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Health Risks of Potentially Toxic Metals (PTMs) in Soil and Water of Agbara Industrial Estate

[1]Usikalu M. R., [1]Olawole O. C., [1]Soyinka B. A. [2]Orosun M. M. and [1,3]Ojo O. F

[1]Department of Physics, Covenant University, Ota, Ogun State Nigeria

[2]Department of Physics, University of Ilorin Kwara State

[3]Ekiti State University, Ado-Ekiti

ABSTRACT

The presence of potentially toxic metals (PTMs) in soil and water is of great concern to the public health, agriculture and environmental health because of their toxicity. This study was carried out to examine the concentration of ten PTMs (Mn, Fe, Zn, Ni, Se, Cd, Co, Cr, Cu, Pb) in soil and water within Agbara Industrial Estate. The samples were analysed for PTMs concentration using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The analysis revealed that the mean concentration of the analysed PTMs in water vary in the following order: Fe > Zn > Se > Mn > Pb > Ni > Cr > Co > Cu > Cd. The concentration of Mn, Cu, Ni, Se, Co, Pb and Cr in water samples were above the WHO set limit while the concentration of Fe, Zn and Cd were below the set limit. The concentration of the heavy metals in soil ranges from 6.097 to 40.676 mg/kg for Mn, 242.91 to 317.87 for Fe, 0.272 to 1.014 for Cu, 0.337 to 30.551 for Zn, 0.060 to 0.289 for Ni, 0.257 to 0.989 for Se, 0.098 to 0.341 for Co, 0.074 to 15.644 for Pb, 0.105 to 0.378 for Cd to 13.74mg/kg. The estimated daily intake (EDI) peaked at 5.1×10^{-8} and 2.5 for Fe in soil and water samples respectively, and minimum of 1.2×10^{-11} (Ni) and 0.003 (Pb) in soil and water samples respectively. The EDI from the soil samples falls at extremely low risk level and are therefore within acceptable range. The EDI for water samples however is at the extremely high-risk level, implying quick solution to avoid any health hazards. The minimum carcinogenic risk of 0.0099 was observed for Cd in the water samples and 1.9×10^{-12} for Ni in soil samples, with the maximum risk of 10.4 and 10×10^{-9} recorded for Fe in water and soil samples respectively. The carcinogenic risk from the soil samples is at extremely low risk level and are therefore within acceptable range. The mean carcinogenic risk from water samples for Mn, Fe, Cu, Zn, Ni, Se, Co and Cr falls within the high-risk level which requires immediate attention for proper action. The carcinogenic risk from water samples for Cd and Pb are within the extremely high-risk level which implied that fast action be taken to avoid health hazards. The study revealed that water from the Agbara Industrial Estate is associated with potential health risk and may not be suitable for consumption which calls for immediate attention and thereby recommend prompt sensitization of the people within this study area on the hazard level.

Keywords: Heavy metals, Carcinogenic and non-carcinogenic risk, Water, Agbara Industrial Estate

INTRODUCTION

Potentially toxic metals (PTMs) commonly referred to as heavy metals (HMs) are a group of metallic elements that are relatively five times denser (5 g/mol) when compared with water (Singh and Steinnes, 2020). They are characterized by their atomic weight which is higher than 5 g/mol, they are highly soluble in water; hence living organisms can easily ingest them while drinking water. Heavy metals can be beneficial as well as harmful to living organisms depending on their level of concentration (Usikalu *et al*., 2021; Orosun *et al.,* 2022). They pose a major health and environmental risk if not properly managed. The presence of heavy metals in soil poses a potential threat to the environment and can cause deterioration of human health when they find their way into the human system through various pathways such as inhalation, dermal contact and direct ingestion (Lu *et al*., 2011; Hoang *et al*., 2021). The presence of these toxic nuclides in the body system can result in serious health issues like cancer, damaging important body organs and it can result in death in some cases (Orosun *et al*., 2023). The dose, genetics and route of exposure are some of the factors on which the toxicity of heavy metals depends. When the reference value of heavy metals is exceeded, it has deleterious effects on humans and the ecosystem (Mansourri and Madani, 2016). They can be found normally in the earth's crust and their presence in soil, water and air can vary depending on geological factors. Also, various industrial activities like mining, smelting and manufacturing can release some level of heavy metals into the environment. Other sources of heavy metals in the surroundings include; natural weathering of the earth's crust, soil erosion, and application of disease or insect control material to the crops and industrial effluent (Morais, 2012). They are major environmental pollutants, some of the heavy metals majorly found in wastewater include; arsenic, cadmium, chromium, nickel, lead, zinc and copper all of which may cause health risks for humans and the environment if in high level (Lambert *et al*., 2000).

