Communication in Physical Sciences, 2026, 13(2): 457-479

Environmental Impact Assessment of Manganese Mining Activities On Groundwater, River Water, Land, and River Sediments in Daranna, Bagudo Local Government Area, Kebbi State, Nigeria

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Received: 28 December 2025/ Accepted: 11 March 2026/Published: 20 March 2026
https://dx.doi.org/10.4314/cps.v13i3.7

Abstract: *Mining of minerals is very important for economic growth, but mining sites are associated with pollution of groundwater, surface water and sediments from the land and river channels in particular by manganese, heavy metals, and trace elements. This research assessed the degree and impact of geochemical interaction of the open-pit manganese mining with various water and sediment sources and the health implication on the inhabitants at the Daranna Area in the Bagudo Local Government of Kebbi State, Nigeria. The samples were obtained based on the human, plant and aquatic organism relationship with water and sediment sources. The methodology involved sample collections: twenty (20) hand-dug water and borehole, twenty (20) sediment samples from same different locations with the groundwater, ten (10) samples each for the river water and river sediment samples. The water samples were collected in sterile bottles, while the sediments were retrieved into polythene bags, and each sample was labeled appropriately. An Atomic Absorption Spectrophotometer (A.A.S.) was used to analyze the samples, except the Na and K elements with Flame Photometer. The results of the well water shows that only the K and Pb ions concentration values are higher than the WHO (2022) toxicity limit, while in the anions, only the Cl and NH4 have higher values than the limits . However, only Cr, Cd, and Co trace elements are having contaminant values. The river water results show similar trend for the heavy metals, anions, PO_4, and the trace elements. In the case of the land sediments, only Cd in Sample DS7 has conc. value greater than Threshold Effect Concentration (TEC) level. The river sediments have Mg and Mn (ions) higher than the safe limit in only Sample DRS10 due to its proximity to the discharge point of the mine wash into the river, and all the samples show high toxicity value for Fe. These pollutants have anomalous values greater than tolerant level of WHO (2022) and recommended Threshold Effect Concentration (TEC) limits, thereby, chronically hazardous to human, animals, and the aquatic life ecosystem. The Daranna community should be sensitised on the danger of the continuous consumption of contaminated water and sediments to the plants and crops, while the state government should urgently provide alternative safe water and remediate the land for farming activities.*

Keywords : *Manganese mining, Toxicity limit, Heavy metals, Trace elements, Anions, Threshold Effect Concentration (TEC)*

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1.0 Introduction

Mineral mining plays a significant role in economic growth at both regional and national levels. Mining is the process of extracting valuable

minerals and geological materials from the Earth for industrial and economic purposes. This is made possible by exploration and exploitation of the run-off mine for processing at the beneficiating plant. Several minerals and trace elements have become increasingly important for modern technological development.
military hardware, telecommunication, electric cars, and in the manufacture of aeroplanes, steel industry (manganese is used extensively as an alloying element in steel production) . As an alloying additive, manganese makes steel harder and improves many of its mechanical properties. The Nigerian government has intensified efforts toward solid mineral development as an alternative source of foreign exchange earnings.

Ihedioha (2019) posited that mining is the bedrock of national industrialization. As a result of this, consequently, several mining areas have been opened for active mineral exploitation.However, the different types of mining have great potential to cause environmental damage affecting humans, animals, and aquatic ecosystems. Therefore, the mining processes must be carefully managed to prevent environmental hazards. Despite careful consideration of the environmental impacts, the mining sites still pose significant risks to miners and their host communities. The extraction of the mineral deposit from its natural environment poses a lot of environmental degradation problems which range from all sort of pollution to ecological imbalance (Gutti *et al*, 2012). Such environmental degradation may force the relocation of local communities for safety reasons.

The manganese deposit located in Daranna Area, Bagudo Local Government Area, Kebbi State, Nigeria, serves as an important source of revenue for both the state and the nation.

In the course of mining activities, a lot of hazardous materials are released to the environment. The negative environmental impacts attributed to mining waste are enormous (Cimbolakova *et al*., 2020). Surface mining is the major method used in most mining activities. Manganese (Mn) is relatively widespread in the earth's crust, with global manganese reserves estimated at 5-6 billion tonnes, and the market value of high-grade manganese fluctuating between 50 and 70% of global production and 80% of global exports.

It involves the exploration of mineral deposits that are close to the surface of the earth. In most of the surface mining, the overburden, the soil above the deposit, are initially removed and dumped somewhere else in creating a new ecosystem at the dump site (Zambiri *et al*., 2022). Open-pit mining operations result in significant environmental pollution, which damages land stability, thus making it hazardous. Some of the issues relating to mining activities and the environmental impacts of Mining Activities shall be considered. Modern mining companies in many countries are required to follow strict environmental and rehabilitation codes, ensuring that mined areas are rehabilitated to their original or improved environmental condition. Mining activities have devastating environmental effects which include formation of pits, destruction of the environment, loss of biodiversity and contamination of ground water by chemical from the mining process and products (Singh & Gupta, 2016).

Previous studies have reported elevated concentrations of heavy metals in groundwater and sediments surrounding mining environments, indicating strong geochemical interactions between mining waste and environmental media. However, site-specific environmental assessments remain limited in many emerging mining regions of Nigeria.Despite numerous studies on mining-related environmental pollution worldwide, limited information exists on the integrated assessment of groundwater, river water, land sediments, and river sediments affected by manganese mining activities in Daranna, Bagudo Local Government Area. The absence of baseline environmental data for this region creates uncertainty regarding the extent of contamination and associated ecological and human health risks.

At present, abundant investigations have been conducted on the widespread environmental pollutants and there effects. Large scale mining operations and unprocessed liberations of these toxic mining pollutants are creating a detrimental effect on the ecosystem and demanding a sustainable solution. The aim of this study is to evaluate the environmental impacts of manganese mining activities on groundwater, river water, land, and river sediments in the Daranna community, Bagudo Local Government Area, Kebbi State, Nigeria.

The objectives include:

(i) collection of well water samples, river water samples, sediment samples from same locations with the well water, and river sediments for geochemical analyses;

(ii) Compare the heavy metals, trace elements, and cations with the World Health Organisation (WHO, 2022) and Threshold Effect Concentration (TEC) minimum toxicity limits

(iii) Effect on the ecological and aquatic habitat in the environment and

(iv) Assess the impact of the manganese mining activities on the area, in particular the environmental health impact of the manganese mining activities on the people living in the environment.

This study provides essential baseline environmental data required for sustainable mining management and environmental monitoring in the region. The findings will support policy formulation, environmental remediation planning, and public health protection while contributing to scientific knowledge on manganese mining impacts in semi-arid environments.

The study area is located in Daranna at coordinates 11°7′48″N and 3°58′47″E, as shown in Fi. 1.

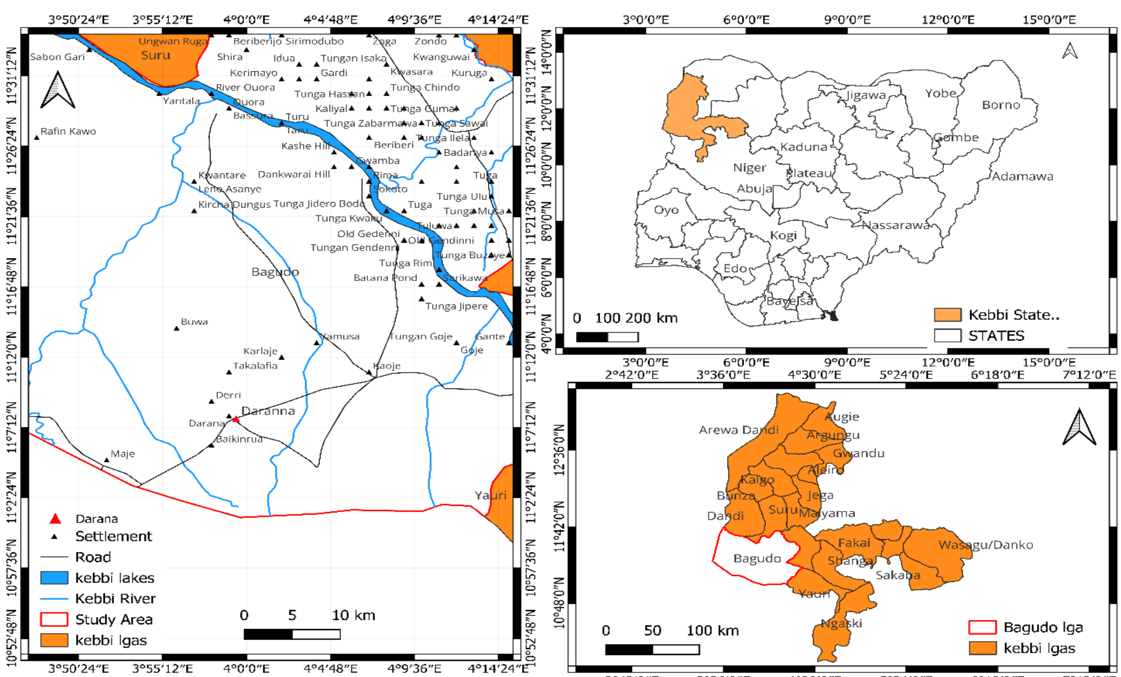

Fig. 1. Location map of the study area (Daranna)

2.0 Materials and Methods

The materials and analytical instruments used in this study included a meter rule, beakers, watch glasses, volumetric flasks, funnels, filter papers, conical flasks, pipettes, burettes, pH meter, a retort stand, Atomic Absorption Spectrophotometer (AAS), Flame Photometer, concentrated nitric acid (HNO_3), sulphuric acid (H_2SO_4), and ammonium acetate.

Samples were collected based on the study objectives to evaluate the effects of mining activities on humans and aquatic ecosystems.

. Therefore, samples were collected from the main village where the people live and from the the river, which serves the community for domestic and agricultural purposes

2.1 Sample collection

Sampling locations were selected based on proximity to mining activities, population density, and water usage patterns within the study area to ensure representative environmental assessment.

Samples were collected from hand-dug wells located within Danama Village. . Twenty (20) sampling locations were selected across the village, , designated as Samples D1-D20. River water samples were collected along the river course traversing the village. Ten river water samples were collected, designated as DRW1-DRW10. This is followed by sediment samples also collected within the village, at the same locations as the well water points. Sediment samples of different spots were collected at approximately 1 m depth using an auger drill.. The last set of samples collected were ten river sediments obtained from the river bed. Sediment samples were stored in labeled polyethylene bags to prevent contamination. However, the water samples from water sources (hand-dug wells and river), were collected in sterilized polyethylene bottles from twenty (20) well locations and ten (10) river locations.

