Assessment Pollution Levels Associated with Heavy Metals Existed in Water, Soil, and Leaves of Plant in Mayo-Kebbi Ouest-Republic of Chad-(2022)

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Abstract: ***This study aims to assess pollution levels associated with heavy metals according to their concentration in water, soil and plant samples that have been taken from the mining area in state of Mayo-Kebbi Ouest in republic of Chad. The samples were taken from two locations, inside mine (mining area) (site 1) and outside of astrologer 20km away (site 2). Samples have been analyzed in laboratories of petroleum ministry in Khartoum city, by using Fluorescent X-ray Spectrometer (X-MET5000). According to laboratory analysis, the pollution index in water sample ranged between (2.8-3.4), whereas, the pollution status in the water sample ranged from serious to very serious pollution. This is attributed to the high concentrations of most elements above the level allowed by the World Health Organization (WHO). The highest concentrations of iron (Fe^2), chromium (Cr^2), tungsten (W^2) and nobelium (Ni^2) respectively were observed in site 2. While same elements in site 1 recorded the low concentration. As for the soil sample, an irregular decrease in the concentration of some elements is observed, which caused decrease in pollution degree. When comparing the values of pollution index occurring in both water and soil for each element separately, it was noted that the percentage of pollution in water sample was greater than the percentage of pollution in the soil sample for the two sites. Where the percentage of water pollution in two sites resulting from tungsten ($W^{1,\,2}$) reached 99.9%, while the percentage of water pollution in site 2 resulting from iron (Fe^1) reached 98%. Grade of pollution in plant sample is observed very low in both two sites, except element of tungsten (W^1). Evaluation both of ecological risk factor (E_rF) and risk degree in soil sample for two locations, showed that both of lead (Pb^2) and zinc (Zn^2) reached very high risk.***

Keyword: Concentration, Heavy Metals HMs, Mine, Mayo-kebbi, Republic of Chad, pollution index, ecological risk index, Risk degree

1. Introduction

Several research studies have shown that heavy metal contamination and pollution emanate principally from natural and anthropogenic activities [1, 2]. By definition, heavy metals (HM) are metals of specific high densities greater than 5 g/cm^3 and of high molecular mass, transition metal, and of negative effects on the living things and the ecosystem [3]. This study aims to assess levels of the concentration and contamination of heavy metals such as in water, soil and plant samples that have been taken from two locations, inside mining and outside mining 20km from mining in state of May-kebbi Ouset in republic of Chad. Practically, the samples were examined in the laboratories of the Ministry of Oil in Khartoum, and they were placed inside plastic bags. Theoretically, some mathematical formulas have been used to determine the levels of contamination arising from heavy metals in each of the water, soil and plant leaves samples in both regions.

Water is essential for the balance of the environment, the economic development, and the social well-being of nations; therefore, the preservation of its quality is necessary [10]. Some metals such as Copper (Cu), Zin (Zn), manganese (Mn), iron (Fe) play essential roles in biochemical processes in the human body [11]. However, long-term exposure to heavy metals can cause high levels of toxin accumulation in the body, leading to the failure of body systems and eventual fatality [13, 14]. In one of the previous studies conducted in the Tigray region in northern Ethiopia, which aimed to assess the state of drinking water in urban areas, the study concluded that the iron concentration is similar to the standard concentration of the World Health Organization (WHO) for the year 2008 [9]. In water sample we revealed that Chromium ($Cr^{1,\,2)}$ as shown in table (1), is recorded high ratio in concentration which is reached 99.9%, followed by ($Fe^{1,\,2)}$ with ration 72% compared with concentration limited by WHO. Soil is an important resource for human survival, whose quality determines the quality of agricultural products and directly affects people's health [15]. In soil sample Nemerow comprehensive index Nemerow comprehensive index (Pj), consist of 5 grades [25], while in this study, we find P_j consist of 3 grades. The result of this study has revealed that accumulates Nickel (Ni^1), and tungsten (W^1) in plant compared with other metals as shown in table (4), and when we compare BCF of Pb, Ni, and Fe in table (4) with BCF of similar element in [24], we noted that BCF of Pb in current study, is less than BCF of Pb in [24] and Ni in current study is greater than BCF Ni in [24], also BCF of Fe in current study is greater than BCF in Fe of [24].

