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HUMAN HEALTH RISK ASSESSMENT OF SELECTED HEAVY METALS IN SOIL SURROUNDING TANK FARMS IN OGHAREKI-OGHARA, DELTA STATE, NIGERIA

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ABSTRACT: *This study investigated the levels of selected heavy metals in the soil surrounding tank farms in the Oghareki community of Delta State, Nigeria. The objectives were to assess the concentrations of volatile organic compounds (VOCs), total petroleum hydrocarbons (TPHs), oil and grease (O and G), selected heavy metals in soil considering variations over distances from the tank farms, and, additionally, human health risks models to estimate the chronic daily intake (CDI), hazard quotient (HQ) and incremental lifetime cancer risk (ILCR) for the local population around the study location. Soil samples were collected at distances ranging from 100 meters to 1 kilometer from the tank farms. Each sample was analyzed for heavy metals using an Atomic Absorption Spectrophotometer (AAS). The data obtained were presented as mean values from triplicate analyses. Results for contaminants in soil, that is, Pb levels, ranged from 9.35–(16.69±1.56) mg/kg; Cd from 9.121±1.050 mg/kg; Fe from 305.08±5.610 to 554.50±7.583 mg/kg; Cu from 5.08±0.520 to 10.919±1.482 mg/kg; and Zn from 2.128±0.610 to 5.118±1.284 mg/kg, based on distance of sampling. The chronic daily intake, hazard quotient and incremental lifetime cancer risk indices were notably high in the soil. Comparisons with control samples indicated that the soil around the tank farms were contaminated with heavy metals, although the results remained within the acceptable limits set by the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) for soil in Nigeria.*

KEYWORDS: Heavy metals, pollution, concentration, contaminant, distance.

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INTRODUCTION

Soil pollution is a form of land degradation resulting from human-made chemicals or changes to the virgin environmental soil. Concerns regarding soil contamination arise from human health risks associated with direct or indirect contact with already contaminated soil, exposure to vapors in these pollutants, and the potential for contamination with secondary supplies of water within or beneath the soil (Münzel *et al.*, 2023). Mapping contaminated soil sites and conducting cleanups is a time-consuming and costly process. It demands a high level of expertise in chemistry and computer modeling, along with a solid understanding of the history of industrial chemistry (Gretchen & Marinus, 2019). In developed countries, the scope of contaminated or polluted soil is well-documented, and many have established legal frameworks to address this environmental issue. In contrast, developing countries often have less stringent regulations, even though some have experienced considerable industrialization (Khan *et al*., 2015). The rapid pace of development or industrialization has led to an increase in man's activities, like industrial production, agriculture and urbanization. As a result, a substantial concentration of anthropogenic contaminants that is of organic source and pollutants are released into the surroundings, particularly in soil and water. These soils and rivers frequently experience heightened levels of micropollutants/contaminants stemming from natural processes and anthropogenic activities (Li *et al.*, 2017).

Tank farm is a site containing many aboveground storage tanks (ASTs), used primarily for the bulk storage of chemicals and fluids, like water, oil, or even jet fuel. They are also used for substances like the acids used in many manufacturing processes. In the oil and gas industry, tank farms may be referred to as oil terminals or oil depots. Tank farms generally consist of a series of storage tanks, usually ASTs and gantries—structures used to discharge substances for transport. Gantries are often bridge-like structures that allow for discharge of the substance into shipping vessels like barges or tanker trucks (Chen *et al*., 2022). Tank farms are most commonly associated with oil and gas, as these are flammable, hazardous substances that are stored as liquids and are used throughout the country for fuel for a variety of applications. Tank farms are often located at the source of extraction for fuel oils or at the ends of pipelines. Tank farms, due to the nature of their operations, can be significant sources of various pollutants. The aim of this research is to study selected heavy metals in soil surrounding tank farms in Oghareki-Oghara, Ethiope West Local Government Area of Delta State in Nigeria. The specific objectives are to determine the presence/concentrations of selected heavy metals in the soil surrounding tank farms in Oghareki-Oghara, Delta State, taking into account variations by distance from the tank farms, and to analyze human health risks by calculating the chronic daily intake, hazard quotient, total hazard quotient, and the incremental lifetime cancer risk of the selected heavy metals with respect to population living near tank farms in Oghareki-Oghara, Delta State.