2.3 Sample preparation

The water samples were treated in the field by addition of a few drops of concentrated hydrochloric acid (HCl) to preserve dissolved metals. The sediment samples required further preparations which include the following.

2.3.1 Drying

The samples were air dried in order to avoid dampness of the samples. This process made the crushing and sieving of the samples much easier.

2.3.2 Crushing and grinding

This procedure is important for grain size reduction and breaking down of lumped samples to ensure proper sieving, prior to sieving using appropriate mesh sizes. The samples were pulverized using mortar and pestle.

2.3.3 Sieving

The selected samples were sieved with 63 micron mesh. The sieved samples were stored in labeled polyethylene bags to prevent contamination and oxidation.

2.3.4 Geochemical analysis for water samples

Metal concentrations in water samples were determined using Atomic Absorption Spectrophotometry (AAS), while sodium (Na) and potassium (K) were analyzed using Flame Photometry. Calibration was performed using standard solutions, and concentrations were obtained by comparing sample absorbance or emission intensity with calibration curves.

2.3.5 Geochemical analysis of sediment samples

This is an elemental analysis which permits determination of metals in a different of samples at the trace concentration level. The Atomic Absorption Spectrophotometer uses a hollow cathode lamp specific to each element as the radiation source. Samples were atomized in a flame system, and metal concentrations were determined based on absorption of characteristic wavelengths. The analyzed elements included Na, K, Ca, Mg, Zn, Pb, Cu, Fe, Mn, Ni, Cr, Co, and Sr.

3.0 Results and Discussion

Twenty water samples were collected from Danama Village in Bagudo Local Government Area, Kebbi State, Nigeria. The village is located approximately one kilometer from the manganese mining site.

The village is about a kilometer from the village. The samples were subjected to geochemical analysis to evaluate the impact of manganese mining activities on groundwater and surface water sources utilized by the Daranna inhabitants for drinking, domestic use, and livestock consumption.

The groundwater samples were collected from hand-dug wells within the village, while the river water samples were collected from the river that passes through the village, from which inhabitants obtain water for drinking and domestic purposes.

The summary of the concentration levels of the dissolved heavy metals and trace elements of the well water obtained from Danama Village, Bagudo Local Government, Kebbi State, Nigeria, is presented in Table 1. The geochemical concentration levels of the heavy metals and trace elements obtained were compared with the Guidelines for Drinking-water Quality (4th Edition) of the World Health Organization (WHO, 2022) for potable water (WHO, 2022) for portable drinking water and Nigerian Standard Water Quality (NSDWQ, 2015) guideline limits for drinking water.

The results of the cations such as Na, K, Ca, Mg, Zn, Pb, Cu, Fe, and Mn concentration values in the well water samples are presented in Table 1. Sodium (Na^+) concentrations ranged from 20.1–44.1 mg/L, with an average value of 32.7 mg/L, which is below the WHO (2022) and NSDWQ (2015) permissible limit of 200 mg/L.. Similar trends were observed for Ca^{2+}, Mg^{2+}, Zn^{2+}, Cu^{2+}, Fe^{2+}, and Mn^{2+}, all of which remained within permissible drinking water limits.

.Ca concentration values range from 10.2-19.5 (av. 13.2); Mg (2.3-5.5; av. 3.6 g/L; Zn values vary between 0.22-0.06g/L, av. 0.4 g/L; Cu value varies from 0.22-0.7, av. 0.42g/L; Fe concentration varies from 0.01-0.055, 0.03g/L; and Mn elemental concentration values from 0.02-0.15, av. 0.05g/L in which all the mentioned elements have concentration sample value levels less than the WHO (2022) and NSDWQ (2015) guidelines for drinking water limits (Table 1). The relatively low concentrations of these cations may be attributed to the distance of the village from the mining site and dilution effects associated with deeper groundwater sources.

However, the concentration values of the K ion vary from 11.0-46.5 g/L and an average value of 29.5 g/L are elevated across all sampling locations (D1–D20) in all the sample locations D1-D20, exceeding the 10.0 g/L recommended by WHO (2022) (see Table 1, Fig. 2). A similar trend was noticeable in Pb concentration values, varying from 0.12-0.86 g/L, compared with 0.01g/L set limit in the guidelines for portable water by WHO (2022) and NSDWQ (2015) (See Fig. 3). The health implications of the continuous exposure to especially Pb and other contaminants in the polluted water are hazardous to the inhabitants of the community. Elevated Pb concentrations indicate possible contamination linked to mining activities and pose significant public health risks due to bioaccumulation and toxicity.

Trace elements such as Ni, Cr, Cd, and Co were analysed in the well water samples (Table 1). Ni have concentration values ranging from 0.017-0.066g/L, and an average value of 0.05g/L compared with 0.07g/L and 0.02g/L of WHO (2022) and NSDWQ (2015), respectively. All the water samples are within the WHO safety limit standard (< 0.07g/L). When the Ni ion concentration values were compared with the NSDWQ toxic limit (0.02g/L), all the samples have values greater the toxicity limit, except Sample D13 with 0.017g/L.

Table 1. Geochemical analysis results of well water samples from Daranna (mg/L)

LOC	Na	K	Ca	Mg	Zn	Pb	Cu	Fe	Mn	Ni	Cr	Cd	Co
D1	29.9	42.0	10.20	2.55	0.022	0.120	0.32	0.05	0.02	0.028	0.080	0.020	0.010
D2	31.8	46.0	12.50	3.20	0.035	0.530	0.30	0.03	0.05	0.035	0.050	0.060	0.007
D3	44.1	11.2	10.30	3.50	0.030	0.260	0.45	0.055	0.04	0.046	0.041	0.009	0.012
D4	28.2	14.0	12.70	2.40	0.025	0.424	0.22	0.04	0.02	0.057	0.082	0.016	0.009
D5	40.9	11.0	12.20	2.30	0.033	0.863	0.30	0.02	0.04	0.064	0.070	0.008	0.012
D6	24.8	14.0	12.50	3.60	0.030	0.739	0.50	0.027	0.02	0.037	0.060	0.014	0.012
D7	33.1	42.5	10.20	3.50	0.036	0.160	0.40	0.010	0.14	0.046	0.080	0.016	0.018
D8	29.3	44.0	12.80	4.60	0.043	0.250	0.35	0.020	0.14	0.066	0.055	0.006	0.013
D9	32.2	45.2	10.60	2.40	0.046	0.160	0.44	0.024	0.15	0.047	0.060	0.009	0.015
D10	44.0	12.5	12.70	3.60	0.049	0.234	0.55	0.030	0.04	0.024	0.052	0.016	0.018
D11	23.3	14.2	10.20	4.40	0.050	0.480	0.45	0.025	0.04	0.026	0.041	0.018	0.015
D12	30.1	40.2	12.80	4.60	0.040	0.340	0.30	0.022	0.14	0.035	0.062	0.014	0.010
D13	31.1	45.1	12.80	5.50	0.050	0.450	0.55	0.015	0.14	0.017	0.040	0.006	0.022
D14	32.2	46.5	14.20	3.70	0.040	0.330	0.60	0.025	0.22	0.036	0.042	0.009	0.004
D15	40.2	11.2	12.10	3.40	0.050	0.450	0.68	0.032	0.04	O.035	0.040	0.014	0.006
D16	20.1	14.0	14.30	4.50	0.030	0.560	0.70	0.028	0.04	0.023	0.020	0.008	0.008
D17	34.4	41.0	17.90	4.40	0.050	0.430	0.26	0.035	0.04	0.026	0.040	0.010	0.006
D18	29.9	42.0	19.60	3.20	0.060	0.330	0.40	0.019	0.02	0.029	0.042	0.009	0.015
D19	31.8	43.0	15.80	4.51	0.040	0.450	0.38	0.038	0.02	0.025	0.040	0.008	0.018
D20	44.1	11.2	17.20	3.54	0.050	0.430	0.30	0.014	0.04	0.026	0.020	0.004	0.020
Lowest value	20.1	11.0	10.2	2.3	0.022	0.12	0.22	0.01	0.02	0.017	0.02	0.004	0.004
Maximum Value	44.1	46.5	19.6	5.5	0.06	0.86	0.7	0.055	0.15	0.066	0.082	0.02	0.022
Average Value	32.77	29.5	13.2	3.67	0.04	0.4	0.42	0.03	0.05	0.04	0.05	0.014	0.013
WHO, 2022	200.0	10.0	75.0	50.0	3.0	0.01	2.0	0.3	0.4	0.07	0.05	0.003	0.005
NSDWQ 2015	200	NA	NA	20	3.0	0.01	1.0	0.3	0.2	0.02	0.05	0.03	NA

