoid the samples from being contaminated. Water samples were preserved with 20 ml of concentrated $HNO_3$ per liter of water to minimize absorption of the dissolved radon on container walls. The water samples were collected from a well, borehole, and stream. At each location, the containers were filled to the brim with the water sample without any head space to prevent $CO_2$ from being trapped and dissolving in water which might affect the chemistry e.g. pH, and then immediately closed to avoid loss of radon by degassing during transport to the laboratory. The samples were sent for analysis immediately after collection without allowing them to stay long (three days maximum) to minimize the influence of radioactive decay. This was done to achieve maximum accuracy and not to alter its composition. Each of the samples was coded with a number for simple identification. The sample codes with the GPS location of each sample were taken.

The samples for analysis were digested by measuring 250 ml of the water sample in a conical flask and 5ml of concentrated nitric acid was added to the measured sample and then heated on a microwave machine until the total volume was reduced to about one-third of the initial volume to break the complex bond and release the sample into solution. The solution was then filtered using a filter paper into another beaker, made up of 50ml with distilled water and mixed thoroughly. The samples were packaged into sample bottles before taking to the Micro Plasma Atomic Emission Spectrometer (MP AES) machine for analysis.

## 2.4 Method of Sample Preparation

The samples for analysis were digested by measuring 250 ml of the water sample in a conical flask and 5ml of concentrated nitric acid was added to the measured sample and then heated on a microwave machine until the total volume was reduced to about one-third of the initial volume to break the complex bond and release the sample into solution. The solution was then filtered using a filter paper into another beaker, made up of 50ml with distilled water and mixed thoroughly. The sample was packaged into sample bottles before taking to the Micro Plasma Atomic Emission Spectrometer (MP AES) machine for analysis.

## 2.5 Method of Sample Analysis

All filtered and acidified water samples were analyzed for all the heavy metals by using a Micro Plasma Atomic Emission Spectrometer under standard operating conditions. Because of data quality assurance, each sample was analyzed in triplicate, and after every 10 samples two standards (one blank and another of 2.5 mg/l) of respective metal were analyzed on atomic emission. The reproducibility was found to be at a 95% confidence level.

Therefore, the average value of each water sample was used for further interpretation. Standard solutions of all elements were prepared by dilution of 1000 mg/L certified standard solutions of corresponding metal ions with double distilled water. All the acids and reagents used were of analytical grade. All these analyses were performed in the Micro Plasma Atomic Emission Spectrometer (MP AES), at the Centre for Dryland Agriculture Bayero University, Kano, Kano State, Nigeria.

## 2.6 Calculation of Hazard Parameters

To assess both non-cancer and cancer risks for children and adults, the chronic daily intake (CDI) of HMs, which represents the lifetime average daily dose (LADD) of exposure to a contaminant was used. The CDI of the HMs via oral ingestion was calculated using Equation 1;

$$CDI = \frac{CxIRxEFxED}{BWxAT} \qquad 1$$

Where: CDI is the chronic daily intake (mg/kg/day); C is the concentration of the contaminant in a water sample (mg/L); IR is the ingestion rate per unit time (1 L/day for a child and 2.2 L/day for an adult); ED is the exposure duration (6 years for a child and 30 years for an adult); EF is the exposure frequency (365 days/year); BW is body weight (15 kg for a child and 70 kg for an adult); AT is the average exposure time (for carcinogens, AT = 70 × 365 = 2550 days for both children and adults; for non-carcinogens, AT = ED x 365 = 2190 days and 10950 days for children and adults, respectively) [9].

i. **Non-Cancer risks:** Non-cancer risks due to non-carcinogenic effects of HMs in drinking water were determined by the non-cancer hazard quotient using Equation 2;

$$HQ = \frac{CDI}{RfD} \qquad 2$$

Where: HQ is the non-cancer hazard quotient; CDI is the chronic daily intake (mg metal/kg/day); and RfD represents the chronic oral reference dose, that approximates the human population's daily oral exposure level, plus delicate subpopulation which is probably to be without a significant risk of harmful effect through a lifetime. Potential risk to human health posed by exposure to multiple HMs was measured by the chronic hazard index (HI), which is the sum of all HQ calculated for each heavy metal. A value of HQ or HI < 1 implies no significant non-cancer risks; a value ≥ 1 implies significant non-cancer risks, which increase with the increasing value of HQ or HI [10].