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Study Location

This research was carried out at Oghareki–Oghara community located at Ethiope West Local Government Area in Delta State of Nigeria. Oghareki-Oghara is situated at Latitude 5°57'2"N and Longitude 5°38'25"E.

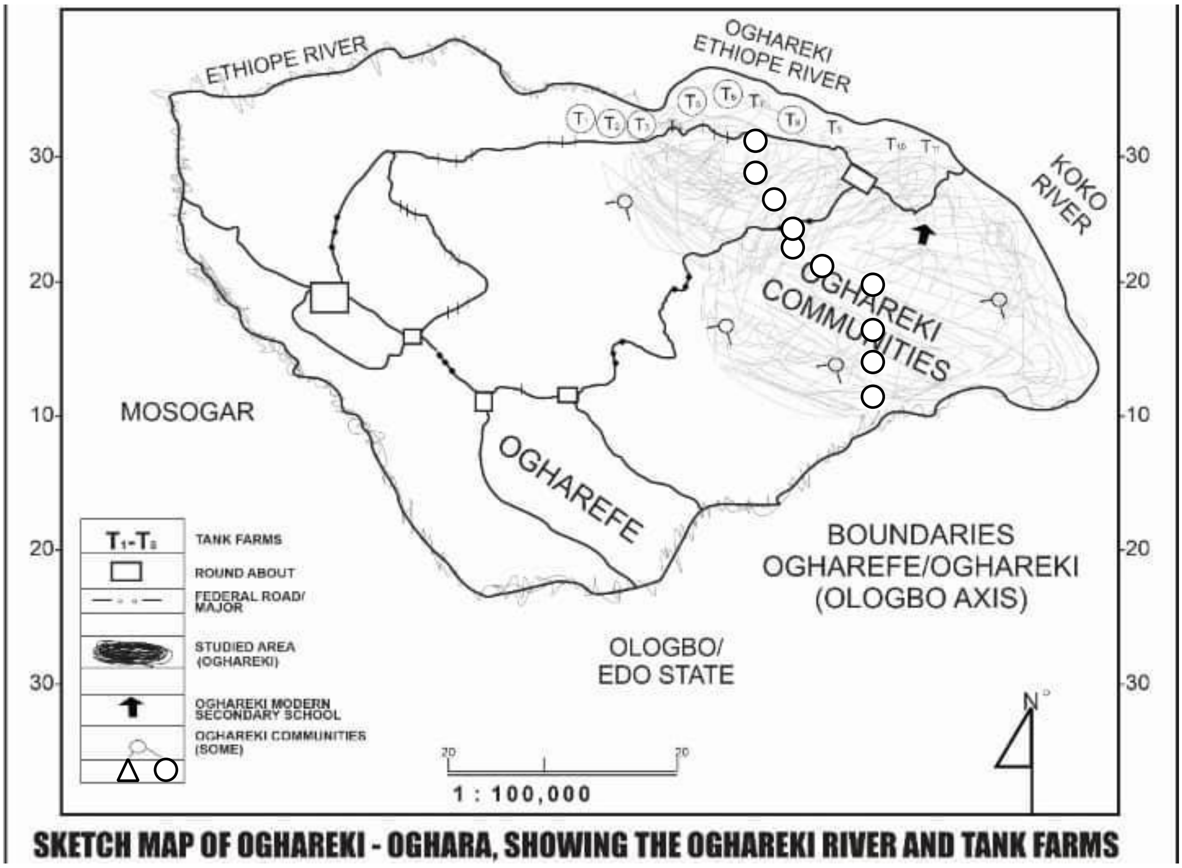

Figure 3.1: Map of Oghara showing study locations

Key: T_1 - Rain Oil; T_2 - Cybernetics Oil and Gas; T_3 - Dutchess Energy; T_4 - Nepal Oil and Gas Ltd; T_5 - Othiel Brooks Energy; T_6 - Prudent Energy and Gas; T_7 - Black Light Energy, and T_8 - Frado Energy Ltd.