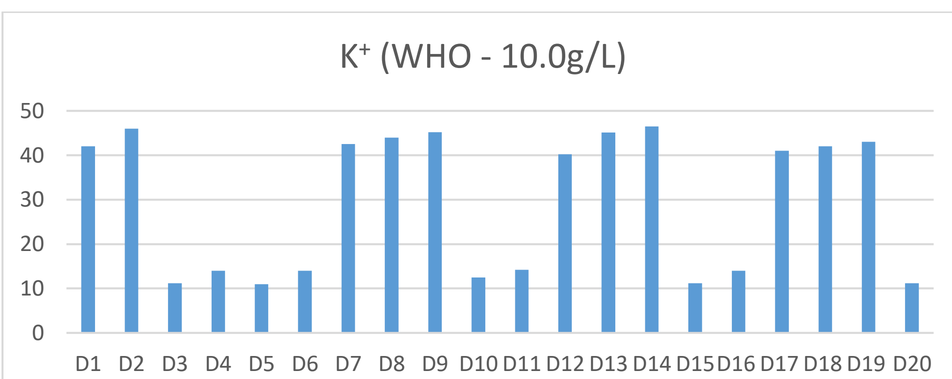

Fig. 1: Variation plot of K^+ ion concentration in Daranna

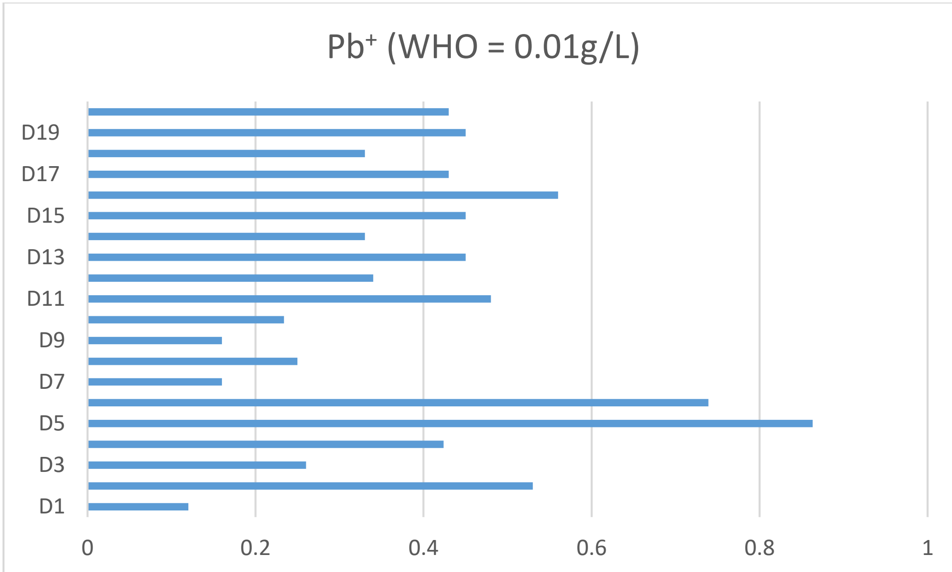

Fig. 2: Variation plot of Pb ion concentration in Daranna

Trace elements such as Ni, Cr, Cd, and Co were analyzed in the well water samples (Table 1). Ni have concentration values ranging from 0.017-0.066g/L, and average value of 0.05g/L compared with 0.07g/L and 0.02g/L of WHO (2022) and NSDWQ (2015) respectively. All the water samples are within the WHO safety limit standard (< 0.07g/L). When the Ni ion concentration values were compared with the NSDWQ toxic limit (0.02g/L), all the samples have values greater the toxicity limit, except Sample D13 with 0.017g/L.

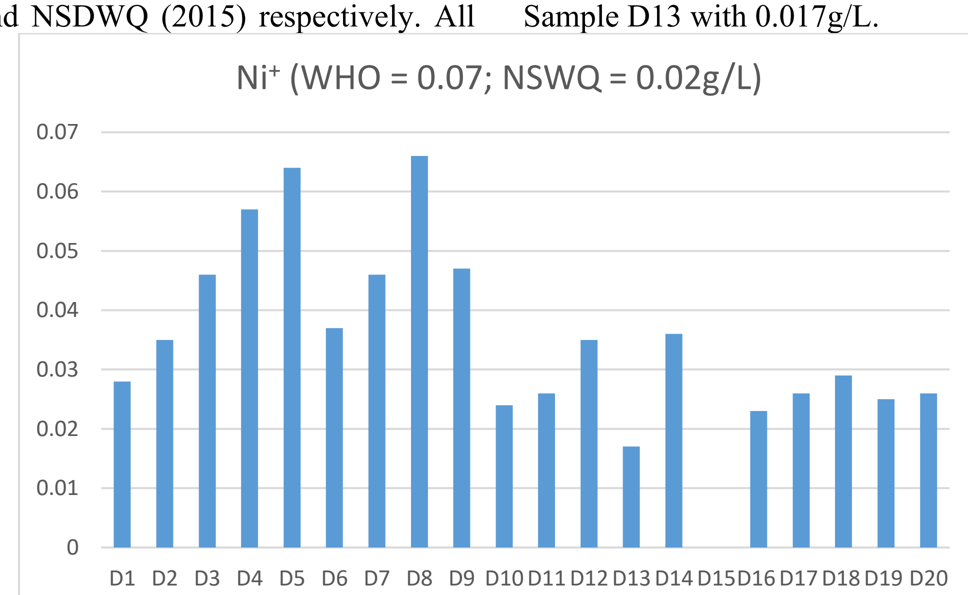

Fig. 3. Variation plot of Ni ion concentration in Daranna

Cr values range from 0.02-0.082g/L, average value of 0.05g/L compared with 0.05g/L set limit of both WHO (2022) and NSDWQ (2015) (Table1, Fig. 4). This shows that Cr concentration values are greater than the allowable limits set by WHO (2022) and NSDWQ (2015). Two Samples D16 and D20 have values lower than the allowable threshold limit by both WHO (2022) and NSWQ (2015). All other sample points are considered contaminated based on regulatory standards

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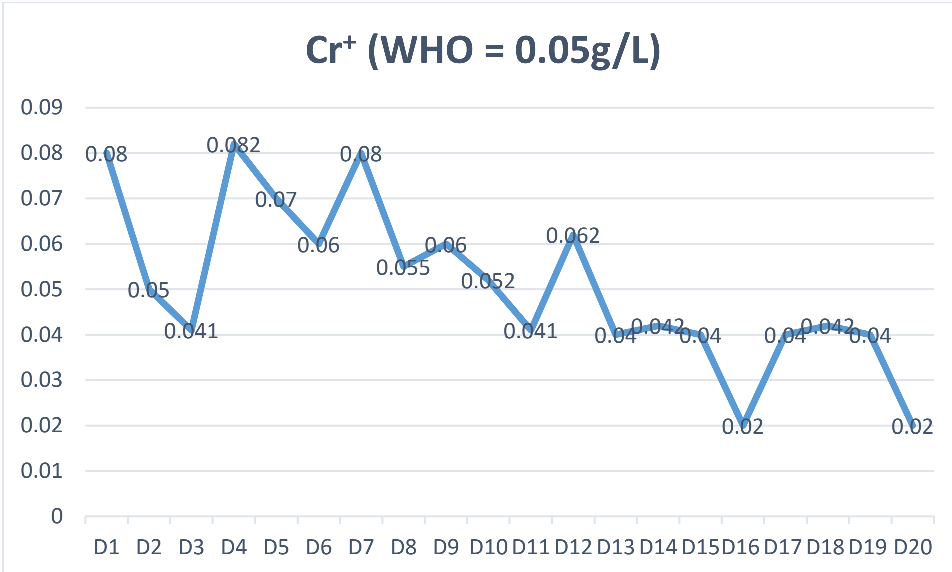

Fig. 4. Variation plot of Cr ion concentration in Daranna

The Cd concentration varies from 0.004-0.02g/L, average value of 0.014g/L compared with 0.003g/L set by WHO (2022). This shows that all the water sample locations are outside the threshold limit of WHO (2022), while only sample D2 with 0.06g/L value is higher than the NSDWQ set limit of 0.03g/L (Table 1, Fig. 5).

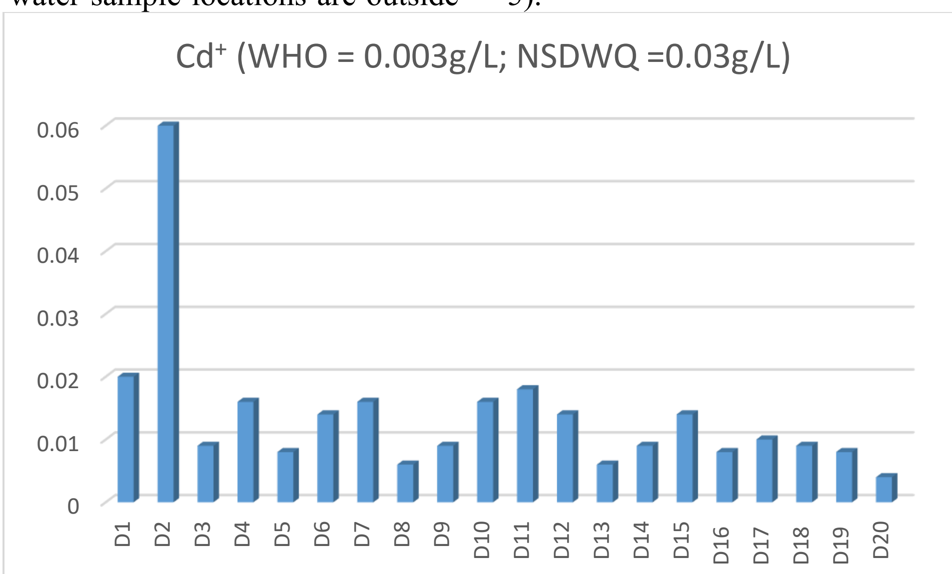

Fig. 5. Variation plot of Cd ion concentration in Daranna

The Co- has values with a range from 0.004-0.022g/L, average value of 0.013g/L, compared with 0.005g/L indicated by WHO (2022). All the samples have higher Co-concentration except Sample D14 with a value 0f 0.004g/L (Fig. 6). Therefore, the high concentration values of the trace elements in the well water samples collected from the community These results indicate that Danama Village is highly vulnerable to contamination associated with manganese mining activities, posing significant potential health risks to the inhabitants.

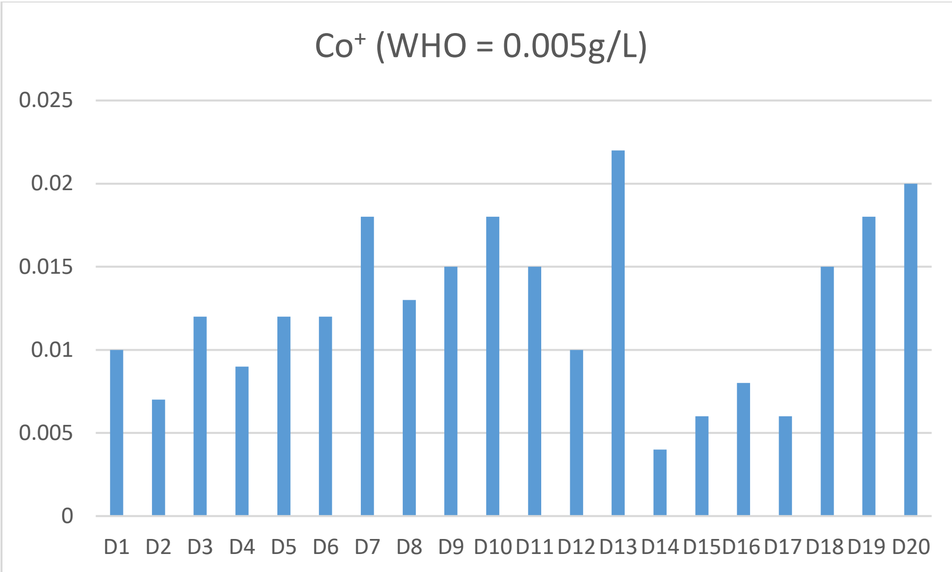

Fig. 6. Variation plot of Co ion concentration in Daranna.