ii. **Cancer risk:** Cancer risk is the hazard from a lifetime average dose exposure to 1 mg/kg body weight/day of a pollutant. Cancer risk was expressed in terms of incremental lifetime cancer risk (ILCR), which is the probability that one may develop cancer over a 70-year lifetime due to a 24-hour exposure to a potential carcinogen (Ugwu *et al.*, 2022). Cancer risk was calculated as the product of CDI (mg/kg/day) and cancer slope factor (CSF) measured in $(mg/kg/day)^{-1}$ [11]:

$$ILCR = CDIxCSF \qquad 3$$

Where: ILCR = incremental life cancer risk; CDI = chronic intake (mg/ kg/BW/day); CSF = cancer slope factor. The total cancer risk as a result of exposure to multiple contaminants due to consumption of a particular type of water was assumed to be the sum of each metal incremental risk (∑ILCR). The United States Environmental Protection Agency (USEPA) considers the minimum or acceptable cancer risk for regulatory purposes within the range of $1 \times 10^{-6}$ to $1 \times 10^{-4}$ [12].

## 3 Results and Discussion

The results of heavy metals concentration in water samples collected from the study area are shown in Figures 4, 5, and 6 for stream, borehole, and well, respectively. The levels of cadmium (Cd), chromium (Cr), Arsenic (As), lead (Pb), and nickel (Ni) in all the water samples collected were determined.

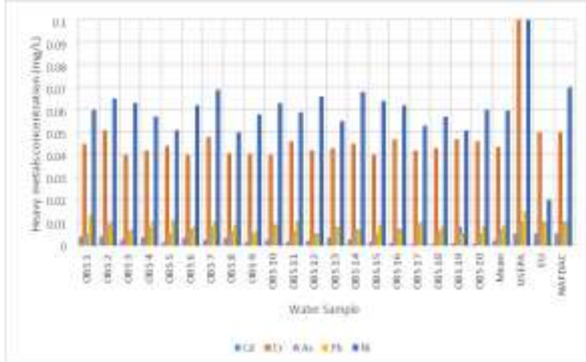

**Fig. 4.** Comparison of heavy metals concentration level in mg/L of the water samples collected from streams in the study area.

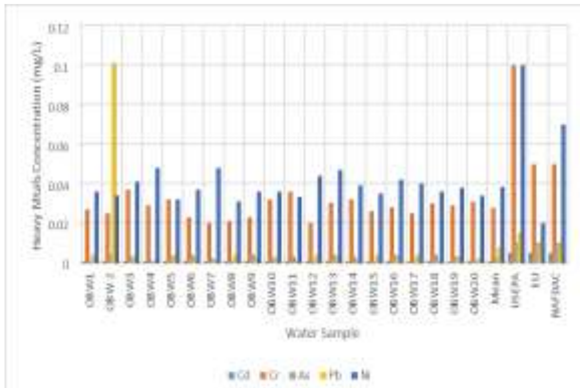

**Fig. 5.** Comparison of heavy metals concentration level in mg/L of the water samples collected from wells in the study area.

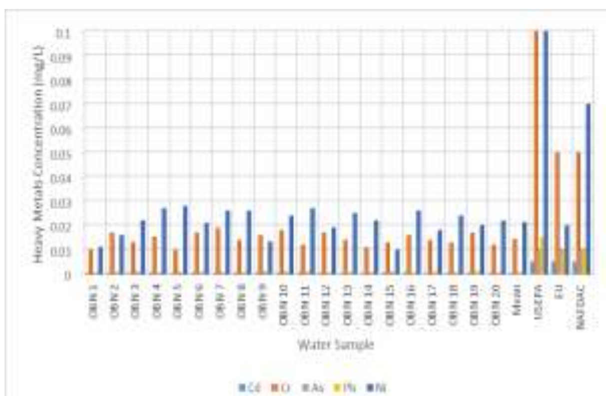

**Fig.6.** Comparison of heavy metals concentration level in mg/L of the water samples collected from boreholes in the study area.