Cadmium is a very toxic metal, it can cause serious health problems, such damage to the kidney, respiratory tract challenges, and cancer. It can accumulate in the body over time, leading to long-term health effects (Genchi *et al*., 2020); Arsenic is a well-known carcinogen and can cause a range of health problems, including skin lesions, cancer (lung, skin, bladder, and liver), cardiovascular diseases, and developmental effects (Palma-Lara *et* al.,2020); Chromium exists in several oxidation states, with hexavalent chromium (Cr(VI)) being the most toxic. It is known to cause lung cancer when inhaled and has been linked to other health issues, including liver and kidney damage (Ukhurebor *et al.,* 2021); Nickel is a known carcinogen, primarily associated with lung cancer. Long-term exposure to nickel can also lead to skin allergies and asthma-like respiratory problems (Prueitt *et al*., 2020).

Lead is a highly toxic metal that can cause serious health effects, especially in children. It can affect the nervous system, leading to developmental delay, behavioural issues, and reduced intelligent quotient. Lead exposure can also cause kidney damage and hypertension in adults (Rees & Fuller, 2020). Zinc is an essential nutrient in small amounts, high levels of zinc in wastewater can be harmful. Excessive zinc exposure can lead to stomach cramps, nausea, and vomiting. Long-term exposure may also affect the immune system and interfere with the body's ability to absorb other essential metals (Rahimzadeh *et al.*, 2020); copper is an essential nutrient, but high levels of copper in water can be harmful. It can cause gastrointestinal issues, such as nausea and vomiting, and long-term exposure may lead to liver and kidney damage (Taylor *et al*., 2020). Also when the permissible threshold of copper is exceeded, it affects the germination and development of plant roots which results in a reduction in the growth of plants (Osobamiro *et al*.,2019, Mir *et al.,* 2021, Cruz *et al*., 2022). Having discovered some of the implications of the high intake of heavy metals through ingestion or inhalation based on some past research work, this study aimed at assessing the concentration of Mn, Fe, Zn, Ni, Se, Cd, Co, Cr, Cu, and Pb in the soil and water of some selected locations at Agbara Industrial Estate to ascertain the safety of humans and the ecosystem of the industrial estate.

STUDY AREA

The study area, Agbara Industrial Estate, one of the largest industrial estates in Sub-Saharan Africa, is situated in Ogun State in the western part of Nigeria with latitude 6.5342 ^{o}N and longitude 3.1256 ^{o}E. It is situated within the coastal plain of Nigeria and characterised by relatively flat terrain. It consists of sedimentary rocks such as sandstone, shale and clay which were deposited millions of years ago. The sedimentary rock usually contains valuable resources such as petroleum, natural gas and groundwater. The industrial estate hosts several companies and industries that release toxic substances into the environment on daily basis in the form of waste. This makes this location suitable for the assessment of heavy metals in the soil and water of the location.