The anions and the compound elements such as Cl^-, F^-, NH_4^-, NO_3^-, SO_4^-, and PO_4^- presented in Table 2 show water concentration values within the limits of WHO (2022) and NSDWQ (2015), except for NH_4^+, which exceeded recommended guideline limits.

Table 2. Geochemical results of well water anions and dissolved compounds (mg/L)

LOC	NH4	NO3-	SO4	Cl-	F	PO4
D1	2	0.048	0.040	3.350	0	0.4
D2	4	0.052	0.135	5.230	0	0.6
D3	5	0.046	0.137	3.160	0	0.8
D4	3	0.055	0.024	3.350	0	0.4
D5	5	0.045	0.020	5.160	0	0.6
D6	2	0.047	0.025	5.230	0	0.4
D7	4	0.042	0.230	3.150	0	0.5
D8	5	0.050	0.034	3.370	0	0.6
D9	4	0.045	0.027	5.160	0	0.8
D10	3	0.036	0.120	4.180	0	0.7
D11	4	0.070	0.012	3.640	0	0.4
D12	6	0.055	0.015	6.220	0	0.5
D13	3	0.042	0.034	4.520	0	0.6
D14	4	0.048	0.020	6.620	0	0.6
D15	5	0.024	0.050	4.350	0	0.8
D16	2	0.033	0.062	3.150	0	0.7
D17	5	0.050	0.060	5.380	0	0.5
D18	3	0.044	0.048	4.260	0	0.6
D19	5	0.052	0.056	4.170	0	0.4
D20	5	0.030	0.069	5.350	0	0.7
Lowest value	2.0	0.024	0.015	3.150	0.0	0.4

Highest value	6.0	0.070	0.23	6.62	0.0	0.8
Average value	3.95	0.05	0.06	4.45	0.0	0.58
WHO std, (2022)	0.5	50.0	250.0	250	1.5	1.0
NSDWQ (2015)	NA	50.0	100.0	250	1.5	NA

The NH_4 ion concentration values range from 2.0-6.0g/L with an average value of 3.95g/L (Table 2). All the twenty analysed well water samples show evidence of high concentrations, with concentration values exceeding 0.5g/L when compared with WHO (2022) threshold limit of 0.5g/L (Fig. 7). The dissolved NH4 compound is hazardous to drinking by the community inhabitants.

Fig.s 1–6 illustrate spatial variations in metal ion concentrations across sampling locations.

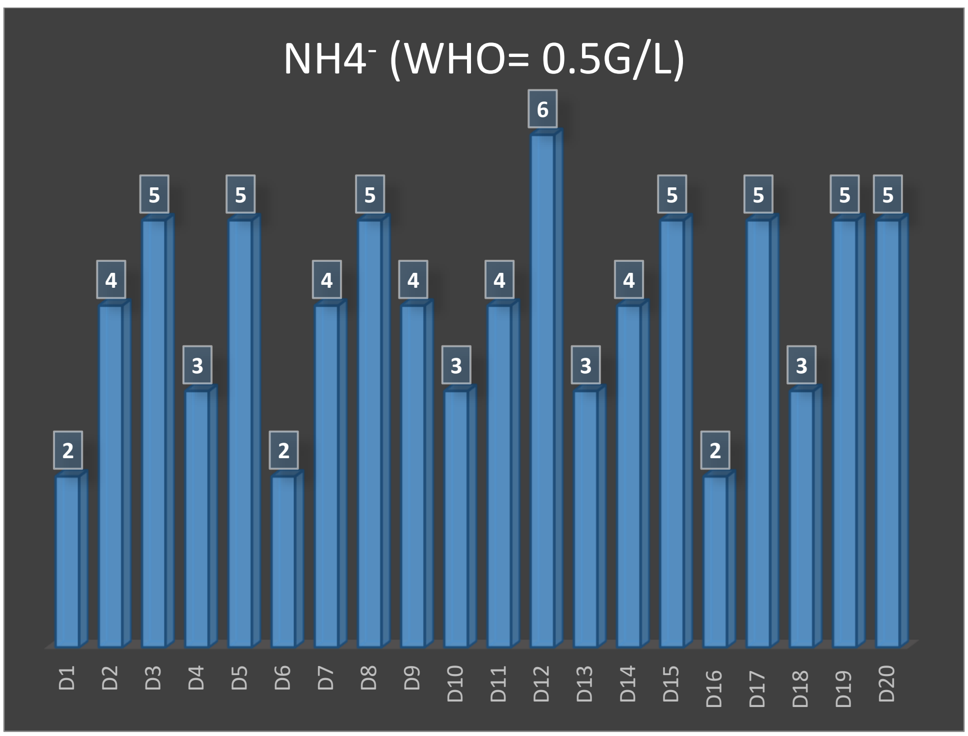

Fig. 7: Variation plot of NH4 ion concentration in Daranna.

3.2 River Water

River water samples from the Daranna mining community were collected for investigation because the residents depend on the water for domestic use, livestock rearing, and fishing activities. Ten river water samples were analyzed, and the geochemical results are presented in Tables 3 and 4. The concentrations of cations and trace elements obtained from samples DRW1–DRW10 are presented in Table 3. The measured concentrations were compared with WHO (2022) guideline limits for drinking and domestic water use.

Table 3. Geochemical concentrations of heavy metals and trace elements in river water samples

LOC	Na	K	Ca	Mg	Zn	Pb	Cu	Fe	Mn	Ni	Cr	Cd	Co
DRW1	28.2	14.0	9.90	5.50	0.06	0.120	0.44	0.095	0.04	0.027	0.021	0.006	0.016
DRW2	23.3	14.2	10.35	8.60	0.04	0.260	0.38	0.099	0.04	0.034	0.040	0.006	0.020
DRW3	30.1	40.2	12.60	4.50	0.05	0.240	0.30	0.094	0.04	0.036	0.051	0.002	0.022
DRW4	31.1	45.1	10.50	4.60	0.02	0.284	0.15	0.098	0.04	0.037	0.050	0.006	0.018
DRW5	32.2	46.5	10.40	5.50	0.05	0.373	0.18	0.095	0.04	0.048	0.040	0.005	0.024
DRW6	40.2	11.2	8.10	4.40	0.05	0.489	0.20	0.084	0.02	0.030	0.020	0.009	0.020
DRW7	20.1	14.0	9.60	5.60	0.04	0.280	0.40	0.089	0.02	0.047	0.040	0.002	0.018
DRW8	34.4	41.0	10.50	6.70	0.02	0.290	0.37	0.094	0.04	0.037	0.051	0.006	0.012
DRW9	29.9	42.0	12.80	5.45	0.02	0.254	0.20	0.094	0.04	0.035	0.050	0.010	0.020
DRW10	31.8	44.0	8.70	4.64	0.02	0.323	0.32	0.098	0.04	0.046	0.020	0.006	0.015
Lowest Value	29.1	11.2	8.10	4.40	0.02	0.24	0.15	0.084	0.02	0.030	0.020	0.002	0.012
Max Value	40.2	46.5	12.8	8.6	0.05	0.489	0.40	0.099	0.04	0.048	0.051	0.10	0.024
Average Value	30.13	31.2	10.35	5.55	0.04	0.29	0.29	0.094	0.036	0.04	0.04	0.006	0.019
WHO, 2022	200	10	75.0	50.0	3.0	0.01	2.0	0.3	0.4	0.07	0.05	0.003	0.005

***Max = maximum**

The concentrations of Na, Ca, Mg, Zn, Cu, Fe, and Mn ions are within the WHO (2022) permissible limits (Table 3).

However, the K ion concentration for the ten samples varies from 11.2-46.5 g/L, with an average value of 31.2g/L in comparison with the WHO (2022) standard toxic limit of 10.0g/L (Table 3, Fig. 8). This contaminant is not permissible for drinking and other domestic uses because it causes hazardous effects on humans (Tassew, 2020). It may as well cause kidney disease, heart disease, hypertension, or diabetes; while the excessive potassium concentration in the blood can lead to cardiac arrest and renal failure.

Elevated potassium concentrations in water may also indicate geochemical interaction between mining wastes and surface water systems.

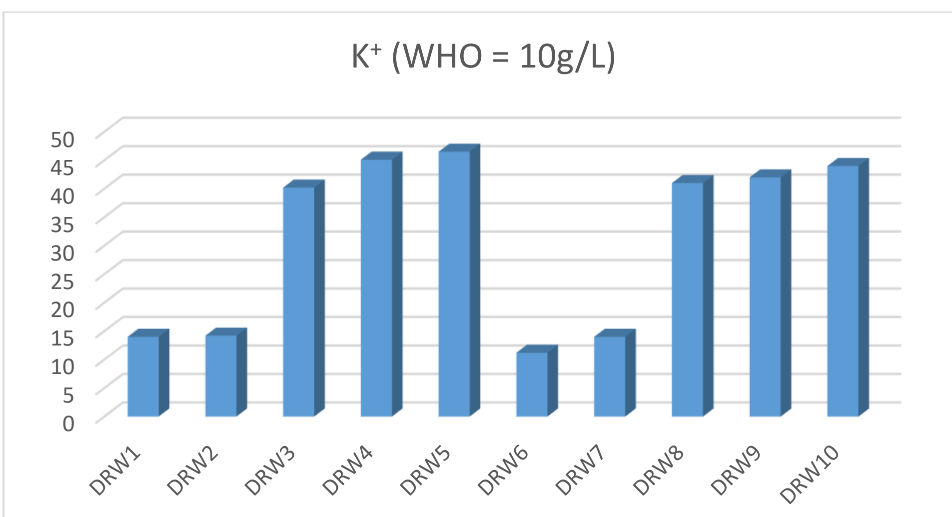

Fig. 8: Variation plot of K ion concentration in Daranna.

The Pb+ concentration values range between 0.24-0.489g/L; average value is 0.29g/L compared with the toxic limit level of 0.01g/L specified by the WHO (2022) (see Table 3, Fig. 9). Lead poisoning poses serious health risks and must be prevented due to its carcinogenic and neurotoxic effects.

