ASSESSMENT OF SELECTED HEAVY METALS CONTAMINATION IN SURFACE WATER AROUND TANK FARMS IN OGHAREKI COMMUNITY: IMPLICATIONS FOR HUMAN HEALTH

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ABSTRACT: *This study investigates the pollution load of selected heavy metals in surface water surrounding tank farms in the Oghareki community and its implications for human health. The results show that the surface water is contaminated with heavy metals, including lead, cadmium, nickel, iron, copper, and zinc, with varying concentrations across different distances from the tank farms. The pollution load index (PLI) and enrichment factor (EF) indicate significant contamination, particularly with cadmium. The chronic daily intake (CDI), hazard quotient (HQ), and incremental lifetime cancer risk (ILCR) values suggest potential health risks, including cancer and non-cancer risks, for individuals consuming contaminated water. The study highlights the need for regular monitoring and mitigation measures to minimize the impact of heavy metal pollution on human health and the environment.*

KEYWORDS: Contamination, Heavy metals, Tank farms, Distance, Health.

INTRODUCTION

The surroundings encompass all living and nonliving elements essential for life and sustainability, playing a crucial role in the health of humans and wellbeing (Pona *et al.,* 2021). In areas near specific industries such as refineries, tank farms, ports, and busy roads, as well as urbanized environments, high levels of contamination have been detected. High concentration of these contaminants serves as an indicator of pollution of the environment (Onwukeme and Etienajirhevwe 2020).

Concerns regarding water have likely existed since the dawn of humanity, particularly as industrialization began and the associated issues emerged as significant challenges (NSCA, 2020). Although water is a vital component of life, its quality has historically fluctuated, often negatively impacting human health. Recently, an increasing number of studies have revealed that contaminants and pollutants affect the health of humans at lower concentrations than previously believed. This has intensified public concern about the need to enhance or manage soil quality and water for generations to come (Etienajirhevwe and Agbini, 2021).

In recent years, the pollution of water environments by inorganic contaminants has emerged as a global issue. These substances are often indestructible and can have severe effects on organisms (MacFarlane and Burchett, 2020). Heavy metals have significant concern among environmental pollutants because of their known severe effects and their capacity to be retained in the aquatic ecosystems (Censi *et. al.,* 2020).

Pollution of water is a global issue that necessitates continuous assessment and validation of water policies at all levels. Water pollution has been suggested to be one of the major causes of disease that results in death, contributing to over 14,000 fatalities each day (Kavitha and Dhandapani, 2018)

While developing countries face urgent water pollution issues, developed nations also grapple with similar challenges. International research on the quality of water in the United States reveals that 44% of the evaluated miles streams, 64% of visited acres of lake, and 30% of surveyed estuarine and bay square miles are considered polluted (US EPA, 2019)

Consuming water sourced from the natural earth is compulsory; they are vital for our survival, even in the short term. These resources have been utilized in their natural state throughout history. The water we drink from birth until death is our most fundamental necessity for continuity (Department of Environment, 2019).

This research is aimed at determining the pollution load of selected heavy metals in surface water surrounding tank farms in the Oghareki community, as it relates to the health of occupants in the nearby vicinity.

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METHODOLOGY

Study location

This research was conducted at Oghareki, a sub–clan of Oghara. Oghareki-Oghara is situated at a Latitude 5°57'2"N, and a Longitude 5°38'25"E. Oghareki is home to a river that originates from the River Ethiope, a freshwater source that flows over 100 kilometers from its starting point in Umuaja. This river passes Abraka to Mosogar and Sapele before reaching Oghareki, where it empties into the Benin River. The river is heavily utilized by local residents for recreational/occupational activities, including fishing, washing, bathing, swimming, and domestic purposes. However, it also poses challenges, as it overflows its banks periodically, carrying domestic/industrial wastes and runoff during the rainy season.