Figures 4, 5, and 6 present the results of heavy metals in the collected stream, borehole, and well water samples from the study area, respectively. The minimum (maximum) values of the combined concentration of Cd, Cr, As, Pb, and Ni in all the water sources are 0.00011 mg/L (0.00377 mg/L), 0.01001 mg/L (0.05101 mg/L), 0.00003 mg/L (0.00906 mg/L), 0.00014 mg/L (0.10100 mg/L), and 0.01002 mg/L (0.01002 mg/L), respectively. The mean concentration of heavy metals is 0.000951418 mg/L, 0.028627167 mg/L, 0.003285667 mg/L, 0.005518 mg/L, and 0.039830667 mg/L, for Cd, Cr, As, Pb, and Ni, respectively. The mean concentration is in the order; of Pb>Ni>As>Cr>Cd. These values are compared with standard guidelines set by regulatory bodies such as the World Health Organization (WHO) and the Environmental Protection Agency (EPA).

The mean concentration of Cd is well below the WHO guideline of 0.003 mg/L, indicating low levels of cadmium contamination. However, the maximum concentration (0.00377 mg/L) slightly exceeds the guideline, which may pose health risks if exposure is prolonged. The mean concentration of Cr is within the WHO guideline of 0.05 mg/L, although the maximum value is at the threshold. This suggests periodic monitoring is necessary to ensure levels do not exceed safe limits. The mean concentration (0.003285667 mg/L) of As is below the WHO guideline of 0.01 mg/L. This indicates that arsenic levels in the water are within safe limits for consumption. The mean concentration (0.005518 mg/L) of Pb is below the WHO guideline of 0.01 mg/L. WHO Guideline: 0.07 mg/L. The mean concentration (0.039830667 mg/L) of Ni is within the WHO guideline, but the maximum concentration (0.06902 mg/L) is very close to the limit. This proximity to the guideline suggests that nickel levels should be regularly monitored to prevent them from exceeding safe limits.

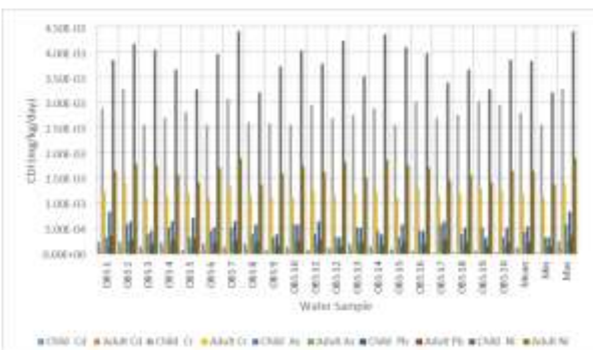

**Fig.7.** Comparison of calculated chronic daily intake (CDI) of various heavy metals in stream water for children and Adults.

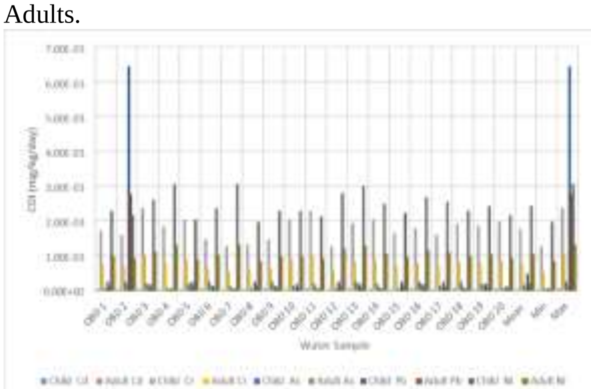

**Fig.8.** Comparison of calculated chronic daily intake (CDI) of various heavy metals in well water for children and Adults.

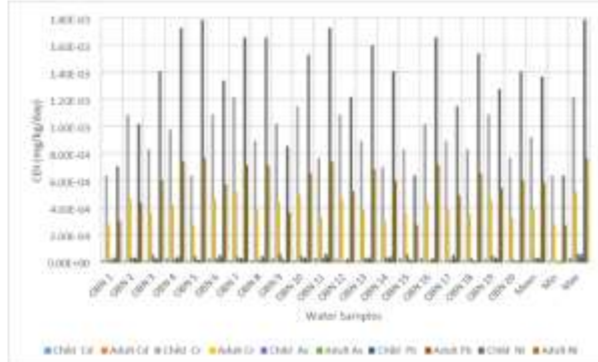

**Fig.9.**Comparison of calculated chronic daily intake (CDI) of various heavy metals in borehole water for Children and Adults.