Collection of Soil Samples

Soil samples were collected from ten points, ranging from 100 meters to 1 kilometer (at an interval of 100 meters) from the tank farms, as well as from a control site (pristine farmland that has never been significantly disturbed by human and industrial activities), resulting in a total of eleven locations. Soil samples were collected at depths of 0–15 cm and 15–30 cm by the use of soil auger. Each representative sample was created by mixing soil samples from both depths. The soil samples were put in black polythene bags, labelled and transported to the laboratory for further chemical analyses.

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Extraction of Soil Samples for Heavy Metals Analysis

Soil samples were dried in a hot air oven at 80±10°C for a period of 10 hours, and were then homogenized for the determination of nickel, cadmium, copper, iron, lead and zinc. A 1.0±0.05 g portion of the dried soil was placed in a crucible and ignited in a furnace at a temperature of 500°C for a period of 3 hours. After ignition, the soil samples were cooled in a desiccator and transferred to a 100 mL beaker, where 10 mL of concentrated hydrochloric acid was added, and swirled. The beaker was then placed in a thermostatic water bath at 70°C to 80°C for an hour. The resulting solution was decanted into a 100 mL flask. Next, the residue remaining in the beaker received 10 mL of concentrated HCl together with 70% $HClO_4$, along with some amount of porous beads, and was further evaporated to dryness by a hot plate. The residues in the flask were completely dissolved in a minimal amount of HCl (concentrated). The solution was then transferred to the same volumetric flask that held the previous extracts. Finally, the flasks were filled to the mark with distilled water and kept for heavy metal analysis (Onwukeme & Etienajirhevwe, 2020).

The soil samples, after digestion and extraction, were tested for the concentration of nickel, cadmium, copper, iron, lead and zinc metals by the use of 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. This 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 (Onwukeme & Etienajirhevwe, 2020).

HUMAN HEALTH RISK ASSESSMENTS

Health risks associated with each toxic contaminant were evaluated by quantifying the risk levels, expressed with regards to cancerous and noncancerous risks (Sun et al., 2015). In order to determine these risks from the ingestion, exposure, or inhalation of soil, chronic daily intake of the toxic contaminants were estimated by calculation following modifications by the USEPA (1992).

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 the ingestion rate per time (In this case, 2 g for a given soil was used for an adult.), while BW is the body mass. (70 kg was used for adults.)

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Hazard Quotient (HQ)

This is a metric used for assessing health risks associated with respect to exposure to chemicals or contaminants. It was calculated by the use of the expression below:

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

In this context, HQ refers to the non-cancer hazard quotient, CDI represents the chronic daily intake, and RfD stands for the 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 risk to harmful effects over a lifetime (Salihu et al., 2019).

Incremental Lifetime Cancer Risk (ILCR)

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

$$ILCR = CDI\ x\ CSF$$

In this context, CDI denotes the chronic daily intake while CSF stands for cancer slope factor. Cancer slope factors for lead, cadmium, nickel, TPHs, and VOCs are 0.0085, 6.3, 0.91, 0.138, and 0.0055, respectively (USEPA, 1997).