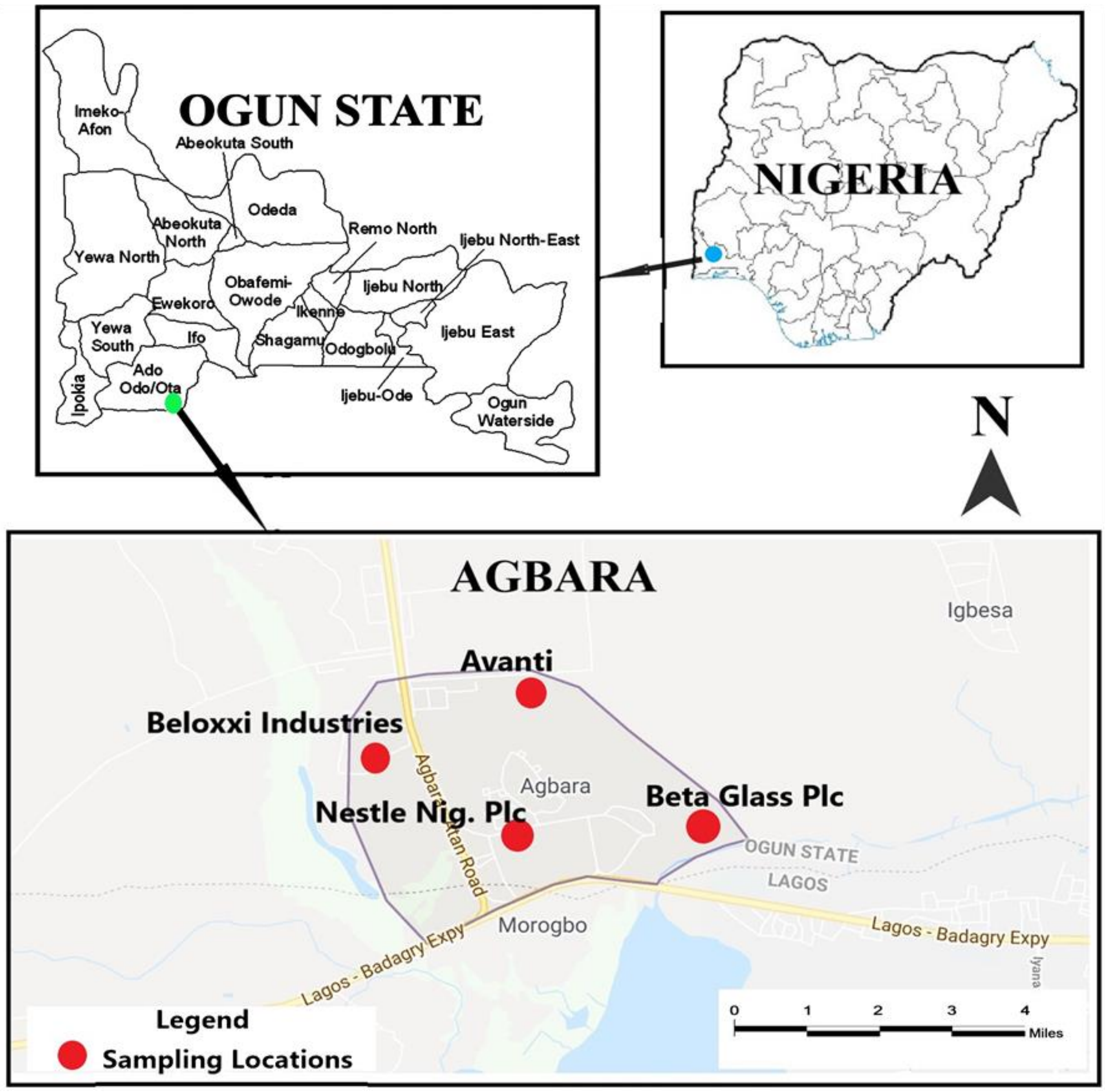

Figure 1: Map of Ogun state showing the study area

MATERIALS AND METHOD

Water and soil samples were collected at ten different sampling points within the Agbara Industrial Estate. Complete dissolution of soil samples was achieved through acid digestion on hot plate at atmospheric pressure. The spectrometric measurement was carried out on the digested samples using inductively coupled plasma mass spectrometry (ICP-MS). The concentrations of Mn, Fe, Cu, Zn, Ni, Se, Co, Pb, Cd, and Cr in the soil samples were analysed using spectrometer in this study. The ICP-MS comprises of six important compartments which include the simple introduction system, inductive coupled plasma, interface, ion optics, mass analyser and the detector as shown in Figure 2. The water samples were nebulised firstly in the sample introduction system in order to create a fine aerosol that was transferred to the coupled plasma. The high temperature plasma atomises and ionizes the sample producing ions which are extracted through the interface region and into the ion optics. The ion optics beams and directs the ion beam into the mass analyser which separates the ions in accordance with their mass-charge ratio and they are determined through the detector point. The analysis results were gotten in ppm and this was later converted to $mgkg^{-1}$ for the evaluation of non-carcinogenic and carcinogenic risk assessment.

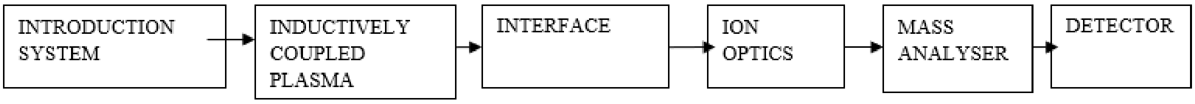

Figure 2: Inductively coupled plasma mass spectrometry

RISK ASSESSMENT DUE TO HEAVY METAL CONCENTRATION

Non-Carcinogenic risk assessment

The non-carcinogenic risk characterization of heavy metals that was estimated includes the estimation of intake daily and the target hazard quotient. The estimated daily intake was evaluated by using equation 1.

$$EDI = \text{Ing}R \times \frac{C}{Bw} \quad (1)$$

where *C* is the concentration of element in $mgkg^{-1}$, *IngR* is the rate of ingestion and *Bw* is the mean of the body weight in kg and it is taken as 70 kg.

The target hazard quotient is the ratio of exposure to the reference dose which is used to express the non-carcinogenic adverse effects of heavy metals in human. The target hazard quotient was calculated using Equation 2.

$$THQ = DIV \times C\ RFD \times B \quad (2)$$

where DIV is the intake of spices daily, *C* is the pollutants concentration, *RFD* is the oral permissible reference dose which is fixed and B is the mean weight of a human body in kg.

Carcinogenic risk assessment

This provides an index of the risk of a particular group developing any type of cancer after exposure to a carcinogen over a given lifetime (Isinkaye, 2018)

Incremental lifetime cancer risk (ILCR) gives the incremental probability of a person developing cancer over certain period due to heavy metals exposure. This was calculated using equation 3.

$$ILCR = EDI \times SF \quad (3)$$

where *EDI* is the daily estimated intake and *SF* is the carcinogenic slope factor. The standard values of some parameters used in evaluation of the human health risk due to exposure is shown in Table 1.