The river is flanked by nine tank farms, including Rain Oil, Cybernetics, Dutchess Energy, Nepal, Othinel Brooks Energy, Prudent Energy, Gas Black Light Energy and Fredo Energy Limited. These facilities receive/discharge various petroleum products, such as diesel, petrol, and kerosene on a daily basis. The discharge occurs through jetties built along the riverbank, often resulting in leaks that contaminate both the river and the surrounding soil.

Additional activities surrounding the river are dredging and bunkering on nearby farms. The transportation of illicit gasoline products by boat on the river, along with human activities, has contributed to contamination and pollution of surface water and soil. These practices have raised significant concerns among local residents who rely on the river and soil for their daily needs, as they have led to pollution and adverse environmental impacts since their inception.

Collection of surface water

Surface waters were collected at ten sampling points situated between 100 meters and 1 kilometer from the tank farms and a control site free from industrial activities. Surface water was gathered using previously cleaned glass bottles that had been treated with an acid and further rinsed using distilled water. Surface water samples were collected at a depth of 5 cm and combined to create a one-liter sample. Samples were then taken to the laboratory in an iced cooler in order to maintain a temperature of 4°C (Kpee and Bekjee, 2021). Twelve sampling events were conducted, resulting in the collection of 120 water samples from the ten sampling points, excluding the control.

Extraction of water for heavy metals analysis

Heavy metals analyses were done in accordance with the method outlined by Akporido and Kadiri (2014). Initially, 5mL Conc. nitric acid was added to 100mL of each water sample in the beaker. The mixture was evaporated to approximately 20 mL by the use of hot plate. After cooling to room temperature, an additional 5mL conc nitric was added, and the solutions were reheated and became colorless and clear. The resulting mixture was then filtered to eliminate any impurities, while the filtrate was retained for heavy metals analysis. A blank determination was conducted using the same procedure, which was applied to all water samples (ASTM, 2015)

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Determination of heavy metals in water

The surface water, after digestion and extractions, was analyzed for the concentration of heavy metals using an atomic absorption spectrophotometer (AAS). Each sample was introduced into the AAS flame as a fine mist by an air stream. It then flowed into the burner via a mixing chamber, where it combined with acetylene fuel gas. The mixture was ignited, producing a flame. The radiation emitted from the flame was directed by a lens to a monochromator and then passed by an optical filter, which allowed only the specific radiation corresponding to the metal being analyzed to reach a photo cell. The results were displayed on the screen of a monitor. The optical densities of the standards for each heavy metal were measured at their specific wavelengths, while standard curves were created by plots of absorbance against concentration (Etienajirhevwe and Okoro 2024).

Pollution index models

Pollution load index (PLI)

Pollution load index was utilized to evaluate the quality of soil and water at the study site, following the method by Thomilson et al (1980) and as reported by Al-Dahar et al (2023). The pollution load index was estimated by multiplying the contamination factors of the analyzed heavy metals

$$PLI = (CF1\ x\ CF2\ x\ CF3\ x \dots \dots \dots CFn)^{1/n}$$

n is the number of metals in the experiment, and CFi is the contamination factor of each specific heavy metal.

Enrichment factor

This factor was utilized to evaluate the level of enrichment in water and soil environments. The enrichment of both water and soil was determined using the expression below:

$$EF = \frac{\left(\frac{Ci}{Fe}\right) sample}{\left(\frac{Cb}{Fe}\right) background}$$

In this context, Ci represents the concentrations of contaminants being analyzed, while Cb denotes the background concentration of the contaminant being analyzed. $\left(\frac{Ci}{Fe}\right)$ is the ratio of the concentration of contaminant in the sample to the concentration of iron for the same sample. Similarly, $\left(\frac{Cb}{Fe}\right)$ indicates the ratio of the concentration of the contaminant in the background to the amount of iron also in the background.

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Human health risk assessments

Chronic daily intake (CDI)

The parameter, chronic daily intake, which could be by ingestion, exposure, and inhalation, was calculated using the expression below:

$$CDI = \frac{C\ x\ IR}{BW}$$

In this context, C represents the value of the contaminants being analyzed, and IR denotes ingestion rate/time (in this case, 2 liters per day) while BW is the body mass (70kg was used for adults).