The Chronic Daily Intake (CDI) of various heavy metals from water samples collected at a crude oil exploration site in Obi, Nasarawa State, provides insight into the potential health risks posed by these contaminants (Figures 7, 8, and 9). The CDI data for combined child (adult) are 6.08E-5 mg/kg/day (2.61E-5 mg/kg/day) for Cd, 1.83E-3 mg/kg/day (7.84E-4 mg/kg/day) for Cr, 2.10E-4 mg/kg/day (9.00E-5 mg/kg/day) for As, 3.53E-4 mg/kg/day (1.51E-4 mg/kg/day), and 2.55E-3 mg/kg/day (1.09E-3 mg/kg/day).

Cadmium exposure is associated with kidney damage, bone loss, and increased risk of cancer. The CDI for children is more than double that of adults, indicating higher exposure risk for children, potentially leading to more significant health impacts. Chromium exposure, particularly hexavalent chromium, is a known carcinogen and can cause skin rashes, stomach upset, and respiratory problems. The CDI for children is approximately 2.33 times higher than for adults, suggesting a greater health risk for children.

Arsenic exposure is linked to skin lesions, developmental effects, cardiovascular disease, neurotoxicity, and diabetes, with long-term exposure leading to cancer. The CDI for children is over twice that of adults, indicating significant health concerns for children. Lead exposure can cause developmental issues in children, affecting IQ, attention span, and academic achievement. For adults, lead can cause cardiovascular issues and kidney damage. The CDI for children is more than twice that of adults, which is concerning given the severe impact of lead on child development. Nickel exposure affects the nervous system, with higher risks for children who can experience developmental delays and cognitive impairments. The CDI for children is over twice that of adults, highlighting the significant health risks for younger populations. The higher CDI values for children across all heavy metals indicate that children are at a substantially higher risk of adverse health effects compared to adults. This is critical because children are more vulnerable to the toxic effects of heavy metals due to their developing bodies and higher intake of water relative to their body weight.