Table 1: Parameters used in evaluating health risk (Ihedioha *et al.*, 2017)

Exposure parameters	Values	SI unit
Rate of ingestion (IngR)	100 in soil 2 in water	mg/day l/day
Frequency of exposure (EF)	365	Day
Duration of exposure (ED)	55	
Mass of the body (Bw)	70	kg
Chronic reference dose (RFD)	Ingestion 3×10^{-3} Inhalation 3×10^{-4}	mg/kg/day
Carcinogenic slope factor (SF)	Ingestion 1.5 Inhalation 1.5×10^{-1}	

RESULTS AND DISCUSSION

Concentration of heavy metals in water sample

The results of the concentration of the ten analysed potentially toxic metals in water samples harvested from various locations are presented in Table 2. The concentration of ten PTMs in water samples were determined and the degree of pollution due to heavy metal was assessed. The analysis revealed that the mean concentration of Mn, Fe, Cu, Se, Pb, Cr, Co, and Ni are above the WHO permissible limit while only Zn and Cd falls below the World permissible limit.

The manganese concentration in the selected water samples ranges from 0.089 mg/l to 0.248 mg/l and the average concentration for the six locations is 0.173 mg/l. Comparing the results with the WHO maximum allowable limit for manganese in water, the mean concentration exceeds the WHO reference limit of 0.02 mg/l. The high concentration of manganese in water may occur due to natural sources such as soil and rock weathering and human activities in the study area such as landfill leaching and industrial discharges. Ingestion of high level of Manganese over a long period of time may result into some health issues such as neurological effects, respiratory issues and liver and kidney damage.

Iron concentration in the selected water samples ranges from 8.76 mg/l to 24.24 mg/l and the mean for the six locations is 13.74 mg/l. Comparing the results with the WHO maximum allowable limit for iron in water, the mean concentration exceeds the WHO permissible limit of 0.3 mg/l. High concentration of iron in the water sample may be attributed to industrial pollution in the area and corrosion of iron pipes in the area. Ingestion of high level of iron may result into some health issues such as increase in oxidative stress and increase in the risk of infection. Copper concentration in the selected water ranges from 0.031 mg/l to 0.054 mg/l and the mean for the six locations is 0.044 mg/l. Comparing the results with the WHO allowable value for copper in water, the average concentration exceeds the WHO reference value of 0.02 mg/l. High intake of copper may result into accumulation within the tissues and gastrointestinal effect (Howell and Gawthorne,1987; Pizaro *et al.*, 1999).

Nickel concentration in the selected water ranges from 0.053 mg/l to 0.13 mg/l and the mean concentration for the six locations is 0.095 mg/l. Comparing the results with the WHO recommended value for nickel in water, the mean exceeds the WHO reference limit of 0.07 mg/l. The concentration of Selenium in the selected water samples ranges from 0.081 mg/l to 0.429 mg/l and the average for the six locations is 0.203 mg/l. Comparing the results with the WHO maximum allowable value for selenium in water, the mean concentration exceeds the WHO reference value of 0.02 mg/l. Cobalt concentration in the selected water ranges from 0.041 mg/l to 0.093 mg/l and the mean for the selected locations is 0.058 mg/l. Comparing the results with the WHO allowable value for cobalt in water, the mean concentration exceeds the WHO reference value of 0.01 mg/l.

Lead concentration in the selected water ranges from 0.009 mg/l to 0.221 mg/l and the mean for the selected locations is 0.115 mg/l. Comparing the results with the WHO allowable value for lead in water, the mean concentration exceeds the WHO reference value of 0.01 mg/l. High concentration of lead in the water sample may be attributed to metal plating, soil waste, factory chimney and exhaust from automobiles (Sharma and Dubey, 2005). Chromium concentration in the selected water ranges from 0.025 mg/l to 0.123 mg/l and the mean for the six locations is 0.074 mg/l. Comparing the results with the WHO maximum allowable limit for chromium in water, the mean concentration exceeds the WHO reference value of 0.003 mg/l.

Table 2: Concentration of heavy metals in water sample (mgl^{-1})

Locations	Mn	Fe	Cu	Zn	Ni	Se	Co	Pb	Cd	Cr
AG1	0.089	8.763	0.046	0.457	0.078	0.429	0.093	0.115	0.023	0.074
AG2	0.184	9.785	0.039	0.506	0.104	0.081	0.041	0.115	0.035	0.025