Hazard quotient (HQ)

This is a metric used for assessing risk associated with exposure to contaminants. It was calculated by the use of the expression below:

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

In this context, HQ refers to the noncancer hazard quotient, while CDI represents chronic daily intake, and RfD stands for chronic oral reference dose. The RfD is an estimate of the daily oral exposure for the general human population, such as sensitive subpopulations, that is expected to pose little / no risks to harmful effects over a lifetime (Etienajirhevwe et al., 2025)

Incremental life-time cancer risk (ILCR)

This is a measure used for evaluating potential cancer risks linked to exposures to contaminants in soil and water. It was estimated by the following formula:

$$ILCR = CDI\ x\ CSF$$

In this context, CDI denotes chronic daily intakes, while CSF stands for cancer slope factor. Cancer slope factors for lead, cadmium, and nickel are 0.0085, 6.3, 0.91, respectively (USEPA, 1997).

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RESULTS AND DISCUSSION

Table 1 Mean heavy metal concentration (mg/L) in surface water

Distance	Pb	Cd	Ni	Fe	Cu	Zn
Control	0.010f	0.001b	0.002g	0.001g	0.010g	0.002g
100m	0.083a	0.031ab	0.137a	0.129a	0.312a	0.279a
200m	0.067abc	0.034a	0.106b	0.118ab	0.276b	0.194b
300m	0.073ab	0.031ab	0.111b	0.104bc	0.266bc	0.194b
400m	0.058bc	0.028ab	0.083c	0.090cd	0.250cd	0.212b
500m	0.064abc	0.024ab	0.072cd	0.092cd	0.247cd	0.163c
600m	0.046cd	0.030ab	0.062cde	0.081de	0.257bcd	0.136d
700m	0.035de	0.019ab	0.062cde	0.075de	0.257bcd	0.162c
800m	0.033de	0.020ab	0.051def	0.067e	0.238d	0.086e
900m	0.026def	0.017ab	0.046ef	0.060ef	0.146e	0.061f
1km	0.018ef	0.016ab	0.029fg	0.040f	0.094f	0.028g
NMDPRA (2021)	0.01-0.10	0.001-0.01	0.10-1.00	0.30 – 1.00	0.01-1.00	0.10-5.00

Table 1 showed the results of mean metals concentrations in surface water for distances of investigations. All heavy metals studied were found present in the surface water samples for the period of investigations.

Lead concentrations in surface water were between 0.011 to 0.083 mg/L at the various distances. In terms of distance, the peak concentration of 0.083 mg/L was found at 100 meters, and lowest, 0.018 mg/L, was at 1 kilometer. These variations are attributed to the flow of water upstream and downstream of the site, with higher concentrations expected near the tank farm and jetty where petroleum products are discharged. The lead levels in surface water are likely linked to activities around the tank farms, particularly observed leakages during barge discharges.

Lead concentrations decreased as the distance from the tank farms increased, although exceptions were noted at 300 and 500 meters, where levels were unexpectedly higher than at 100, 500, and 700 meters. Overall, lead levels at all sampling points exceeded the control, which had a concentration of 0.011 mg/L. The measured lead values were below targeted range of 0.01 - 0.10 mg/L set by NMDPRA in Nigeria. Parametric analysis indicated significant differences between the controls and various distances, suggesting that surface water closest to the tank farms is more contaminated.

Cadmium concentrations in the surface water around the Oghareki tank farm ranged from 0.160 - 0.034 mg/L for the distances respectively. Cadmium concentrations levels were above the NMDPRA (2021) targeted of 0.001 to 0.01 mg/L and the control, indicating contamination. Cadmium concentrations decreased with increase in distance from the tank farms, except at 200, 600, and 800 meters, where levels were unexpectedly elevated compared to 100, 500, and 700 meters. Statistical analysis confirmed significant differences between distances indicating contamination, although inter-distance comparisons showed similar contamination levels across distances. The presence of cadmium is likely due to activities around the tank farms, including leakages during petroleum product discharges, untreated effluent discharges, and local practices such as washing with detergents and defecation in the water. Cadmium is a priority pollutant that poses ecological and toxicological risks to marine organisms,

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accumulating in the environment and causing physiological alterations in fish (Ju-Wook et al., 2023). High cadmium levels could lead to serious health conditions in humans, including kidney toxicity and bone diseases (Upadhyay, 2022), and have been linked to increased cancer risks (Khushbu et al., 2022).