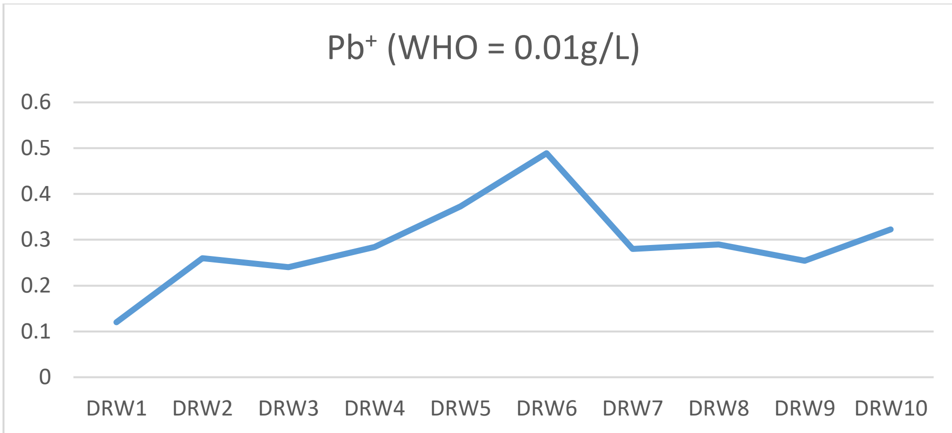

Fig. 9: Variation plot of Pb ion concentration in Daranna.

Among the effects of lead poisoning are high blood pressure, joint and muscle pains, difficulties with memory and concentration, headache, abdominal pains, mood disorder, reduced sperm count, and abnormal sperm, miscarriage, stillbirth, and premature birth (Moyoclinic.org). The toxic effect could lead to cardiovascular problems and kidney damage (WHO, 2024). A high level of the lead poisoning from the contaminated water can course seizure, unconsciousness and death. A continuous consumption of high level Pb like that of Danama community can take months or years to develop lead poisoning (info.health. AZ, 2026).

Three trace elements show concentration levels greater than the permissible toxic level of WHO (2022). The only exception of these is Ni+ concentration which are lower than the set limit (Table 3, Fig. 9). However, Cr+ concentration vary between 0.02-0.051g/L compared to 0.05g/L established limit of WHO (202). Only Samples DRW3 and DRW8 (0.051g/L) show a slight increase in toxicity level compared with the 0.05g/L safety level (Fig. 10).

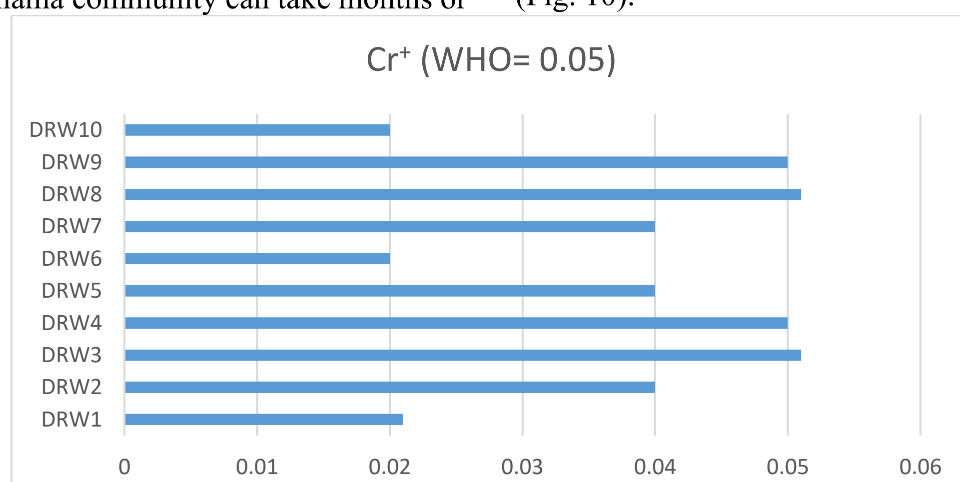

Fig. 10: Variation plot of Cr ion concentration in Daranna.

The health effects of chromium ion exposure have severe consequences which include cancer, organ damage, and allergic reactions. Inhalation of Cr^{+6} could lead to lung cancer, irritation, ulcer, and perforation of the nasal septum, chronic bronchitis, asthma, and reduced lung function. Ingestion of the Cr^{+6} can lead to severe gastrointestinal effects, vomiting, hemorrhage, liver damage, kidney damage, and possibly their cancers if exposed to it in drinking water (Achmad *et al*., 2017; Dong *et al*., 2023). Maria-Nefell and Mariana (2023) were of the view that a study indicated that the some studies suggest trace levels of chromium may play biological roles; however, elevated concentrations constitute a significant health risk.

The Cd+ concentration values range from 0.002-0.01g/L, average value of 0.006g/L (Table 3). Only two locations have Cd^{2+} sample concentrations lower than 0.003g/L (WHO, 2022). The samples with greater safety limit concentration values (0.003g/L) are DRW1, DRW2, DRw4, DRW6 (0.009), DRW7, DRW8, DRw9 (0.01g/L), and DRW10 (0.006g/L) (see Table 3, Fig. 11).

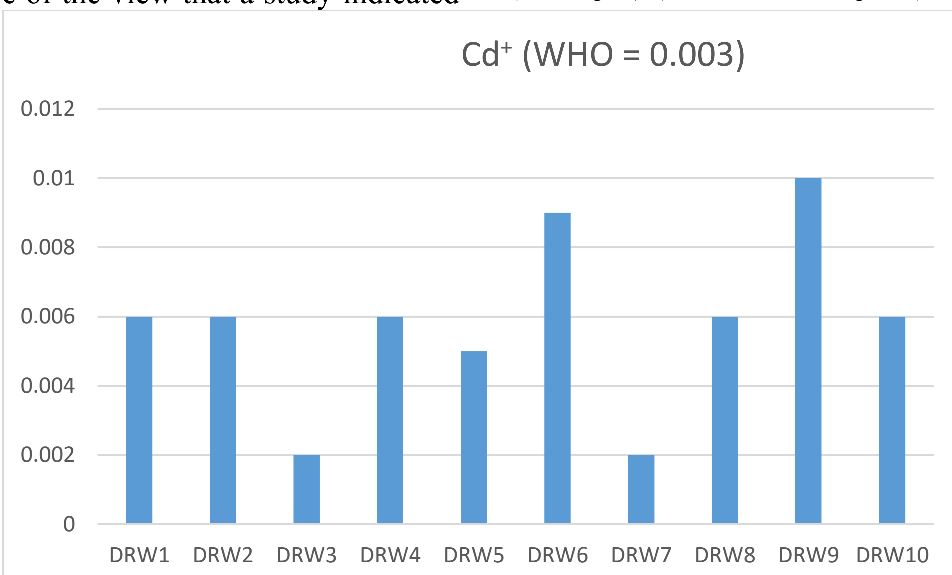

Fig. 11: Variation plot of Cd ion concentration in Daranna.

The associated health effects of cadmium toxicity are in kidney damage; inhalation of the cadmium dust is harmful to the respiratory system. Cadmium could interfere with calcium metabolism and vitamin D activation, leading to bone demineralization, severe bone pain, and fracture. Cadmium could exist as carcinogen, thereby causes cancer of the lungs, prostrate, kidney, pancreas, and breast. Cadmium exposure could as well lead to cardiovascular diseases, nervous system disorder, and damage to reproductive system. Other important exposure sources include cigarette smoking and dietary intake, such as consumption of contaminated food, organ meats, leavy vegetables, and crops grown in polluted soils like in Daranna Are, but not reported in this paper.

Co+ values range between 0.015-0.02g/L, average value is 0.019g/L (Table 3, Fig. 12), compared with 0.005g/L (WHO, 2022). All the samples show higher Co+ concentrations. Lauwery (1994) shows that health risk associated with cobalt exposure include allergic dermatitis, rhinitis, and asthma. Therefore, efforts must be made towards reducing the exposure of people in Daranna to Co+ from experiencing health hazard associated with the consumption of the trace elements contaminants present in the river.

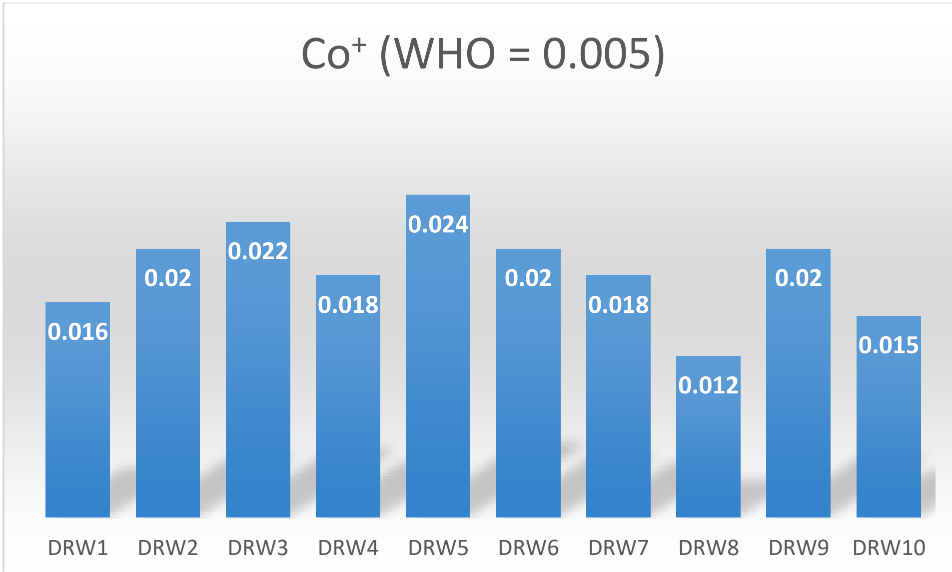

Fig. 12: Variation plot of Co ion concentration in Daranna.

The anion elements and essential compounds of the river water samples were analyzed to deduce the abnormality of the toxicity levels in the Daranna River associated with the Manganese mining in the community, Bagudo Local Government Area, Kebbi State, Nigeria. The anion tested for include $NH4^{-}$, $NO3^{-}$, $SO4^{2-}$, Cl^{-}, F^{-}, and $PO4^{2-}$. Their concentration values were compared with WHO (2022) river water tolerant level for domestic uses (Table 4). Three anions which include NH4, Cl, and PO4 show toxic level greater than allowed limits by WHO (2022).