2. Material and Methods

2.1. Overview of the Study Area

The region of Mayo-Kebbi Ouest is one of the 23 regions of Chad, and its capital is Pala (09°210 50.72100N, 14°54034.86400E). It covers an area of 12, 479 km^2 and had 564, 470 inhabitants in 2009. This region has a long history of mineral prospecting and mining. A cement plant was built there, the exploitation of gold is artisanal, and the prospection of uranium and oil has been intensified.

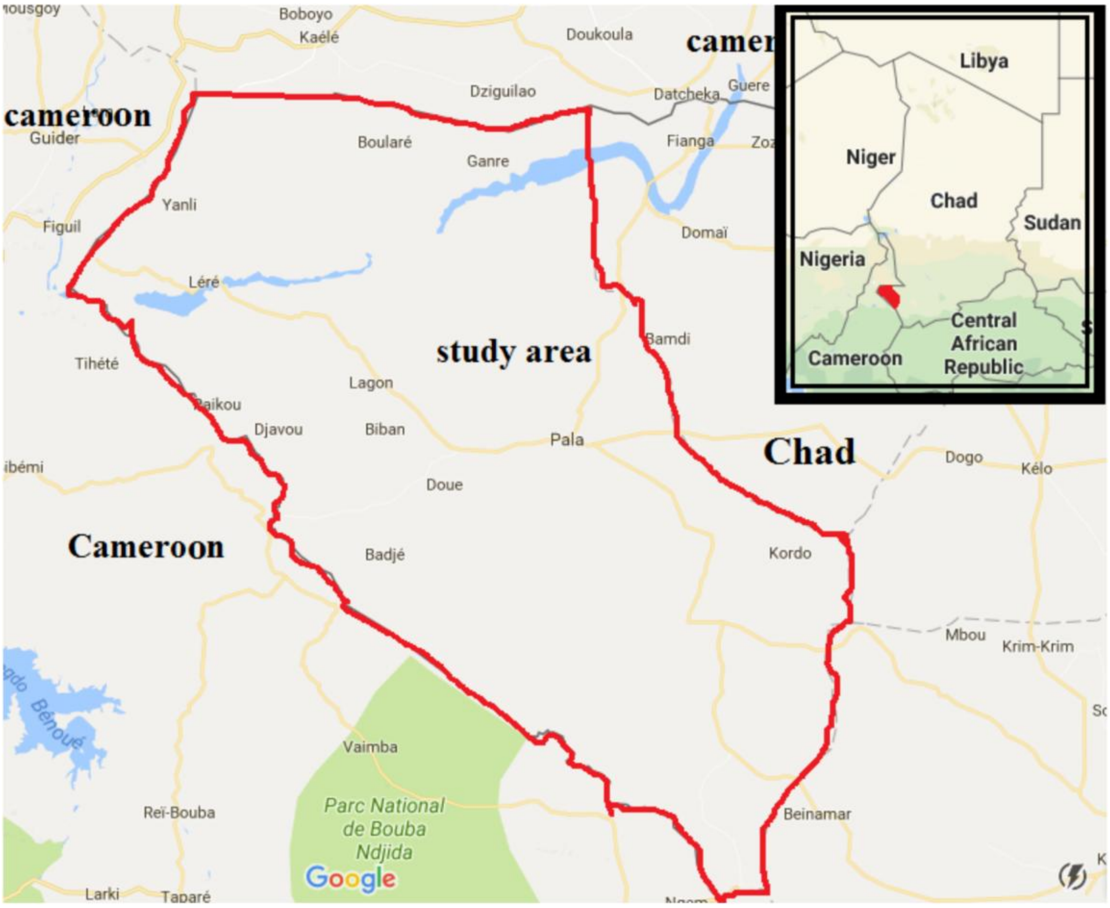

Figure 1: Map showing the location of May-kebbi Ouset region (provided by Google Map)

A previous study similar to the current one was conducted in 1970, it aimed to determine the level of radioactivity emanating from buildings materials [20, 21]. . These mining activities are performed in a disordered way, and without respecting the international standards (ISO/TC 82/ SC 7) that can help minimize the potential long-term damage from mining activities, thus enhancing the quality of life of residents living in a mining area [20, 21]. . Our investigation covered two locations, inside mining and outside mining 20 km from mining.