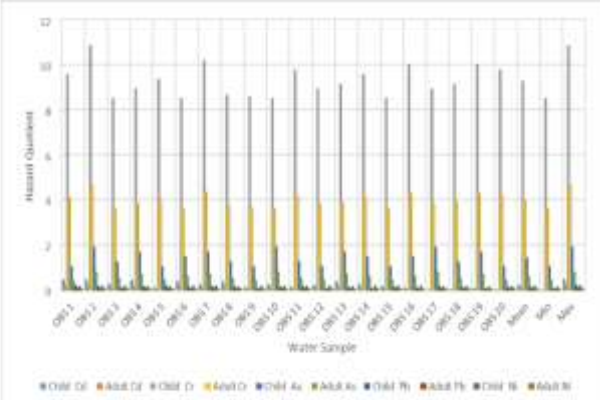


**Fig.10.** Comparison of calculated hazard quotients of water samples collected from streams in the study area.

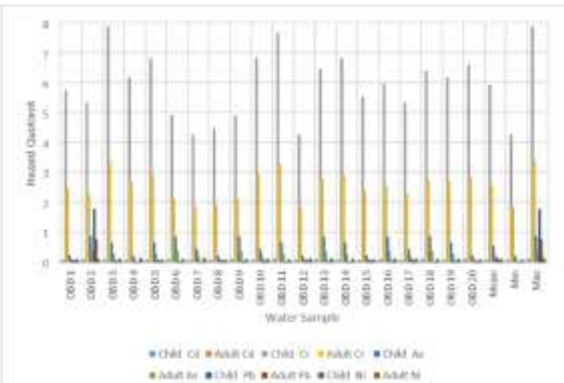


**Fig.11.** Comparison of calculated hazard quotients of water samples collected from wells in the study area.

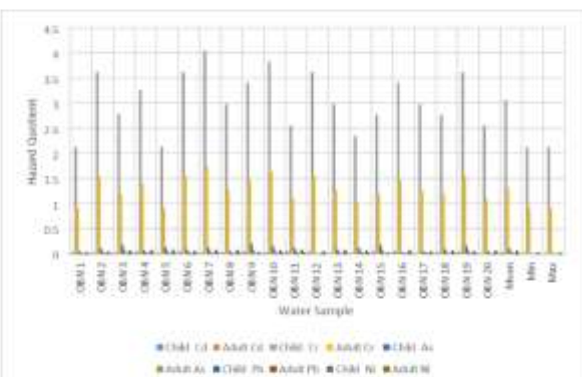


**Fig. 12.**Comparison of calculated hazard quotients of water samples collected from boreholes in the study area.

Tables 10, 11, and 12 present the calculated hazard quotients of stream, borehole, and well water samples collected from the study area. The hazard quotient (HQ) is a risk assessment measure used to evaluate the potential health risks posed by exposure to hazardous substances. It is defined as the ratio of the potential exposure to a substance and the level at which no adverse effects are expected. An HQ greater than 1.0 indicates a potential health risk. The HQ data for the child (adult) are 0.121643 (0.052133) for Cd, 6.100457 (2.614353) for Cr, 0.700142 (0.300061) for As, 0.097986 (0.041994), and 0.127313 (0.054563) for Ni. Both values of Cd for children and adults are below 1.0, indicating that the risk of adverse health effects from cadmium exposure is low for both children and adults. Both values for children and adults of Cr significantly exceed 1.0, indicating a high potential health risk from chromium exposure for both children and adults [13-16].

The HQ for children is notably higher, suggesting a greater vulnerability. Both values for As are below 1.0, indicating that the risk of adverse health effects from arsenic exposure is low for both children and adults, though the HQ for children is relatively higher, suggesting increased sensitivity. Both values for Pb are below 1.0, indicating that the risk of adverse health effects from lead exposure is low for both children and adults. Both values for Ni are below 1.0, indicating that the risk of adverse health effects from nickel exposure is low for both children and adults.

The most concerning result is the HQ for chromium, which is well above 1.0 for both children and adults. This suggests a significant health risk associated with chromium exposure, especially for children. Immediate attention and mitigation efforts are necessary to address chromium contamination. The HQ values for children are higher than those for adults across all metals, highlighting the increased vulnerability of children to heavy metal exposure. This is particularly critical for chromium, where the HQ for children is more than double that of adults. While the HQs for cadmium, arsenic, lead, and nickel are below 1.0, indicating low immediate risk, the presence of heavy metals still warrants regular monitoring and preventive measures to ensure that concentrations do not increase to hazardous levels.