Table 4. Geochemical results of Anions concentrations in River Water samples

LOC	NH4	NO3-	SO4	Cl-	F	PO4
DRW1	5.0	0.072	0.015	5.660	0	0.5
DRW2	2.0	0.045	0.017	5.230	0	0.8
DRW3	4.0	0.049	0.203	2.530	0	0.6
DRW4	5.0	0.038	0.014	7.650	0	0.5
DRW5	3.0	0.015	0.055	4.370	0	0.6
DRW6	5.0	0.040	0.074	3.140	0	0.7
DRW7	2.0	0.055	0.150	3.350	0	1.2
DRW8	4.0	0.060	0.154	5.230	0	0.6
DRW9	5.0	0.046	0.049	3.150	0	0.6
DRW10	4.0	0.010	0.053	3.380	0	0.8
Lowest value	2.0	0.015	0.0015	2.530	0.0	0.5
Maximum value	5.0	0.072	0.203	7.650	0.0	1.2
Average value	4.6	0.43	0.074	4.69	0.0	0.69
WHO Std., 2026	0.5	50.0	250.0	5.0	1.5	1.0

All the ten samples show higher NH4 concentration values greater than set limits by WHO (2022). Ammonia (NH4+) ion concentration values vary from 2.0-5.0 g/L, average value of 4.6g/L in comparison with 0.5g/L of the WHO (2026) permissible concentration level (Table 4, Fig. 13). The anomalous high concentration could be as a result of leaching of farm fertilizer.

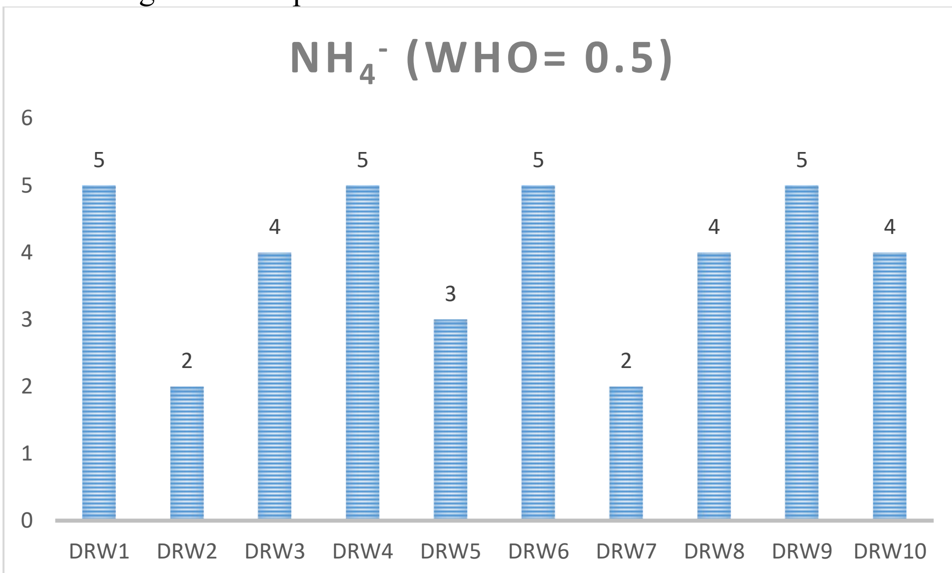

Fig. 13: Variation plot of NH_4 ion concentration in Daranna

The Cl-concentration in the samples shows a range of 2.53-7.65g/L (av. 4.69g/L). Four samples DRW1, DRW2, DRw4, and DRW8 have Cl- concentration greater than the safe limit set by WHO (2022) (Table 4, Fig. 14). The effect of long-term exposure of excess chlorine in the body could lead to vomiting, burning throat, and breathing difficulties. Other health effect could include redness, irritation, pain, blistering upon content with high concentration liquids. It could also result to abdominal discomfort, bladder and colorectal cancer; headache, fatigue, lightheadedness, and muscle weakness (CDC = U.S. Center for Disease Control and Prevention, 2026).

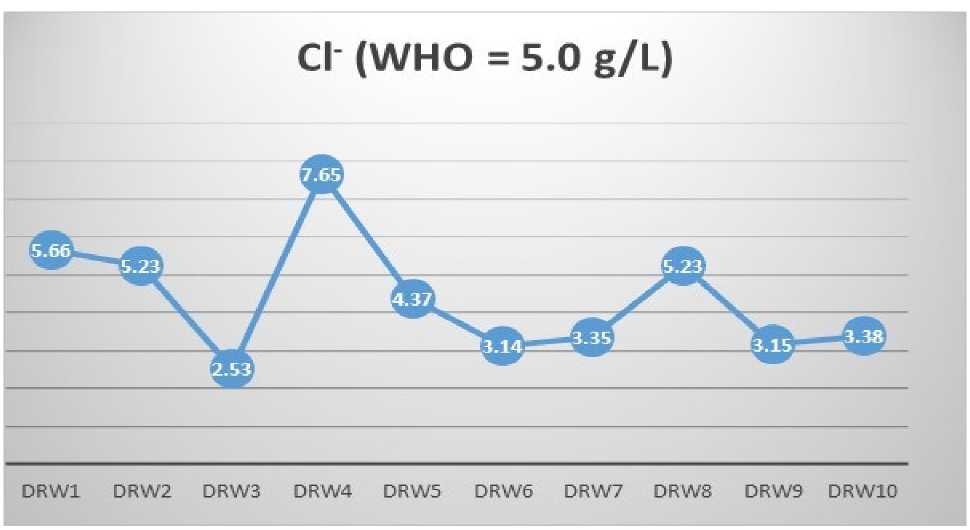

Fig. 14: Variation plot of Cl ion concentration in Daranna

PO_4^- (ion) concentration values vary from 0.5-1.3g/L, average value is 0.67g/L, and the toxic limit by WHO (2022) is 1.0g/L (Table 4). All the water samples from the ten locations have values lower than the set toxicity set limit by WHO (2022), except sample DRW7 characterized by 1.2g/L (Table 4, Fig. 15). The high value noted at the location could be responsible to fertilizer decomposition from farming in the community.

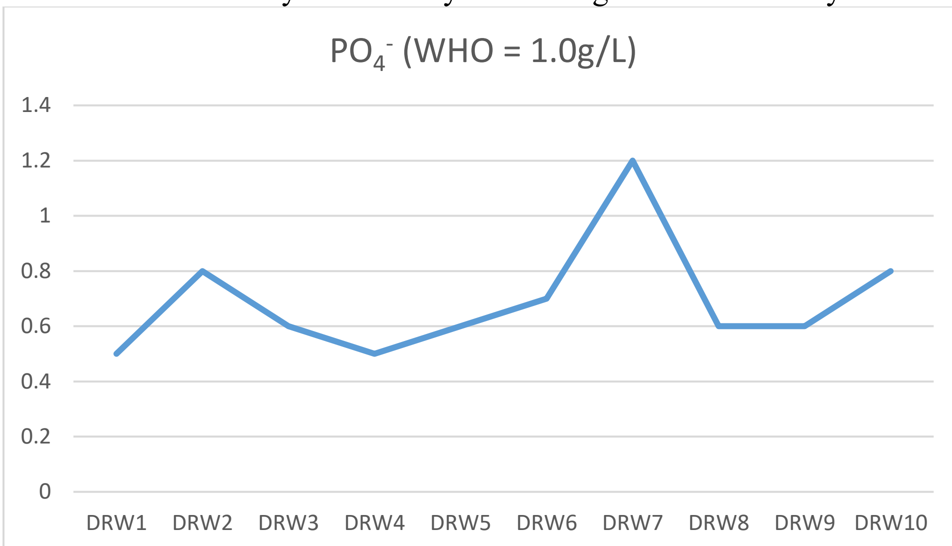

Fig. 15: Variation plot of PH_4 ion concentration in Daranna.

3.4 Land Sediment

Shallow surface sediments of Daranna mining community were investigated to determine the effect of manganese mining in the soils. Twenty sediment samples were collected and analyzed for heavy metals and trace elements. The geochemical results were presented in Table 5. The results obtained were compared with Threshold Effect Concentrations (TECs) and Probable Effect Concentrations (PECs) which are important means used for assessing heavy metals and trace elements in Nigerian sediments and other parts of the world. The tool serves as guideline in determining the potential of toxicity of contaminants like Cd, Pb, Cu, Cr, and Zn and other metals for both plants, crops and aquatic life.

The TEC assessment represents concentration levels below which do not affect organisms, while the PECs indicate levels above which adverse effects are expected. In this study both the heavy metals and trace elements were investigated for the land sediments in Daranna mining community. The results show that the heavy metals and the trace elements have concentrations values lower than the TEC values except the Cd+ which ranges in value from 0.02-1.02%, compared with TEC value of 0.099% (Table 6, Fig. 15). Therefore, the Location DS7 is characterized by Cd contaminant. The undervalue of heavy metals and other trace elements concentrations could be as a result of factors of distance from the source and relative higher rate of percolation of other cations compared to Cd ion into a deeper depth than the shallow depth of samples recovery.

3.5 River Sediment

The river sediments of Danama Village were investigated for anomalous concentration of heavy metals and trace elements. Danama River is located behind the Manganese mining site which also inhabit the Fadama for different crops planting and in the upland of the Fadama are other crops and plants for human and animal consumption. The Daranna people use the river water for irrigation and animal husbandry apart for domestic purposes.