AG3	0.248	24.240	0.054	0.093	0.104	0.158	0.093	0.115	0.023	0.074
AG4	0.184	21.120	0.031	0.202	0.130	0.120	0.041	0.115	0.023	0.074
AG5	0.152	9.102	0.046	0.397	0.104	0.158	0.041	0.009	0.023	0.074
AG6	0.184	9.444	0.046	0.178	0.053	0.274	0.041	0.221	0.035	0.123
Mean	0.173	13.742	0.044	0.305	0.095	0.203	0.058	0.115	0.027	0.074
WHO	0.020	0.300	0.02	3.000	0.07	0.020	0.01	0.010	0.050	0.003
Min.	0.089	8.763	0.031	0.092	0.053	0.081	0.041	0.009	0.023	0.025
Max.	0.248	24.240	0.054	0.506	0.130	0.429	0.093	0.221	0.035	0.123

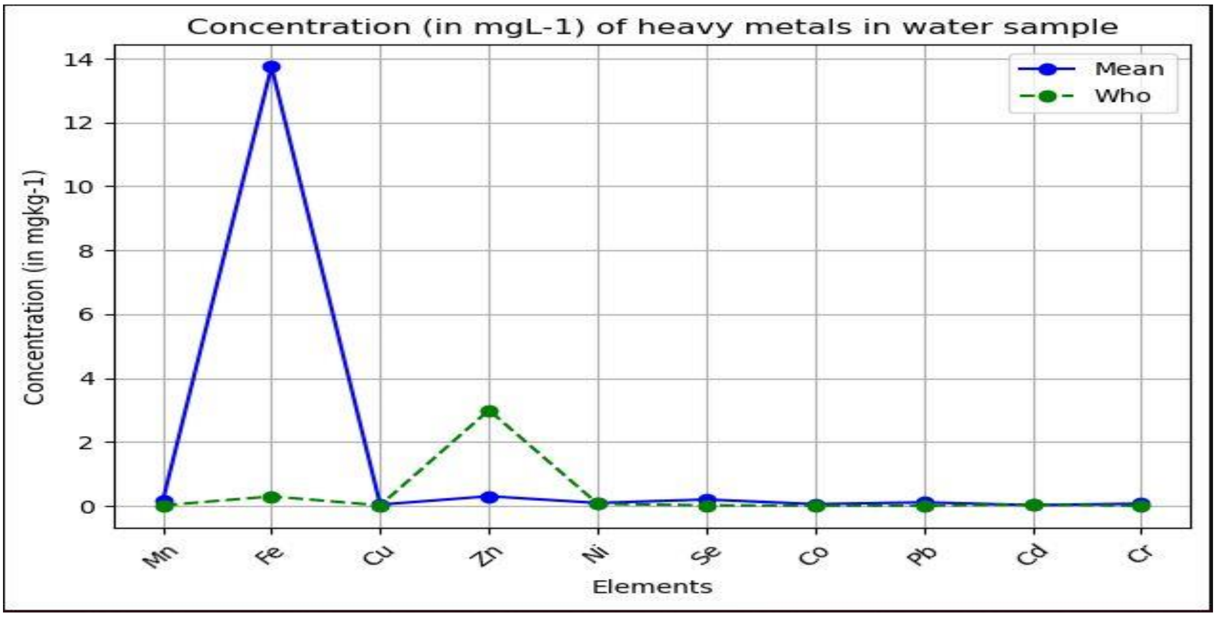

Figure 3: Chart showing the concentration of heavy metals in water

Concentration of heavy metals in soil samples

The results of the concentration of the ten potentially toxic metals (Mn, Fe, Cu, Zn, Ni, Se, Co, Pb, Cd, Cr) analysed in soil samples collected from different locations are shown in Table 3. The average concentration ranges from 0.199 to 288.63 mg/kg. Cobalt has the least concentration while Fe has the highest mean concentration. Comparing the concentration of all the elements with the WHO limit, they are all below the world limit. The results obtained in this study is comparable with other past studies (Ojekunle *et al*., 2023; Aendo *et al*., 2022).

Health Implications of the Estimated Parameters

Tables 4-5 present the assessment of estimated daily intake (EDI) through inhalation and ingestion respectively. The EDI obtained for inhalation ranges from 1.2×10^{-11} to 5.1×10^{-8} while the EDI through ingestion ranges from 0.003 (Pb) to 6.93 (Fe). Table 6 shows the assessment of the target hazard quotient (THQ) and it revealed that the THQ for all the elements are less than one (<1) which is an acceptable threshold set by the United State of Environmental Protection Agency (USEPA) according to Bortey *et al* (2015). Tables 7 and 8 present the result of the carcinogenic risk for the analysed element through inhalation and ingestion respectively. The mean incremental life time cancer risk through inhalation falls at the extremely low risk level ($<10^{-6}$) which is acceptable as they do not pose any cancer risk to humans whereas the mean incremental cancer risk through ingestion for Mn, Fe, Cu, Zn, Ni, Se, Co, and Cr falls at the high risk level which is 5 $x10^{-4}$ to $1x10^{-3}$ while the mean concentration of Pb and Cd are at the extremely high risk level ($>10^{-3}$). Cancer risk at these levels is considered high because they pose higher cancer risk to humans. The high concentration of the PTMs in the water samples may be attributed to the effluent that is being released by the companies and industries around the study area into the water bodies in the environment. Ingestion of water with high concentration of these PTMs may result into health issues for the dwellers in the study area.