2.2 Collection and analysis samples

In January 2022, 29, samples of water, soil, and plant leaves were collected from two locations in the study area, the first location is the vicinity of the mine, while the second location is twenty kilometers from the mine. The samples were taken in plastic containers, and then labeled so as to distinguish between them according to their locations. Samples have been analyzed in laboratories of petroleum ministry in Khartoum city, by using Fluorescent X-ray Spectrometer (X-MET5000). Firstly, 5 grams were taken from each sample, then placed on one of the calibration slices, which are used to adjust the analysis device (X-ray spectrometer x-MET5000). X-ray spectrometer (X-MET5000) is characterized by the ability to analyze chemical elements according to their atomic numbers, starting from the helium element to the heavy elements whose atomic weight exceeds 11. Determining the concentration of an element in a sample, this requires preparing the selected sample according to the metal slices used in the calibration; afterward adjust the analyzer by using calibration slices (metal slices). After the preliminary procedures, the sample was placed inside the irradiation chamber within the analyzer. The measurement process requires placing the head of the analyzer in the sample and then pressing the power button so that the pressing continues for five seconds. Then it can be seen that a spectrum of the sample appears. For more accurate results, the sample must be dry, clean, homogeneous, and have a flat surface. Also, to obtain a more reliable analysis, the analyzer window must be in direct contact with the sample, because the X-ray signal decreases with increasing distance in the tube.

In order for soil samples and plant leaves to be ready for the analysis process, in lab, samples should be dried in a vacuum freezer dryer. The drying process of the samples took place after ensuring that the plastic containers were free of chemical elements such as: Titanium (Ti), and Zinc (Zn), because these elements distort the analysis process. Finally, according to the procedural arrangement in the laboratory, the concentrations of heavy metals were measured in water, soil and plant leaves samples at the two sites within the study area.

2.3 Evaluation of the heavy metals pollution

Nemerow comprehensive index method has been used to obtain a comprehensive pollution index of various pollutants through a single factor pollution index (Pi), so as to comprehensively evaluate the pollution degree of all pollutants [4]. P_i could be described as follow

$$P_i = \frac{C_{ij}}{C_{is}} \quad (1)$$

Where C_{ij} is the concentration of element i in sampling point j, and C_{is} is the risk screening value of element i[5].
The pollution degree and potential ecological hazard of heavy metals in the soil were evaluated by the Nemerow comprehensive pollution index [4], geoaccumulation index [5], and potential ecological hazard index [6].

The formula for the Nemerow comprehensive index is as follows [7]

$$P_j = \sqrt{\frac{P_{j\,max}^2 + P_{av}^2}{2}} \quad (2)$$

To evaluate the impact of heavy metals on the soil [18, 19], , the geo-accumulation index I_{geo} has been used, where

$$I_{geo} = \log_2 \left[\frac{C_i}{1.5B_i}\right] \quad (3)$$

Where C_i is the measured concentration of element i, B_i is reference value of element i

In other ward To characterize the adsorption and accumulation effect of HMs in crops from the soil [8], the bioconcentration factor [5] was determined as follow

$$BCF = \frac{C_{plant}}{C_{soil}} \quad (4)$$

Where C_{plant} is concentration of individual elements in the plants (mg/kg), and C_{soil} represents the corresponding value in the soil (mg/kg).

To know ecological risk factor (E_rF), and risk index (RI) we can used [15]

$$E_rF = RI \times CF \quad (5)$$

and

$$RI = \sum E_rF \quad (6)$$

Where CF is contamination factor which is given by expression

$$CF = \frac{C_m}{C_b} \quad (7)$$

Where C_m is the concentration of heavy metal, and C_b is background concentration.

CF is based on four categories of contamination illustrated by [17]

1- Low $CF < 1$
2- Moderate $1 < CF < 3$
3- Considerable $3 > CF > 6$
4- Very high $CF > 6$

Also, ErF can be calculated by using formula [17]

$$E_rF = TR \times CF \quad (8)$$

Where TR is toxic response factor.