Table 5. Heavy Metals and Trace Elements Concentrations in Daranna sediments

LOC	Na	K	Ca	Mg	Zn	Pb	Cu	Fe	Mn	Ni	Cr	Cd	Co	Sr
DS1	1.0	1.1	1.5	3.85	0.15	2.14	1.18	4.7	0.4	1.02	0.02	0.02	3.26	0.01
DS2	0.75	0.75	1.6	4.1	0.60	1.50	1.20	4.6	0.5	1.02	0.02	0.11	3.32	0.010
DS3	0.8	0.9	1.75	4.0	0.07	2.22	1.19	4.9	0.35	1.08	0.02	0.07	3.42	0.012
DS4	0.7	1.0	1.5	3.95	0.12	2.42	1.18	4.75	0.45	1.02	0.02	0.04	3.28	0.010
DS5	0.8	0.75	1.85	4.4	0.14	0.86	1.40	4.85	0.05	1.02	0.01	0.03	1.42	0.008
DS6	0.9	0.6	1.75	3.6	0.43	0.78	1.22	4.75	0.06	1.03	0.02	0.04	1.24	0.006
DS7	1.0	0.5	1.5	4.0	0.40	0.14	1.10	4.6	0.45	1.02	0.02	1.02	2.33	0.007
DS8	1.0	O.75	1.8	3.85	0.05	3.20	1.38	4.5	0.05	1.03	0.O1	0.02	3.22	0.004
DS9	1.0	0.9	1.9	3.5	0.25	0.13	1.10	4.6	0.06	1.04	0.01	0.03	3.25	0.009
DS10	0.85	1.0	1.65	4.2	0.24	2.20	1.15	4.6	0.05	1.04	0.01	0.06	3.35	0.08
DS11	0.75	0.7	1.8	4.0	0.22	3.00	1.10	4.5	0.06	1.05	0.01	0.03	3.33	0.010
DS12	1.0	0.6	1.75	3.6	0.22	3.70	1.22	4.9	0.05	1.06	0.01	0.03	2.22	0.011
DS13	0.9	0.75	1.6	4.4	0.56	NA	1.15	4.5	0.05	1.03	0.02	0.03	2.02	0.006
DS14	0.5	0.5	1.7	3.5	0.44	1.36	1.16	4.6	0.05	1.04	0.01	0.05	2.04	0.005
DS15	0.7	0.6	1.65	2.45	0.65	0.49	1.43	3.0	0.06	1.06	0.02	0.05	2.21	0.008
DS16	0.6	0.5	1.75	2.75	0.48	0.53	1.22	4.4	0.05	1.04	0.03	0.02	2.23	0.012
DS17	1.2	0.8	1.5	4.2	0.55	0.44	1.10	4.85	0.06	1.02	0.02	0.055	2.25	0.010
DS18	1.3	0.85	1.6	4.45	0.12	2.26	1.38	4.75	0.06	1.02	0.01	0.02	3.22	0.014
DS19	1.1	1.0	1.75	3.45	0.63	2.42	1.10	6.5	0.05	1.02	0.02	0.04	2.23	0.010
DS20	0.6	1.0	1.5	3.5	0.04	2.86	1.15	4.5	0.05	1.01	0.01	0.08	3.65	0.006
Lowest Value (mg/L)	0.5	0.4	1.5	2.45	0.07	0.13	1.10	3.0	0.05	1.01	0.01	0.02	1.2	0.004
Maximum Value (%)	1.3	1.1	1.9	4.45	0.65	3.7	1.43	6.5	0.5	1.08	0.03	1.02	3.65	0.014
Average value (%)	0.91	0.78	1.67	3.79	0.30	1.61	1.36	4.67	0.15	1.03	0.02	0.09	2.68	0.012
TEC (%)	5.0	ND	25	10.	12.0	35.0	31.6	ND	ND	22.7	4.34	0.099	4.0	ND

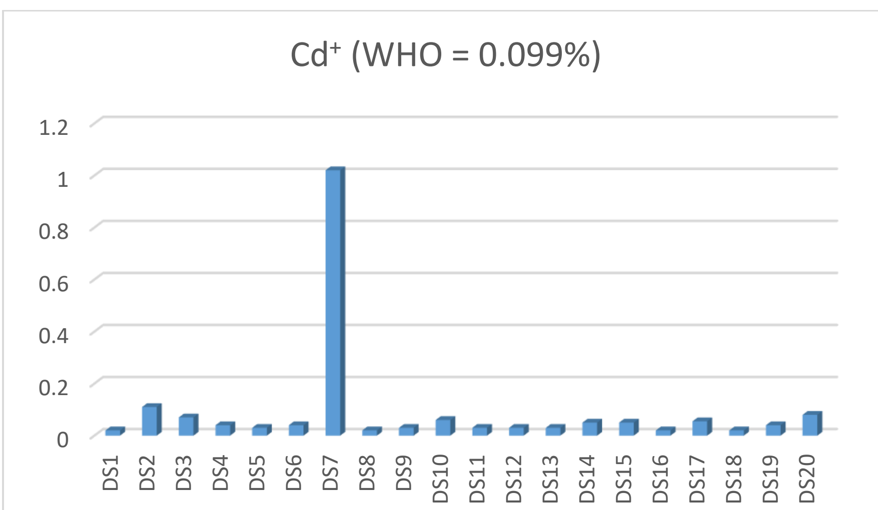

Fig. 16: Variation plot of Cd ion concentration in Daranna sediment

Table 6. Cation concentrations in Daranna River sediments

LOC	Na	K	Ca	Mg	Zn	Pb	Cu	Fe	Mn	Ni	Cr	Cd	Co	Sr	Al
DRS1	0.75	0.7	1.85	3.8	0.15	0.74	1.17	4.6	0.06	1.03	0.05	0.028	3.23	0.01	26.5
DRS2	1.0	0.6	1.75	4.0	0.13	1.16	1.55	4.7	0.07	1.03	0.01	0.026	1.44	0.004	27.30
DRS3	1.1	0.75	1.5	3.8	0.43	3.25	1.25	4.85	0.06	1.02	0.01	0.072	1.22	0.006	32.1
DRS4	0.75	0.5	1.75	4.0	0.40	1.16	1.15	4.6	0.06	1.02	0.01	1.020	2.53	0.004	32.0
DRS5	1.0	0.6	1.9	3.75	0.05	2.23	1.33	4.5	0.06	1.04	0.01	0.017	3.32	0.002	27.5
DRS6	1.1	0.5	1.65	4.0	0.23	3.48	1.15	4.75	0.05	1.02	0.01	0.032	3.22	0.006	27.15
DRS7	1.3	0.75	1.65	3.4	0.24	3.34	1.20	4.6	0.07	1.03	0.01	0.058	3.50	0.008	29.0
DRS8	1.1	1.0	1.8	3.2	0.25	1.33	1.17	6.5	0.055	1.03	0.01	0.018	3.34	0.014	29.6
DRS9	1.2	1.0	1.6	4.0	0.22	0.45	1.60	4.5	0.06	1.01	0.01	0.037	2.42	0.010	31.25
DRS10	0.85	0.75	1.7	104.25	0.56	0.56	1.20	154.75	115.5	1.03	0.02	0.022	0.03	0.006	30.2
Lowest Value (%)	0.75	0.5	1.5	3.2	0.05	0.45	1.15	4.5	0.05	1.01	0.01	0.018	0.03	0.01	26.5
Maximum Value (%)	1.3	1.0	1.9	104.25	0.56	3.48	1.60	154.75	115.5	1.04	0.05	1.02	3.5	0.08	32.1
Average value (%)	1.02	0.72	1.72	13.82	0.31	1.77	1.28	19.84	11.6	1.03	0.02	0.13	2.42	0.007	26.33
TEC (%)	5.0	0.25	25	10.0	12.0	8	31.6	4.09	0.4	22.7	0.05	0.099	ND	ND	ND

The river sediments DRS1-DRS10 were collected along the river channel, covering the length of the village. The results of the concentration values of the heavy metals and the trace elements such as the Ni, Cr, Cd, Co, and Sr were given in Table 6. The results obtained were compared with TEC values (Table 6). In the river sediment samples, the heavy metals with values greater than the TEC values are Mg and Fe.

However, consensus sediment quality guidelines (CSQGs) include the Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC). The guidelines serve to protect aquatic organisms. It should be noted that the concentration value below the TEC value indicates non-harmful, while those values above the PEC are likely to be harmful. The Mg+ concentration for the ten samples are low except Sample DRS10. The Samples DRS1-DRS9 values vary from 3.2-4.0%; less than the TEC value of 10.0%. However, Sample DRS10 has exceedingly high value of Mg+ of 104.25%, far greater than the TUC value of 10% (Table 6; Fig. 17). Toxicity level of the Mg+ in Sample DRS10 could be as a result of the proximity of the sampled point to the mining site, while the other sampled points are relatively farer from the entrance of discharge of the mining washed wastes into the river. The toxic effect of the high Mg ion exposure can lead to hypermagnesemia which include effect on neuromuscular system, cardiovascular system such as nausea blocker, low blood pressure (hypotension), bradycardia (slow heart rate), arrhythmias, and complex heart block or cardiac arrest; gastrointestinal and general symptom such as nausea, vomiting, abdominal cramps, facial flushing, and infusion.

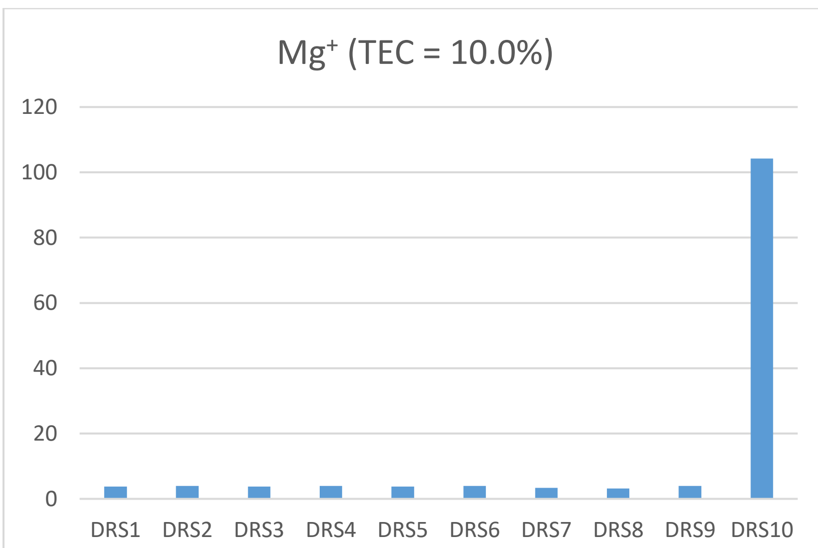

Fig. 17: Variation plot of Mg ion concentration in Daranna River sediments

In the case of Fe (ion), the concentration value is high in all the analysed 10 samples. The value ranges from 4.5-154.75% (Table 6; Fig. 18). The toxicity of Fe is as a result of the manganese mining. Its toxicity level is hazardous to life and could cause series of health complications such as oxidative stress, and damage to tissues, particularly the liver, heart and pancreas. Others are joint pains, reproductive issues, (lower libido, erectile dysfunction, and irregular menstrual periods), contribute to a wide range of cancers (Wasserman *et al*., 2006; Menezes-Filho *et al*., 2009; Miah *et al*., 2022). Excessive iron consumption contributes to cancer in developed countries (Jaishakar *et al*., 2014).