Iron concentrations in the surface water ranged from 0.040 to 0.129 mg/L for distances of investigation, respectively. 100 meters from the tank farms recorded the highest concentration, while the lowest was at 1 kilometer. Iron levels generally decreased with distance from the tank farms, except at 500 meters, which had higher levels than 400 meters. The iron concentrations were within the NMDPRA (2021) target range of 0.30 to 1.00 mg/L. Statistical analysis indicated a significant difference between distances and the control site, suggesting contamination due to local activities such as untreated effluent discharges and petroleum product leakages.

Copper concentrations in surface water surrounding the tank farms were in the range of 0.180 - 0.249 mg/L for the various distances. Copper levels decreased with increasing distance from the tank farms, indicating significant contamination. All measured copper concentrations exceeded those at the control site but remained within the NMDPRA (2021) maximum value of 1.00 mg/L. Inter-distance comparisons showed significant differences in contamination levels, except between 400 and 500 meters and 600 and 700 meters. Copper is regarded as an essential nutrient at low levels but could be toxic to aquatic life at higher concentrations, leading to adverse health issues in humans, including Wilson's disease (Kochanek, 2019).

Zinc concentrations in the surface water ranged from 0.028 to 0.279 mg/L for different distances. The lowest concentration was recorded at 1 kilometer, while the highest was at 100 meters. Zinc levels generally decreased with distance, although some increases were noted at 400 and 700 meters, indicating random contamination. All zinc concentrations exceeded those at the control site but remained within the NMDPRA target range of 0.1 to 5.00 mg/L. Statistical analysis revealed significant differences between distances and the control, indicating contamination.

Nickel concentrations in the surface water ranged from 0.029 to 0.137 mg/L for different distances. The highest concentration was found at 100 meters, while the lowest was at 1 kilometer. Nickel levels generally decreased with distance, except at 300 meters, which was higher than at 200 meters. Although nickel concentrations were within the NMDPRA target range of 0.10 to 5.00 mg/L, they were higher than those of the control, indicating contamination. Statistical analysis revealed significant differences between distances, with no significant difference between 200 and 300 meters or 600 and 700 meters.

Figure 1 below details the comparative distributions of heavy metals in the surface water of the Oghareki community around tank farms. For all the distances of investigation, copper was observed to be in abundance, followed by zinc, while cadmium was the least.