3. Results and discussion

Table 1: classification of Contamination index P_N of some heavy metals in water sample for two locations

Metal	Concentration (µg/L)	Concentration limited by WHO (µg/L)	Pollution index Pi	Grade	pollution Status
Ni_1	4010 ± 1	20	2.9	I	polluted
Ni_2	7350 ± 1331	20	3.1	Π	seriously polluted
Pb_1	5010 ± 0.000	10	3	Π	Seriously polluted
Pb_2	-	10	-	-	-
Cr_1	3520 ± 3	50	2.8	I	polluted
Cr_2	11640 ± 1666	50	3.4	ш	Very seriously polluted
Fe_1	8010 ± 9	300	3.2	ш	Very seriously polluted
Fe_2	12110 ± 960	300	3.4	ш	Very seriously polluted
W_1	7070 ± 124	-	3.1	Π	seriously polluted

W_2	9670 ± 7	-	3.3	ш	Very seriously polluted
Mn_1	4010 ± 1	400	2.9	I	polluted
Mn_2	3270 ± 389	400	2.8	I	polluted
Nb_1	8340 ± 443	-	3.2	ш	Very seriously polluted
Nb_2	6070 ± 100	-	3.1	П	Seriously polluted

According to Eq (1) P_j index is equal 3.1 which is confirm very seriously polluted occur in water sample for both two locations of study area.

Table 2: illustrates classification of contamination factor index of some heavy metals according to their concentration in soil sample for two sites

Metal	Concentration (µg/k)	CF	Range of CF	Grade	pollution Status
Ni_1	13 ± 1	0.41	$CF < 1$	I	low
Ni_2	1010 ± 1	2.3	$1 < CF < 3$	П	Moderate
Pb_1	180 ± 0.000	1.5	$1 < CF < 3$	П	Moderate
Pb_2	3010 ± 1	2.8	$1 < CF < 3$	П	Moderate
Zn_1	20 ± 1	0.6	$CF < 1$	I	low
Zn_2	4190 ± 6	2.9	$1 < CF < 3$	П	Moderate
Cu_1	2010 ± 439	2.6	$1 < CF < 3$	П	Moderate
Cu_2	5010 ± 4	3	$1 < CF < 3$	П	Moderate
Fe_1	413 ± 10	1.92	$1 < CF < 3$	П	Moderate
Fe_2	11030 ± 8	3.34	$3 > CF < 6$	ш	Considerable
W_1	8050 ± 231	3.21	$3 > CF < 6$	ш	Considerable
W_2	7280 ± 4	3.2	$3 > CF < 6$	ш	Considerable

Table 3: illustrates values of geo-accumulation index of some heavy metals according to their concentration in soil sample for two sites

Metal	Concentration (µg/k)	P_i	I_{geo}	pollution Status
Ni_1	13 ± 1	0.41	0.76	Slight pollution
Ni_2	1010 ± 1	2.3	7	Moderate pollution
Pb_1	180 ± 0.000	1.5	4.5	Moderate pollution
Pb_2	3010 ± 1	2.8	8.6	Moderate Severe pollution
Zn_1	20 ± 1	-0.22	1.4	pollution
Zn_2	4190 ± 6	2.9	9.1	Severe pollution
Cu_1	2010 ± 439	2.6	8	Moderate Severe pollution
Cu_2	5010 ± 4	3	9.4	severe pollution
Fe_1	413 ± 10	1.9	5.8	Moderate pollution
Fe_2	11030 ± 8	3.3	10.5	Extremely severe pollution
W_1	8050 ± 231	3.2	10	Extremely severe pollution
W_2	7280 ± 4	3.1	9.9	severe pollution

Table 4: shown classification of Pollution index P_i, Bio concentration factor (BCF), and their grade pollution of some heavy metals in sample of plant leaves for two sites

Metal	Concentration µg/kg	Pi	BCF	Grade	pollution Status
Metal	10 ± 1	0.3	0.77	П	Slight polluted
Ni_1	10 ± 1	0.3	0.009	П	Slight polluted
Ni_2	2 ± 3	-0.39	0.011	I	No polluted
Pb_1	10 ± 1	0.3	0.0033	П	Slight polluted
Pb_2	30 ± 7	0.78	-	П	Slight polluted
Cr_1	30 ± 0.008	0.78	-	П	Slight polluted
Cr_2	10 ± 5	0.3	0.024	П	Slight polluted
Fe_1	10 ± 4	0.3	0.000907	П	Slight polluted
Fe_2	6340 ± 8	3.1	0.79	ш	Very seriously polluted
W_1	6340 ± 8	3.1	0.79	ш	Very seriously polluted