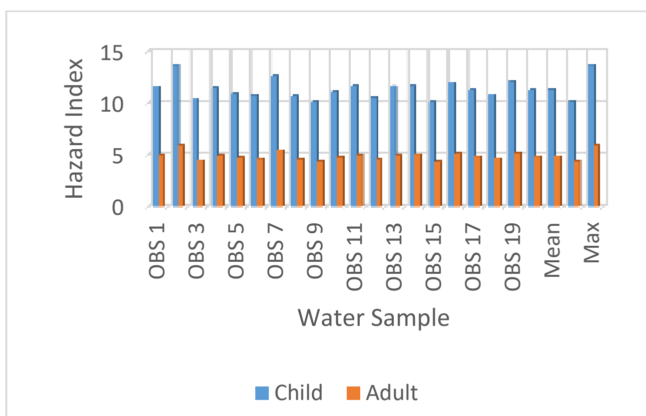


**Fig.13.** Comparison of calculated hazard Index of water samples collected from streams in the study area.

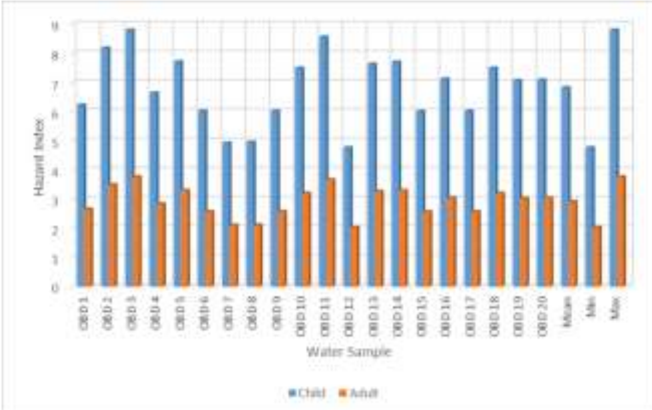


**Fig. 14.** Comparison of calculated hazard Index of water samples collected from wells in the study area.

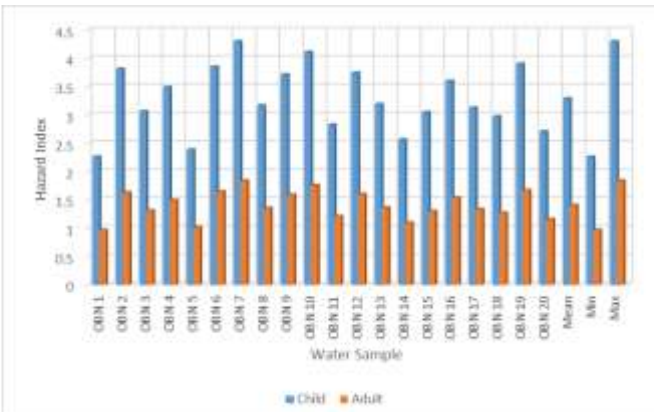


**Fig.15.** Comparison of calculated hazard Index of water samples collected from boreholes in the study area.

Figures 13, 14, and 15 show the calculated hazard Index of stream, borehole, and well water samples collected from the study area, respectively. The Hazard Index (HI) is the sum of hazard quotients for multiple substances, providing an overall indication of the potential non-carcinogenic risk from simultaneous exposure to multiple contaminants. An HI greater than 1.0 suggests a potential health risk, with higher values indicating a greater likelihood of adverse health effects. The HI data for children and adults are 7.14724 and 3.063103, respectively.

An HI of 7.14724 for children indicates a substantial potential health risk for children due to combined exposure to multiple heavy metals. This value is significantly above the threshold of 1.0, suggesting that cumulative exposure could lead to adverse health effects. The high HI is primarily driven by the elevated hazard quotient for chromium (Cr), which had an HQ of 6.100457 for children. This alone indicates a major risk, and when combined with the other metals, the overall risk increases substantially.

An HI of 3.063103 for adults also indicates a significant potential health risk, though it is lower than that for children. This value is still well above 1.0, suggesting that adults are at risk of adverse health effects from the cumulative exposure to the heavy metals present. Similar to children, the high HQ for chromium (2.614353) is a major contributor to the overall HI for adults, exacerbating the combined risk from exposure to all five heavy metals.
Children are more vulnerable to the harmful effects of heavy metals due to their developing bodies and higher intake of water relative to their body weight. An HI of 7.14724 indicates a severe risk and immediate actions are necessary to reduce exposure. The combined exposure could potentially lead to developmental issues, cognitive deficits, and other health problems associated with heavy metal toxicity.

While the HI for adults is lower than for children, it still represents a considerable risk. An HI of 3.063103 is significantly above safe levels, indicating that adults could also experience adverse health effects, albeit potentially less severe than those for children. Adults could face health issues such as kidney damage, cardiovascular problems, and other chronic conditions linked to prolonged heavy metal exposure.