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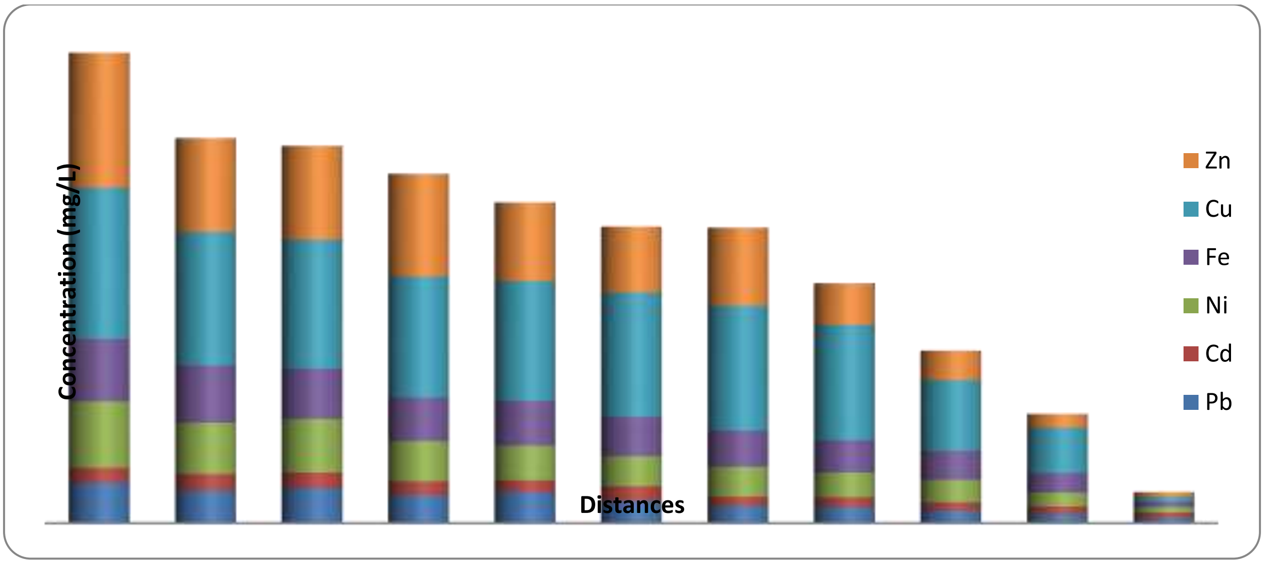
Figure 1: Comparative distribution of heavy metals in surface water surrounding the tank farms in the Oghareki community



The concentration of metals in the surface water for both the distances of investigations followed the order: Cu>Zn>Ni>Fe>Pb>Cd.

Table 2: Correlation between heavy metals in the surface water of the Oghareki community

	Pb	Cd	Ni	Fe	Cu	Zn
Pb	1					
Cd	0.786	1				
Ni	0.833	0.778	1			
Fe	0.757	0.759	0.977	1		
Cu	0.687	0.522	0.775	0.723	1	
Zn	0.713	0.574	0.861	0.819	0.865	1

Table 2 illustrates the relationship between heavy metals concentrations detected in the surface water. The findings reveal a strong positive correlation among the heavy metals. Lead exhibited high correlation with cadmium (0.786), nickel (0.83), iron (0.76), copper (0.69), and zinc (0.71), with copper showing the lowest correlation. Cadmium had a strong correlation with nickel (0.78) and iron (0.76), while its correlation with copper (0.52) and zinc (0.57) was lower but still positive. Nickel was highly correlated with iron (0.88), copper (0.78), and zinc (0.86). Iron also showed a strong correlation with copper (0.72) and zinc (0.87), while copper correlated with itself at 0.87. These strong correlations among the heavy metals suggest that the contamination of surface water is not solely due to inputs from a specific area. Instead, it is influenced by various anthropogenic activities in the vicinity, such as bunkering, industrial effluent discharges, and domestic waste disposal along the banks of the water body, which can enter the water during rainfall and erosion.

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Table 3 Principal Components of heavy metals in surface water around tank farms in Oghareki community

	Principal 1	Principal 2	Principal 3	Principal 4
Pb	0.407	0.279	0.683	-0.465
Cd	0.375	0.657	-0.067	0.572
Ni	0.438	0.026	-0.129	-0.232
Fe	0.422	0.053	-0.616	-0.169
Cu	0.39	-0.542	0.329	0.581
Zn	0.413	-0.439	-0.157	-0.191
Eigen value	4.788	0.61	0.249	0.159
Proportion	0.798	0.102	0.042	0.027

Table 3 presents results of principal components analysis of heavy metals that significantly contribute to the contamination of surface water around the tank farms. The metals analyzed—nickel, iron, zinc, lead, copper, and cadmium - account for 44%, 42%, 41%, 41%, 39%, and 38% of the pollution, respectively. Nickel is the largest contributor, while cadmium is the smallest.