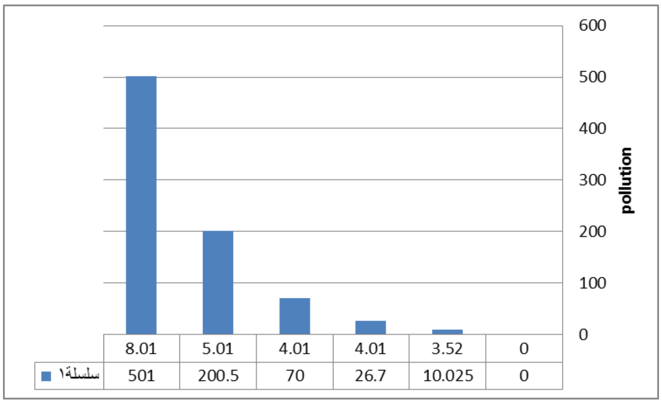

Figure 2: show the relationship between HMs concentration in water sample and their pollution index, for site 1

Table 5: shown the concentration of HMs, Ecological Risk Factor, and risk degree in soil sample

Metal	Concentration (μg/kg)	E_rF	Range	Risk degree
Ni^1	130 ± 1	36.4	$E_rF < 40$, $RI < 40$	Low risk
Ni^2	1010 ± 1	464.6	$E_rF < 500$, $RI < 500$	High risk
Pb^1	180 ± 0.000	54	$E_rF < 60$, $RI < 60$	Moderate
Pb^2	3010 ± 0.001	1625	$E_rF < 1700$, $RI < 900$	Very high risk
Zn^1	20 ± 1	2.4	$E_rF \ll 40$, $RI \ll 40$	Low risk
Zn^2	4190 ± 6	2430	$E_rF < 2500$, $RI < 2500$	Very high risk
Cu^1	2010 ± 439	1045	$E_rF < 1100$, $RI < 1100$	Very high risk
Cu^2	5010 ± 4	3006	$E_rF < 4000$, $RI < 4000$	Very high risk
Fe^1	413 ± 10	155	$E_rF < 160$, $RI < 160$	Moderate
Fe^2	11030 ± 8	7279	$E_rF < 8000$, $RI < 8000$	Very high risk

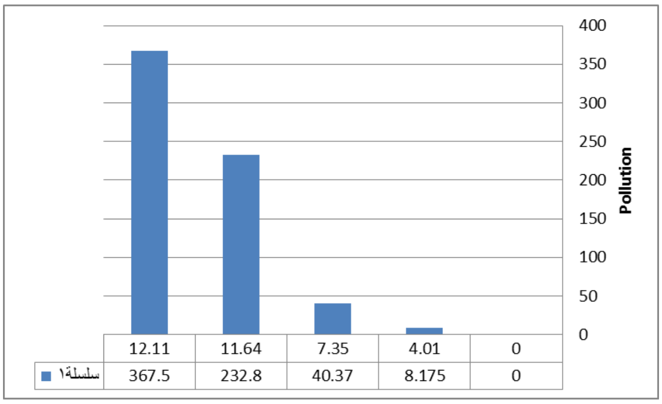

Figure 3:. show the relationship between HMs concentration in water sample and their pollution index, for site 2.

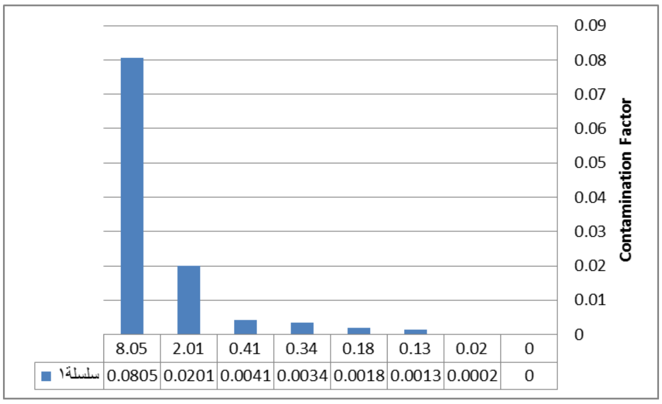

Figure 4: illustrates the relationship between HMs concentration in soil sample and Contamination factor