Table 1: Mean Metal Concentration (mg/kg) in Soil around Tank Farms in Oghareki Community

Distance	Pb	Cd	Ni	Fe	Cu	Zn
Control	0.012k	0.001k	0.002k	0.038k	0.020k	0.093k
100m	16.694a	8.047a	4.593a	554.500a	10.919a	5.118a
200m	15.751b	7.696b	4.338b	530.333b	9.914b	4.882b
300m	14.766c	7.253c	4.043c	511.918c	9.508c	4.501c
400m	13.953d	6.810d	3.653d	461.167d	9.038d	4.209d
500m	13.000e	6.161e	3.263e	436.500e	8.738e	4.012e
600m	11.953f	5.732f	3.078f	409.000f	7.918f	3.610f
700m	11.509g	5.247g	2.867h	381.667g	7.663g	3.169g
800m	10.683h	4.904h	2.894g	372.417h	6.688h	3.029h
900m	10.456i	4.577i	2.112i	353.417i	5.855i	2.583i
1km	9.350j	3.891j	1.566j	305.083j	5.087j	2.128j
NMDPRA	85.00	0.80	35.00	38000	36.00	140.00

The average concentrations of heavy metals in the soil surrounding the tank farms in Oghareki-Oghara community are presented in Table 1 above, which detailed the findings by distance from the tank farms. The heavy metals analyzed were all detected in the surrounding soil. Lead concentrations were found in the range of 9.35–16.69 mg/kg across different distances. Though the lead levels were below the NMDPRA's target value of 85 mg/kg, they were significantly higher than the control measurement of 0.011 mg/kg, indicating soil contamination. Notably, lead contamination decreased with regard to increasing distance from the tank farms, with the

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lowest concentration (9.35 mg/kg) found at 1 km and the highest (16.69 mg/kg) at 100 meters. Statistical analysis affirmed significant differences in lead concentrations among the various distances and control, suggesting that proximity to the tank farms influences contamination levels. The lead contamination in Oghareki community is likely due to anthropogenic activities associated with the tank farms, including petroleum product leaks during discharges, crude oil deposits during transport, emissions from diesel engines, and the use of pesticides. Lead has detrimental health effects, even at low concentrations, with no established safe exposure level. The WHO/FAO targeted value for lead in soil is 100 mg/kg, while the NMDPRA limit is 85 mg/kg. Exposure to lead concentrations above 0.01 mg/kg can be harmful, particularly through contaminated food, leading to neurological damage in fetuses and complications in young children. Lead uptake by plants disrupts enzyme activity and hormonal balance, adversely affecting nutrition and water absorption, resulting in stunted growth and other symptoms.

When plants absorb lead through their roots and leaves, despite it not being a necessary nutrient, it disrupts enzyme activity and hormonal balance, negatively impacting their nutrition and water absorption (Baghel *et al*., 2019). This can result in symptoms such as stunted growth, chlorosis, and root blackening (Busairi & Syahir, 2018). Similar to other stressors, lead toxicity adversely affects the photosynthetic rate, ultimately reducing crop productivity (Sadeghipour, 2017). Since photosynthesis is crucial for plant survival, the accumulation of lead leads to significant consequences, including a decrease in the photosynthetic rate and a halt in chlorophyll synthesis. This disruption affects the Calvin cycle, resulting in a carbon dioxide deficiency that can cause the stomata to close (Khan *et al*., 2015).

Cadmium concentrations in the soil surrounding the tank farms ranged from 3.891–8.047 mg/kg across various distances. The highest concentrations of cadmium were recorded at 100 meters, and lowest were at 1 km. Similar to lead, cadmium concentrations decreased with increasing distance from the tank farms although higher than the control value (0.011 mg/kg), indicating soil contamination. Statistical analysis confirmed significant differences between distances and the control, suggesting random contamination that decreases with distance. Cadmium contamination was attributed to anthropogenic activities at the tank farms, including petroleum product leaks and atmospheric deposition from coal combustion. Cadmium, being a hazardous trace element, can cause learning disabilities and other health issues, even at low concentrations. Its accumulation in agricultural soils raises concerns due to its impact on plant growth and yield.

Iron concentrations in soil surrounding the tank farms ranged from 305.08 to 554.50 mg/kg across various distances. The highest concentration was at 100 meters while the lowest was at 1 km. Iron levels decreased with distance from the tank farms, indicating higher concentrations closer to the source. Although the iron concentrations were within the NMDPRA target value of 35,000 mg/kg, they were significantly higher than the control (0.038 mg/kg), indicating contamination. Statistical analyses confirmed significant differences between various distances and that of the control. The observed differences in iron concentrations can be attributed to the effects of the activities at the tank farms, including improper waste disposal and emissions from diesel engines.