Table 3: Heavy metals Concentration in soil (in $mgkg^{-1}$)

Locations	Mn	Fe	Cu	Zn	Ni	Se	Co	Pb	Cd	Cr
AG1	24.261	313.002	0.465	0.337	0.174	0.500	0.219	0.074	0.159	1.474
AG2	14.103	254.935	0.272	0.591	0.060	0.866	0.219	0.074	0.105	0.864
AG3	21.084	294.450	0.817	2.778	0.174	0.378	0.341	1.833	0.214	0.560
AG4	6.458	246.335	0.349	4.950	0.174	0.989	0.098	0.954	0.159	1.372
AG5	6.097	242.905	0.504	3.497	0.231	0.257	0.219	1.833	0.214	1.474
AG6	40.676	317.873	0.407	2.389	0.289	0.621	0.341	3.584	0.379	0.560
AG7	16.886	308.142	0.797	3.497	0.232	0.378	0.219	0.954	0.159	0.661
AG8	32.584	310.792	0.797	21.909	0.232	0.257	0.098	0.954	0.159	1.067
AG9	27.321	300.210	0.465	17.820	0.117	0.866	0.219	0.954	0.269	0.864
AG10	26.848	272.238	0.407	18.231	0.232	0.621	0.219	15.644	0.269	0.966
AG11	12.167	285.743	0.543	30.552	0.232	0.989	0.098	2.710	0.324	1.169
AG12	31.298	316.987	1.014	1.711	0.289	0.500	0.098	1.833	0.214	0.661
Mean	21.649	288.634	0.570	9.022	0.203	0.602	0.199	2.617	0.219	0.974
WHO	437	50000	36	50	35	2	5	85	0.8	100
Max.	40.676	317.873	1.014	30.551	0.289	0.989	0.341	15.644	0.378	1.474
Min.	6.097	242.905	0.272	0.337	0.060	0.257	0.098	0.074	0.104	0.559