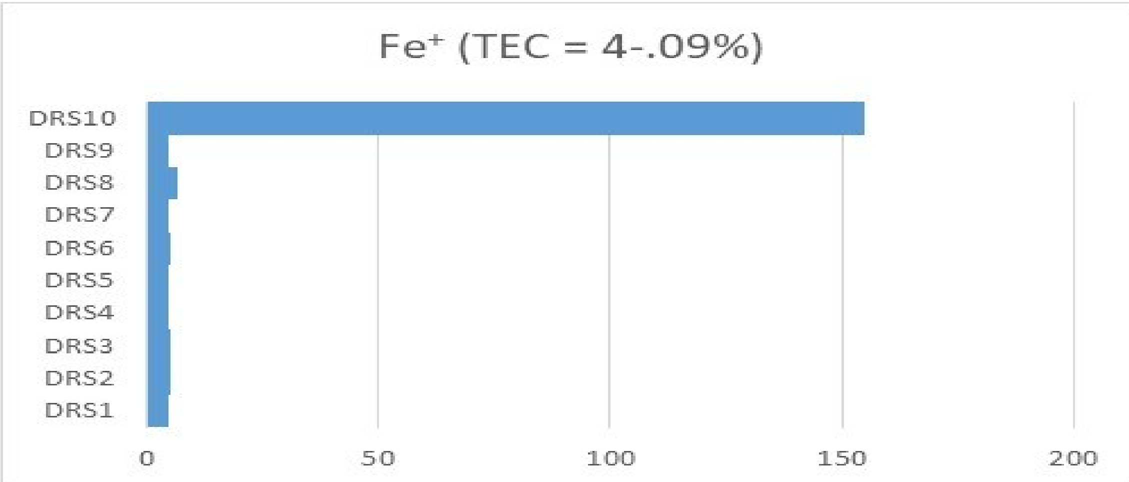

Fig. 18: Variation plot of Fe ion concentration in Daranna River sediments

Another contaminant element that is prevalent in the river sediment with high toxicity level is Mn (ion) which is noticeable in only one sample. The Sample DRS10 is the only sample with Mn concentration value far above the TEC for river sediment. Generally, the manganese concentration varies from 0.05-115.5% compared to WHO (2022) safety limit of 0.4%.Only Location DRS10 has the anomalous toxicity of 115.5% (Table 6; Fig 19). The high value is suggested to be as a result of the location of the location point very close to the mining discharge point to the river. This high level of toxicity is hazardous to the community

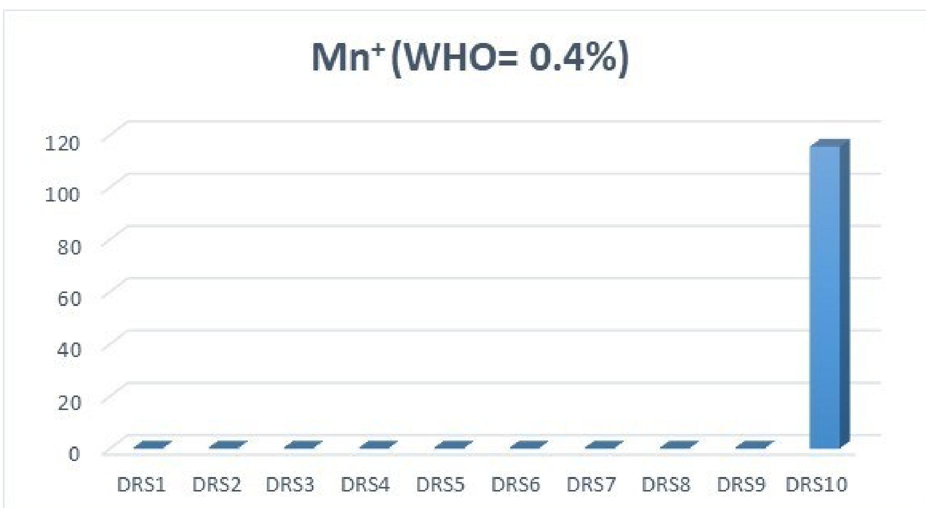

Fig. 19: Variation plot of Mn ion concentration in Daranna River sediments

The toxic effects of the manganese contaminant are enormous. It could cause intellectual impairment such as lower scores in mathematics and IQ tests, memory loss, attention problems; increased hyperactivity, aggressive behavior, and motor dysfunction (Bouchard *et al*., 2011; Menezes-Filho *et al*., 2014; Bjorklund *et al*., 2017).

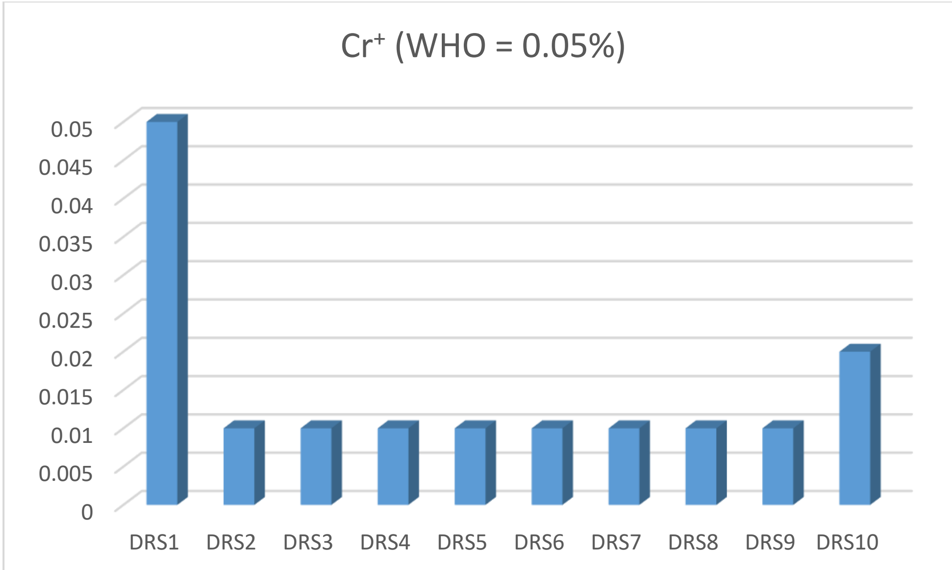

Fig. 20: Variation plot of Cr ion concentration in Daranna River sediments

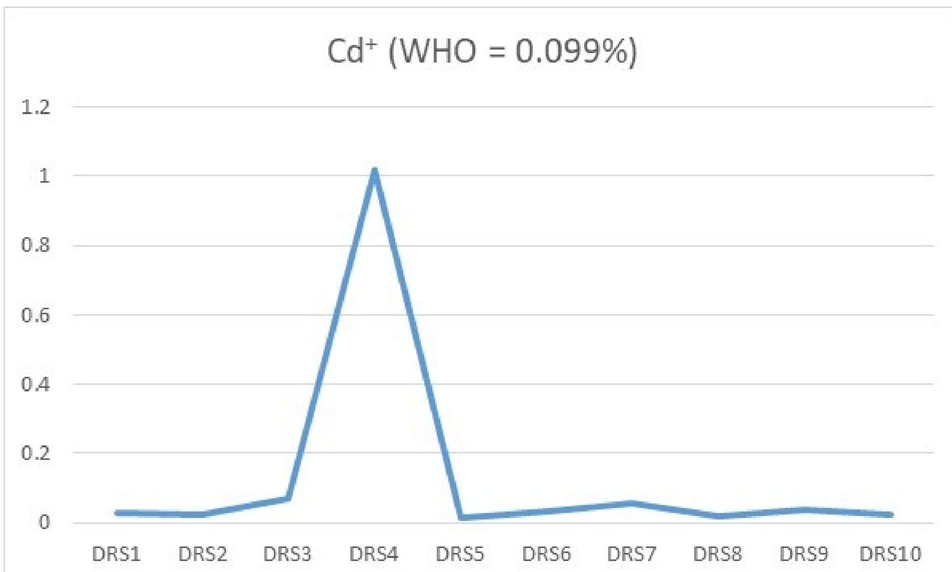

Fig. 21: Variation plot of Cd ion concentration in Daranna River sediments

4.0 Conclusion

Geochemical analyses of well (groundwater) and river waters, land and river sediment were carried out on Daranna Mining community to determine the environmental impact of the mining activities on the inhabitant and the aquatic organisms. The results of the well water shows that out of the twenty samples, only the K and Pb concentration values from the heavy metals show higher concentration values greater than the WHO (2022) toxicity limit, while in the anions, only the Cl and NH4 have higher values than the limits in all the samples. The trace elements show that only the Cr, Cd, and Co trace elements had toxic values. River water results show similarity in the Cl and NH_4 for the heavy metals, anions (PO_4), and the trace elements. Land sediments have only Cd toxicity presence in Sample DS7, greater than Threshold Effect Concentration

(TEC) level. The river sediments have Mg and Mn (ions) higher than safe limit in only Sample DRS10, possibly due to proximity to discharge point into the river, and all the samples show high toxicity value for Fe. These pollutants have anomalous values greater than tolerant level of WHO (2022) and TEC toxicity limits, thereby, are health hazards to human, animals, and aquatic life ecosystem.

Acknowledgement

The authors are gratefully indebted to the Federal University Birnin Kebbi, Nigeria for the opportunity given to carry out this research through the sponsorship assistance from Tertiary Educational Trust Fund (TETFUND; Internal Based Research of the University). We appreciate the Head of the Daranna community and local people for granting us permission to collect well water, river water, land sediment and river sediment samples from various sources for the study. We are immensely grateful to the reviewer for his constructive corrections and suggestions towards improving the quality of this paper.

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Declaration

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public

Conflict of Interest

The authors declared no conflict of interest

Ethical Considerations

Not applicable

Competing interest

The authors report no conflict or competing interest

Funding

The author declared no source of funding

Authors' Contributions (60 words)

Ola-Buraimo Abdulrazaq Olatunji conceived the study, designed the methodology, supervised sampling and analyses, and prepared the manuscript. Adeleye Mutiu Adesina supported methodological development, data interpretation, and critically reviewed the manuscript. Yusuf Aminu conducted field sampling, assisted laboratory analyses, organized data, compiled literature, and contributed to manuscript preparation and editing.