Excessive iron in soil can hinder plant growth because free intracellular iron generates harmful reactive oxygen species. Conversely, when iron is scarce, plants enhance their root iron absorption and mobilize stored intracellular iron for essential proteins (Gretchen & Marinus, 2019). Iron deficiency disrupts various cellular functions in plants, particularly photosynthesis,

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which has a significant iron requirement. Given iron's importance, one might question why plants do not accumulate it in larger quantities to prevent deficiency. However, excessive iron can be detrimental, weakening and ultimately killing plants. Therefore, maintaining balanced iron levels is crucial to avoid both deficiency and toxicity (Naranjo-Arcos & Baue, 2016). In humans, consuming high concentrations of iron on an empty stomach leads to gastrointestinal issues, such as constipation, stomach upset, vomiting, abdominal pain, nausea, and diarrhea (Okoye & Ebiana, 2022). Excessive iron can also result in more severe complications, like inflammation of the stomach lining and ulcers. Additionally, high iron levels inhibit zinc absorption, while extreme concentrations cause organ failure, coma, convulsions, and even death (Ebong *et al*., 2022).

Copper concentrations in soil ranged from 5.080–10.919 mg/kg across various distances. The highest concentration was recorded at 100 meters, while the lowest was at 1 km. Although copper levels were within the NMDPRA target value of 36 mg/kg, they were higher than the control (0.010 mg/kg), indicating contamination. Statistical analysis confirmed significant differences between distances and the control, suggesting random contamination. High and low concentrations of copper in soil, accumulated over time, lead to non-carcinogenic risks, including neurological issues, headaches, and liver disease (Prabhat *et al*., 2019). While copper is essential for agricultural crops, excessive levels pose significant threats to terrestrial ecosystems and the health of both animals and humans (Hussain *et al*., 2022). The bioaccumulation of copper can increase the pollution burden in the soil rhizosphere, compromising the immune systems of humans and ruminants, and leading to neurological problems such as kidney failure, digestive disorders, and heart disease (Akhtar *et al*., 2022). Numerous studies have previously quantified risks associated with consumption of heavy metals, including copper, through contaminated crops. For plants, many heavy metals serve as essential microelements involved in various enzymatic reduction and oxidation processes. However, root nodulation can be inhibited, resulting in a significant decrease in the number of beneficial nodules (Chen *et al*., 2022).

Zinc concentrations in the soil surrounding the tank farms ranged from 2.128–5.118 mg/kg across various distances, while zinc levels were within the NMDPRA target value of 140 mg/kg, but higher than the control (0.011 mg/kg), indicating contamination. Contamination levels decreased with distance from the tank farms, with the highest value at 100 meters and the lowest at 1 km. Statistical analysis confirmed significant differences between distances and the control. The differences in zinc concentrations in soil around the tank farms and the control site can be attributed to human activities occurring at the tank farms. These activities lead to petroleum product leaks and the indiscriminate disposal of waste materials in the surrounding soil. Additionally, pesticides used for fumigation are deposited in the soil, and the discharge of diesel and petrol during illegal "black market" activities further contaminates the area. The emissions from diesel engines used by sand dredgers also contribute to soil pollution, along with other natural phenomena that may affect soil quality. Zinc is crucial for various biological mechanisms and it is an essential trace element for proper growth and reproduction of plants, as well as for the health of animals and humans. However, it can also lead to soil, water, and food chain contamination (Noulas *et al*., 2018). Excessive zinc exposure in plants can result in several toxic effects, disrupting biophysicochemical processes. Zinc toxicity can cause deficiencies in other essential nutrients due to its similar ionic radius, which interferes with their uptake and movement within plants. This disruption can negatively impact photosynthesis, transpiration, and other vital physiological processes (Bankaji *et al*., 2019). As

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one of the most readily available heavy metals in soil, excessive zinc levels can have phytotoxic effects, significantly affecting crop quality and yield, and posing health risks to humans through accumulation via absorption or deposition (Hussein *et al*., 2022).