Table 5: Pollution load index of heavy metals in surface water around tank farms in Oghareki community

Distance	Pollution load index
100m	0.126
200m	0.107
300m	0.105
400m	0.093
500m	0.086
600m	0.079
700m	0.071
800m	0.060
900m	0.054
1km	0.031
Mean	0.078

Tables 5 present the pollution load indices (PLI) by heavy metals in surface water, categorized by month and distance. For the surface water, the pollution load by heavy metals ranged from 0.031 to 0.126 with average of 0.078

Pollution load by the heavy metals for both soil and surface water was notably higher near the tank farms, indicating significant contamination at these locations. Additionally, the PLI was greater during rainy season compared to dry season, which is likely due to the dilution of contaminants by increased rainfall.

Overall, the pollution loads by the heavy metals were all below 1.00. Contamination levels are classified as follows: 0, 1, 3, 4, 5 and 6 for none, medium, moderate, strong, strongly polluted

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and very strongly polluted respectively. The findings indicated very slight contamination, as all values were below 1 although above 0.

It is important to recognize that prolonged accumulation of contaminants in surface water can disrupt aquatic life and the food chain, leading to ecosystem imbalances. Consuming contaminated water poses health risks, including cancer and organ damage, while polluted water can negatively impact recreational activities, tourism, and industrial processes, resulting in economic losses. Elevated PLI levels can lead to loss of biodiversity, environmental degradation, and adverse impacts on water and soil quality, as well as human health and the economy (Verla et al., 2017). To manage these effects, it is crucial to regularly monitor PLI values, implement pollution control measures, and develop and enforce regulations aimed at minimizing pollution while promoting sustainable practices

Table 6: Enrichment factor of heavy metals in surface water around tank farms in Oghareki community

Distances	Pb	Cd	Ni	Fe	Cu	Zn
100m	0.64	80.10	10.60	1.00	1.86	0.43
200m	0.57	96.05	8.98	1.00	1.80	0.33
300m	0.70	99.36	10.67	1.00	1.97	0.37
400m	0.64	103.70	9.22	1.00	2.14	0.47
500m	0.70	86.96	7.83	1.00	2.07	0.35
600m	0.57	123.46	7.65	1.00	2.44	0.34
700m	0.47	84.44	8.27	1.00	2.63	0.43
800m	0.49	99.50	7.61	1.00	2.73	0.27
900m	0.43	94.44	7.67	1.00	1.87	0.20
1km	0.62	133.33	7.25	1.00	1.81	0.14
Mean	0.58	100.13	8.57	1.00	2.35	0.33

The average concentrations of enrichment factors in surface water are as follows: 0.59 for lead (Pb), 100.13 for cadmium (Cd), 8.57 for nickel (Ni), 1.00 for iron (Fe), 2.35 for copper (Cu), and 0.33 zinc (Zn). The findings indicate that in the surface water, cadmium is also the most enriched metal, with value 93.80. Nickel (8.57) and copper (2.35) also exceed one (1.00), while lead and zinc are both below one (1.00), and iron remained at one (1.00).

Overall, the surface water surrounding the petroleum tank farms exhibit significant enrichment in cadmium. The enrichment factors, being substantially greater than one, suggest that the contamination originates from sources other than the local background levels of surface water, likely due to anthropogenic or natural influences. High enrichment values in water can lead to issues such as eutrophication, toxicity, and significant alterations in water chemistry (Al-Dahar et al., 2023).

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Table 7: Chronic daily intake (CDI) of heavy metals in surface water around tank farms in Oghareki community

Distance	Pb x 10^{-3}	Cd x 10^{-3}	Ni x 10^{-3}	Fe x 10^{-3}	Cu x 10^{-3}	Zn x 10^{-3}
100m	2.37	1.00	3.91	3.69	8.90	8.00
200m	1.91	0.97	3.03	3.37	7.89	5.50
300m	2.09	0.86	3.17	2.97	7.60	5.50
400m	1.66	0.80	2.37	2.57	7.10	6.10
500m	1.83	0.69	2.06	2.63	7.00	4.70
600m	1.31	0.86	1.77	2.31	7.30	3.90
700m	1.00	0.54	1.77	2.14	7.30	4.60
800m	9.43	0.57	1.46	1.91	6.80	2.50
900m	7.43	0.49	1.31	1.71	4.20	1.70
1km	5.10	0.46	8.29	1.14	2.70	0.80
Mean	3.41	0.73	2.91	2.44	5.95	4.33