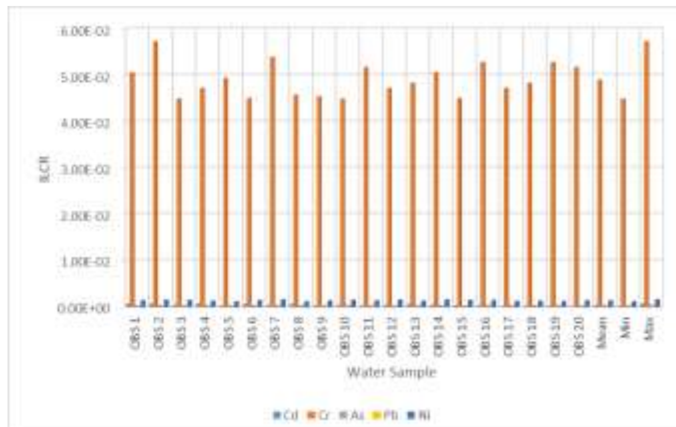


**Fig. 16.** Comparison of increment life cancer risk (ILCR) of water samples collected from streams in the study area.

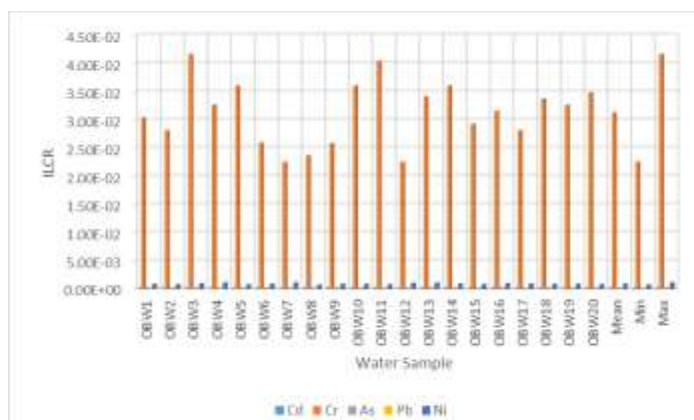


**Fig.17.**Comparison of increment life cancer risk (ILCR) of water samples collected from wells in the study area.

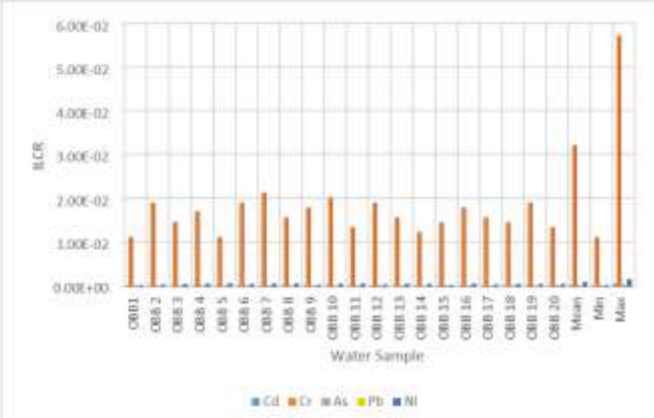


**Fig.18.** Comparison of increment life cancer risk (ILCR) of water samples collected from boreholes in the study area.

Figures 16, 17, and 18 show the incremental life cancer risk (ILCR) of stream, borehole, and well water samples collected from the study area, respectively. The Incremental Lifetime Cancer Risk (ILCR) estimates the probability of an individual developing cancer over a lifetime due to exposure to carcinogenic substances. An ILCR value greater than 1 in 1,000,000 (1.0E-6) is typically considered significant, with regulatory bodies often setting thresholds of concern at 1 in 100,000 (1.0E-5) or 1 in 10,000 (1.0E-4).

The ILCR data for Cd, Cr, As, Pb, and Ni are 1.64E-4, 3.22E-2, 1.35E-4, 1.29E-6, and 9.17E-4, respectively. The total ILCR value is 3.34E-2. The Cd value indicates a risk of 1.64 in 10,000, which exceeds typical regulatory thresholds of concern (1.0E-4). Thus, cadmium poses a notable cancer risk. The ILCR for chromium is 3.22 in 100, a very high risk significantly exceeding the threshold of concern. This indicates a substantial cancer risk from chromium exposure, necessitating urgent intervention. An ILCR of As (1.35E-4) translates to a risk of 1.35 in 10,000, which also exceeds typical regulatory thresholds. Arsenic, therefore, poses a considerable cancer risk. The ILCR for lead is 1.29 in 1,000,000, which is below most regulatory thresholds of concern. Hence, lead does not present a significant cancer risk at the detected levels. The ILCR of Ni indicates a risk of 9.17 in 10,000, surpassing typical thresholds. Nickel poses a substantial cancer risk. The combined ILCR of 3.34E-2 represents a cumulative risk of 3.34 in 100. This cumulative risk is well above acceptable levels, highlighting a severe overall cancer risk from the combined exposure to these metals [17-21].

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## 4 Conclusion

The study concluded that the heavy metal concentrations in the water sources around the proposed crude oil exploration sites present potential health risks to local communities. Elevated levels of heavy metals such as lead, cadmium, and arsenic pose toxicological risks, potentially leading to various health issues such as kidney damage, cancer, and neurological disorders. The findings underscore the need for pre-drilling environmental assessments and ongoing monitoring to manage and mitigate these risks effectively.

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