Nickel concentrations in soil surrounding the tank farms ranged from 1.566–4.590 mg/kg across various distances. Although these levels were within the NMDPRA target value of 35 mg/kg, they were higher than the control (0.010 mg/kg), indicating contamination. Nickel concentrations decreased with distance from the tank farms, with the highest levels at 100 meters and the lowest at 1 km. Statistical analysis confirmed significant differences between various distances and the control. Statistical analysis comparing the distances of investigations to those of the control site revealed a significant difference, indicating contamination or pollution of soils surrounding the tank farms. Further analysis of the inter-distance investigations also showed significant differences, suggesting that the soil contamination is random. These observed differences can be linked to anthropogenic activities in the study area, particularly around the tank farms. Such activities include improper disposal of industrial solid and liquid wastes; atmospheric deposition by tank farm operators; disposal of high metal wastes, gasoline, and sewage sludge; wastewater irrigation; application of fertilizers and pesticides; and emissions from diesel engines used during dredging. These factors can periodically contaminate the soil. Additionally, natural processes can release volatile compounds containing nickel, which may settle in the soil over time. Exposure to nickel poses risks for the general population and employees in the nickel industry, as it can enter the human body through various pathways, including food, water, dermal contact, and inhalation. While nickel is recognized as an essential element for several biological mechanisms, including the healthy growth of animals, plants, and soil and water microbes, excessive amounts can be toxic to flora and fauna. Nickel can impair the photosynthetic function of higher plants, lead to soil fertility degradation, and contribute to chronic diseases in humans (Begum *et al*., 2022). In plants, nickel metabolism is crucial for certain enzymatic activities, helping to maintain proper cellular redox states and various physiological and growth responses (Gupta *et al*., 2017). However, high concentrations of nickel in soil and nutrient solutions can be toxic to most plant species, severely hindering seed germination in many crops (Ahmad & Ashraf, 2011).

The results of this study indicated that iron was the most abundant heavy metal, with concentrations 305.083–554.500 mg/kg, while nickel had the lowest concentrations, ranging from 1.566–4.593 mg/kg. The high levels of iron were consistent with its prevalence in the Earth's crust and specific conditions of the Nigerian soil environment, exacerbated by anthropogenic activities associated with the tank farms.

Table 2: Chronic Daily Intake (CDI) of Heavy Metals in Soil around Tank Farms in Oghareki Community for Distances

Distance	Pb x 10^{-4}	Cd x 10^{-4}	Ni x 10^{-4}	Fe x 10^{-4}	Cu x 10^{-4}	Zn x 10^{-4}
100m	8.80	1.00	13.10	63400	780	5850
200m	8.30	0.90	12.40	60600	708	5580
300m	7.40	0.90	11.60	58500	679	5140
400m	6.90	0.80	10.40	52700	646	4810
500m	6.30	0.70	9.30	49900	624	4590
600m	6.10	0.70	8.80	46700	566	4130
700m	5.60	0.70	8.20	43600	547	3620
800m	5.50	0.60	8.30	42600	478	3460

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900m	5.50	0.50	6.00	40400	418	2950
1km	4.90	0.50	4.50	34900	363	2430
Mean	6.53	0.66	9.26	49330	580.90	4256

Table 3: Hazard Quotient (HQ) of Heavy Metals in Soil around Tank Farms in Oghareki Community for Distances

Distance	Pb	Cd	Ni	Fe	Cu	Zn
100m	0.251	0.200	0.066	9.053	0.780	1.950
200m	0.237	0.180	0.062	8.658	0.708	1.860
300m	0.223	0.160	0.058	8.358	0.679	1.715
400m	0.211	0.140	0.052	7.529	0.646	1.603
500m	0.197	0.140	0.047	7.127	0.624	1.528
600m	0.180	0.140	0.044	6.678	0.566	1.375
700m	0.174	0.120	0.041	6.231	0.547	1.207
800m	0.160	0.120	0.042	6.080	0.478	1.254
900m	0.157	0.100	0.030	5.770	0.418	0.984
1km	0.140	0.100	0.023	4.981	0.363	0.811
Mean	2.222	1.128	0.308	76.881	6.345	15.480

Tables 2 and 3 above present the calculated chronic daily intake (CDI), and total hazard quotient (THQ) of heavy metals in soil, categorized by distances of investigation.