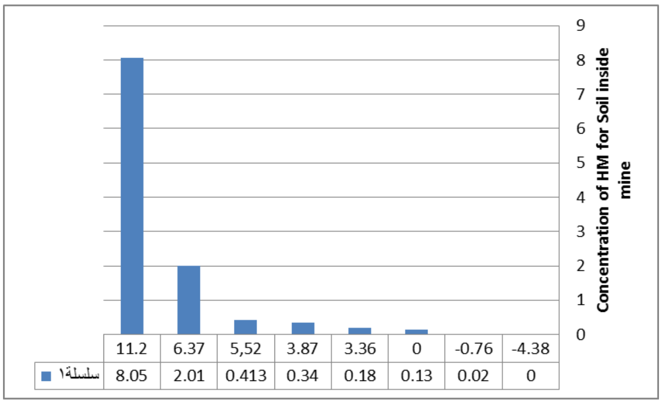

Figure 5: show the relationship between geo-accumulation index I_{geo} and concentration of HMs for soil sample.

From table (1), it is noted that iron ($Fe^{1, 2)}$ recorded highest average concentration in the water sample within the two sites, accompanied by an average pollution index (3.3.). Whereas an excess iron in vital organs increases the risk for liver disease, as shown by [23], Tungsten ($W^{1, 2}$) ranked second after ($Fe^{1, 2)}$ with an average concentration (8370 µg /L) with an average pollution index (3.2). While the manganese element ($Mn^{1, 2)}$ recorded the lowest average concentration (3640µg /L) in the water with an average pollution index (2.85). The results in table (1), show that all elements have an average concentration higher than the concentrations approved by the World Health Organization (WHO), except Tungsten (W) and Niobium (Nb). The average concentrations of elements in the water in table (1) enhance the possibility of environmental pollution in the study area at rates that may reach the serious risk. According to [22], insufficient or excess levels of iron can have negative effect on body functions. In general, according to a previous study [24], and according to the results in table (1), we find the following elements, $Cr^{1, 2}$, $Fe^{1, 2,}$ $Mn^{1, 2,}$ $Ni^{1, 2}$, $Pb^{1, 2}$, may cause health risks for humans in the study of area.

Tables 2 and 3, indicate low levels of pollution from most of the elements in the soil sample, except ($Fe^{1, 2)}$ and ($W^{1, 2}$). Table (4), shows very low pollution levels for the plant sample except ($W^{1, 2}$). Table (5), confirms the high level of environmental hazards in the study area in terms of the ecological risk factor (E_rF) and risk index (RI) caused by elements (Fe^2), (Pb^2), (Zn^2), (Cu^2).

Figures 2 and 3, show the different levels of pollution of the water sample in the two locations, where a higher degree is observed in location 2 than for location 1. While Figures 4 and 5, show the difference between the geo-accumulation index I_{geo} and contamination factor (CF) and their impact on the environment of the study area, where a high geo-accumulation index was observed.

4. Conclusion

The results of our study have revealed that the levels concentration of $Fe^{1.2,}$ $W^{1, 2}$, $Cr^{1, 2,}$ $Ni^{1, 2}$, $Pb^{1, 2,}$ $Nb^{1, 2}$, and $Mn^{1, 2}$ in water sample, were found exceed the concentration values that recommended by WHO. According to the results of the analysis conducted on water, soil and plant samples in the two locations within the study area, different levels of pollution were observed in all samples, caused by high and low concentrations of heavy elements, and this may lead to risks threatening the environmental and vital systems in the study area. In plant sample, we observed that BCF of (Ni) in current study is greater than BCF of (Ni) found by [26]. Therefore, it is expected that the soil pores allow the passage of some heavy elements such as lead (Pb), nickel (Ni) and iron (Fe) as sediment to the plant. In addition, gold mining, cement plant and other factories of materials building may play a main role of source pollution caused hazardous for population of the study area.

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