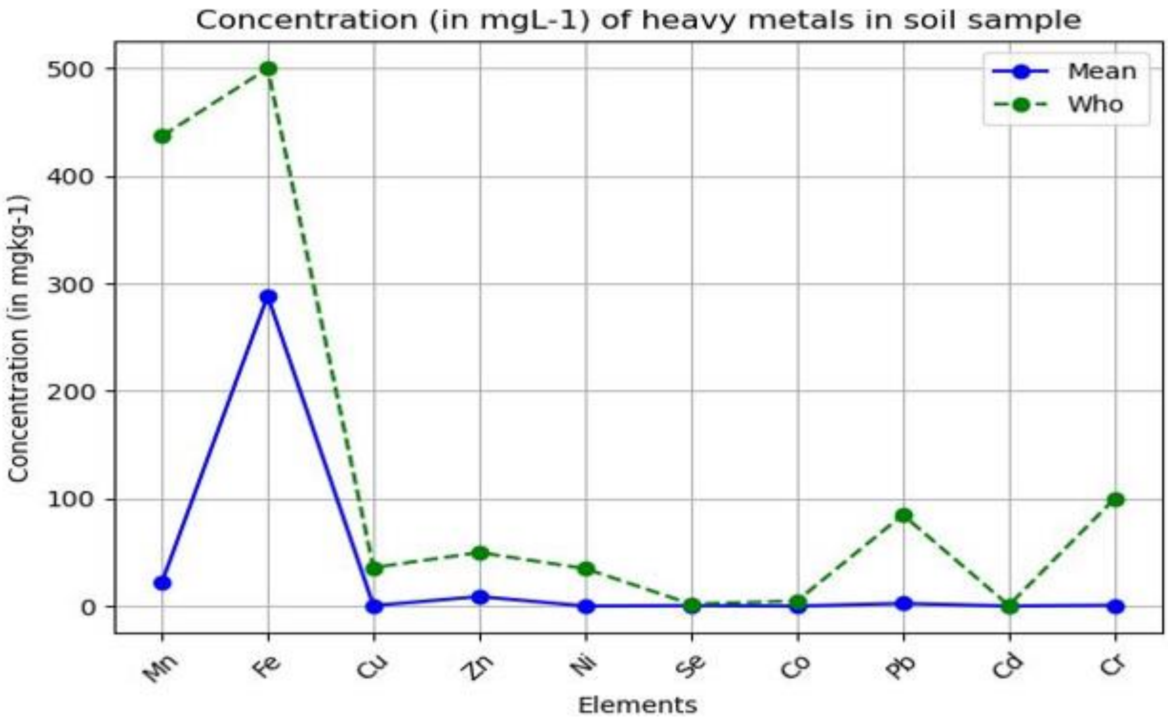

Figure 4: Chart showing concentration of heavy metals in soil

Table 4: Estimated daily intake through inhalation

Locations	$Mn\times10^{-9}$	$Fe\times10^{-8}$	$Cu\times10^{-11}$	$Zn\times10^{-10}$	$Ni\times10^{-11}$	$Se\times10^{-10}$	$Co\times10^{-11}$	$Pb\times10^{-10}$	$Cd\times10^{-11}$	$Cr\times10^{-10}$
AG1	5.097	6.576	9.774	0.709	3.664	1.050	4.603	0.156	3.350	3.096
AG2	2.963	5.356	5.705	1.243	1.264	1.820	4.603	0.156	2.206	1.815
AG3	4.429	6.186	0.172	5.837	3.664	0.795	7.155	3.851	4.498	1.176
AG4	1.357	5.175	7.329	10.399	3.664	2.077	2.049	2.005	3.350	2.883
AG5	1.281	5.103	0.106	7.346	4.867	0.539	4.603	3.851	4.498	3.096
AG6	8.545	6.678	8.550	5.019	6.070	1.305	7.155	7.530	7.960	1.176
AG7	3.547	6.474	0.168	7.346	4.867	0.795	4.603	2.005	3.350	1.389
AG8	6.845	6.529	0.168	46.027	4.867	0.539	2.049	2.005	3.350	2.242
AG9	5.740	6.307	9.774	37.438	2.464	1.820	4.603	2.005	5.648	1.815
AG10	5.640	5.719	8.550	38.300	4.867	1.305	4.603	32.867	5.648	2.029
AG11	2.556	6.003	1.141	64.186	4.867	2.077	2.049	5.692	6.802	2.456
AG12	6.575	6.659	0.213	3.594	6.070	1.050	2.049	3.851	4.498	1.389
Mean	4.550	6.060	0.120	19.000	4.270	1.260	4.180	5.500	4.600	2.050
Min.	1.280	5.100	5.700	0.709	1.260	0.539	2.050	0.1560	2.210	1.180
Max.	8.550	6.680	0.213	64.200	6.070	2.080	7.150	32.900	7.960	3.100

Table 5: Estimated Daily Intake through Ingestion

Locations	Mn	Fe	Cu	Zn	Ni	Se	Co	Pb	Cd	Cr
AG1	0.025	2.504	0.013	0.131	0.022	0.122	0.027	0.033	0.007	0.021
AG2	0.053	2.796	0.011	0.145	0.030	0.023	0.012	0.033	0.010	0.007
AG3	0.071	6.926	0.015	0.027	0.030	0.045	0.027	0.033	0.007	0.021
AG4	0.053	6.034	0.009	0.058	0.037	0.034	0.012	0.033	0.007	0.021
AG5	0.043	2.601	0.013	0.113	0.030	0.045	0.012	0.003	0.007	0.021
AG6	0.053	2.698	0.013	0.051	0.015	0.078	0.012	0.063	0.010	0.035
Mean	0.049	3.930	0.012	0.087	0.027	0.058	0.017	0.033	0.008	0.021
Min	0.025	2.500	0.009	0.027	0.015	0.023	0.012	0.003	0.007	0.007
Max	0.071	6.930	0.015	0.145	0.037	0.122	0.027	0.063	0.01	0.035

Table 6: Target Hazard Quotient

Locations	Mn	Fe	Cu	Zn	Ni	Se×10^{-4}	Co×10^{-3}	Pb×10^{-4}	Cd×10^{-5}	Cr×10^{-4}
AG1	0.238	15.337	0.001	0.007	2.442	1.750	1.534	0.182	1.116	3.095
AG2	0.138	12.492	0.001	0.012	0.843	3.030	1.534	0.182	0.735	1.815
AG3	0.207	14.428	0.002	0.058	2.442	1.320	2.384	4.491	1.499	1.175
AG4	0.063	12.070	0.001	0.104	2.442	3.460	0.683	2.338	1.116	2.882
AG5	0.060	11.902	0.001	0.073	3.243	0.898	1.534	4.491	1.499	3.095
AG6	0.399	15.576	0.001	0.050	4.045	2.170	2.384	8.782	2.652	1.175
AG7	0.165	15.099	0.002	0.073	3.243	1.320	1.534	2.338	1.116	1.388
AG8	0.319	15.229	0.002	0.460	3.243	0.898	0.683	2.338	1.116	2.241
AG9	0.268	14.710	0.001	0.374	1.642	3.030	1.534	2.338	1.882	1.815
AG10	0.263	13.340	0.001	0.383	3.243	2.170	1.534	38.328	1.882	2.028
AG11	0.119	14.001	0.002	0.642	3.243	3.460	0.683	6.638	2.266	2.455