The average CDI values of heavy metals in soil in the distances investigated are 3.41 (Pb x 10^{-3}), 0.73 (Cd x 10^{-3}), 2.91 (Ni x 10^{-3}), 2.44 (Fe x 10^{-3}), 5.95 (Cu x 10^{-3}), and 4.44 (Zn x 10^{-3}), with corresponding THQ values of 1,436 (Pb x 10^{-3}), 2,418 (Cd x 10^{-3}), 1,153 (Ni x 10^{-3}), 81.47 (Fe x 10^{-3}), 51.40 (Cu x 10^{-3}), and 85.60 (Zn x 10^{-3}). The calculated THQ values were used to assess potential non-cancer risks. Values exceeding one indicate a possible lifetime risk for individuals eating food grown and produced from the soil. Among the heavy metals assessed, lead, cadmium, and nickel had THQ values greater than one, suggesting a potential cancer risk, while iron, copper, and zinc had values below one.

Table 4: Incremental Lifetime Cancer Risk (ILCR) of Heavy Metals in Soil around Tank Farms in Oghareki Community for Distances of Investigation

Distances	Pb x 10^{-4}	Cd x 10^{-4}	Ni x 10^{-4}
100m	0.0075	0.1500	11.9200
200m	0.0071	0.1350	11.2800
300m	0.0066	0.1350	10.5600
400m	0.0063	0.1200	9.4600
500m	0.0059	0.1050	8.4600
600m	0.0054	0.1050	8.0100
700m	0.0052	0.9000	7.4600
800	0.0048	0.9000	7.5500
900m	0.0047	0.7500	5.4600
1km	0.0042	0.7500	4.1000
Total	0.0058	0.4050	8..426

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Table 4 above presents the calculated mean incremental lifetime cancer risk (ILCR) of heavy metals in soil based on various distances of investigation. The ILCR values were 0.0580 (Pb x 10^{-4}), 4.050 (Cd x 10^{-4}) and 84.26 (Ni x 10^{-4}). These calculated ILCR values were utilized for cancer risk assessment. All ILCR values for soil, across different distances, exceeded 1.0 x 10^{-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

Soils around the Oghareki-Oghara community were found to be contaminated with heavy metals. Analyses results indicated that the tank farms have adversely affected the soil with contamination levels significantly higher than those in the control sites that are either unaffected by such activities or located farther from the tank farms. Statistical analysis revealed significant differences amongst the contamination levels in the soil compared to the control samples, indicating contamination. In some instances, the analysis results exceeded targeted values established by NMDPRA. Results of calculated health risk showed that occupants around the study location may be susceptible to cancer risk if they continue to consume food from the nearby soil.

Planting in soil is essential for life, making it crucial to manage it effectively for a sustainable future. We must explore global scientific methods and techniques to address the issues of contaminated soil. As individuals, we need to reflect on the impact of our actions and strive to enhance the quality of soil. Tank farms should be located in non-residential areas to mitigate pollution, even though this does not completely eliminate the problem. Strict measures must be implemented to control leaks into the soil during transportation and storage. Bunkering has become prevalent and should be actively discouraged, as it significantly contributes to soil pollution. New strategies on pollution management, such as improvement on wastewater treatment, adopting sustainable agriculture, regulating industrial discharges, implementation of green infrastructure, remediation of contaminated soil sites, sustainable land use, and possible prevention of soil pollution should be ensured.

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