Table 8: Hazard quotient of heavy metals in surface water around tank farms in Oghareki community

Distance	Distance	Pb x 10^{-3}	Cd x 10^{-3}	Ni x 10^{-3}	Fe x 10^{-3}	Cu x 10^{-3}	Zn x 10^{-3}
100m	**100**	237.00	332.00	196.00	12.30	6.90	2.70
200m	**200**	191.00	324.00	152.00	11.20	6.10	1.20
300m	**300**	209.00	295.00	159.00	9.90	5.80	1.20
400m	**400**	166.00	267.00	186.00	8.57	5.50	20.00
500m	**500**	183.00	229.00	103.00	8.76	5.40	16.00
600m	**600**	131.00	286.00	88.60	7.71	5.60	13.00
700m	**700**	100.00	181.00	88.60	7.14	5.60	15.00
800m	**800**	94.00	190.00	72.90	6.38	5.20	8.00
900m	**900**	74.00	162.00	65.70	5.71	3.20	5.80
1km	**1000**	51.00	152.00	41.40	3.80	2.10	2.70
Mean	Total	1436	2481	1153	81.47	51.40	85.60

Table 9: Incremental lifetime cancer risk (ILCR) of heavy metals in surface water around tank farms in Oghareki community

Distance	Pb x 10^{-4}	Cd x 10^{-4}	Ni x 10^{-4}
100m	0.201	0.627	0.978
200m	0.162	0.612	0.758
300m	0.178	0.558	0.793
400m	0.141	0.504	0.593
500m	0.156	0.432	0.515
600m	0.111	0.540	0.443
700m	0.085	0.432	0.443
800m	0.080	0.360	0.365
900m	0.063	0.306	0.328
1km	0.043	0.288	0.207
Total	0.122	0.476	0.542

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The calculated mean CDI values are 6.53 (Pbx10^{-4}), 0.66 (Cdx10^{-4}), 9.26 (Nix10^{-4}), 49,330 (Fex10^{-4}), 580.90 (Cux10^{-4}), and 4,256 (Znx10^{-4}), with THQ values of 1.930 (Pb), 1.40 (Cd), 0.465 (Ni), 70.465 (Fe), 5.809 (Cu), and 14.287(Zn).

The THQ values were utilized to estimate non-cancer risk for individuals living around the tank farms who may consume contaminated food over their lifetime. Values greater than one indicate a potential risk. The findings of this study suggest that consuming water contaminated with these pollutants could lead to various health issues, including neurological effects that harm the brain and nervous system; reproductive and developmental effects that impact fertility and child development; respiratory issues affecting the lungs and airways; cardiovascular problems that may damage the digestive system, liver, and kidneys; immunological effects that weaken the immune system; endocrine disruption affecting hormonal balance; dermal effects causing skin irritation; ocular effects leading to eye irritation or vision changes; and renal effects resulting in kidney disease or damage.

For the surface water, the mean ILCR values for heavy metals were as follows: 0.122 (Pb x10^{-4}), 0.476 (Cdx10^{-4}) and 0.542 (Nix10^{-4}). These calculated ILCR values were utilized for cancer risk assessment. All ILCR values for both surface water and soil, across different months and distances, exceeded 1.0x10^{-6} (USEPA, 1997), indicating a significant cancer risk for nearby residents. It is important to recognize that the ILCR can have widespread implications, affecting individuals, communities, and society at large. By understanding ILCR, we can better address cancer risks and strive to create a healthier living environment.

CONCLUSION

The surface water around the tank farms in Oghareki community is contaminated with heavy metals, posing potential health risks to individuals consuming the water. The findings suggest that the contamination is likely due to anthropogenic activities, including petroleum product leakages and industrial effluent discharges. Regular monitoring and mitigation measures are necessary to minimize the impact of heavy metal pollution on human health and the environment

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