AG12	0.307	15.532	0.003	0.036	4.045	1.750	0.683	4.491	1.499	1.388
Mean	0.212	14.100	0.002	0.189	2.842	2.100	1.390	6.410	1.530	2.050
Min.	0.060	11.902	0.001	0.007	0.843	0.898	0.683	0.182	0.735	1.175
Max.	0.399	15.576	0.003	0.642	4.045	3.460	2.384	38.328	2.650	3.095

Table 7: Incremental Lifetime Cancer Risk through Inhalation

Locations	**$Mn\times10^{-10}$**	**$Fe\times10^{-9}$**	**$Cu\times10^{-11}$**	**$Zn\times10^{-10}$**	**$Ni\times10^{-12}$**	**$Se\times10^{-11}$**	**$Co\times10^{-12}$**	**$Pb\times10^{-11}$**	**$Cd\times10^{-12}$**	**$Cr\times10^{-11}$**
AG1	7.650	9.860	1.470	0.106	5.500	1.580	6.900	0.234	5.030	4.640
AG2	4.440	8.030	0.856	0.186	1.900	2.730	6.900	0.234	3.310	2.720
AG3	6.640	9.280	2.570	0.876	5.500	1.190	10.700	5.780	6.750	1.760
AG4	2.040	7.760	1.100	1.560	5.50	3.120	3.070	3.010	5.030	4.320
AG5	1.920	7.650	1.590	1.100	7.300	0.809	6.900	5.780	6.750	4.640
AG6	12.800	1.000	1.280	0.753	9.110	1.960	10.700	11.300	11.900	1.760
AG7	5.320	9.710	2.510	1.100	7.300	1.190	6.900	3.010	5.030	2.080
AG8	10.300	9.790	2.510	6.900	7.300	0.809	3.070	3.010	5.030	3.360
AG9	8.610	9.460	1.470	5.620	3.700	2.730	6.900	3.010	8.470	2.720
AG10	8.460	8.580	1.280	5.750	7.300	1.960	6.900	49.300	8.470	3.040
AG11	3.830	9.000	1.710	9.630	7.300	3.120	3.070	8.540	10.200	3.680
AG12	9.860	9.990	3.200	0.539	9.110	1.580	3.070	5.780	6.750	2.080
Mean	6.820	9.090	1.800	2.840	6.400	1.900	6.260	8.250	6.890	3.070
Min.	1.920	7.65S	0.856	0.106	1.900	0.809	3.070	0.234	3.310	1.760
Max	12.800	10.000	3.200	9.630	9.110	3.120	10.700	49.300	11.900	4.640

Table 8: Incremental Lifetime Cancer Risk through Ingestion

Locations	**$Mn\times10^{-2}$**	**Fe**	**$Cu\times10^{-2}$**	**$Zn\times10^{-1}$**	**$Ni\times10^{-2}$**	**$Se\ \times10^{-2}$**	**$Co\times10^{-2}$**	**$Pb\times10^{-2}$**	**$Cd\times10^{-3}$**	**$Cr\times10^{-2}$**
AG1	3.810	3.760	1.970	1.960	3.350	18.400	3.980	4.920	9.900	3.170
AG2	7.880	4.190	1.670	2.170	4.460	3.470	1.760	4.920	15.000	1.070
AG3	10.600	10.400	2.310	0.398	4.460	6.770	3.980	4.920	9.900	3.170
AG4	7.880	9.050	1.320	0.864	5.570	5.130	1.760	4.920	9.900	3.170

AG5	6.510	3.900	1.970	1.700	4.460	6.770	1.760	0.390	9.900	3.170
AG6	7.880	4.050	1.970	0.762	2.270	11.700	1.760	9.470	15.000	5.270
Mean	7.430	5.890	1.870	1.310	4.100	8.71	2.500	4.920	11.600	3.170
Min.	3.810	3.760	1.320	0.398	2.270	3.470	1.760	0.390	9.900	1.070
Max.	10.600	10.400	2.310	2.170	5.570	18.400	3.980	9.470	15.000	5.270

CONCLUSION AND RECOMMENDATION

The concentration of ten different heavy metals was determined in soil and samples collected from selected locations within Agbara Industrial Estate. The results obtained revealed that the average concentration of Mn, Fe, Cu, Se, Pb, Cr, Co, and Ni in water are above the WHO permissible limit while Zn and Cd falls below the permissible limit. Moreover, the concentration of all the heavy metals analysed in soil samples are below the WHO permissible limit. The evaluated hazard indices for all the elements are less than one which falls below the reference value given by USEPA (2001) and the mean incremental life time cancer risk through inhalation falls at the extremely low risk level whereas the mean incremental life time cancer risk through ingestion of water falls at high risk level and extremely high risk level. This might likely pose health risk on the people if they ingest the water from those locations. This study hereby recommends that water from those selected locations should not be ingested into the body system without proper treatment and the people in that area should be sensitized about the health risk associated with the ingesting of water in those locations.

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