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Relationship Between Soil Physico-chemical Parameters and Trace Element Concentrations in Clay Loam Soil in West EL-Fashir City, North Darfur State, Western Sudan

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Abstract: Monitoring of trace elements in soil provides efficient way to assess the qualitative and quantitative differences in element concentrations at different sites within a region. The aim of the study was to assess levels of trace elements regarding accumulation of the metals, as well as investigate whether of the soil factors (chemical and physical) which influence trace element concentrations in soil. The physico-chemical parameters (viz. pH, EC, MC, OC, and textural class) and trace elements concentrations i.e Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb and Zn have been determined in the soils from caly loam region in west AL-Fashir city, Western Sudan. The top soil of this region is predominantly loamy sand. The soil pH varies within the acidic or slightly neutral and range between 6.62 – 7.72. The EC values were found to vary between 0.155-0.360. OC is very low (mean 0.081±0.007). MC range between 0.230 – 0.430%. Average trace element concentrations decreased according to: Fe-Co-Ni-Cr-Zn. The sub-soil of this region is predominantly loamy sand. The soil pH varies within the range 6.02-7.10. The EC values were found between 0.162-0.275. OC is very low (mean 0.093+0.020). MC range between 0.230-0.430%. Average trace element concentrations decreased according to: Fe -Mn-Cr-Zn. The t-test showed that, elemental pairs: Ni-Cd, Cd-Cr, Mn-Cr, Pb-Cd, Cu-Cr, Cu-Cd, Cu-Mn, Zn-Cd, Fe-Mn, Fe-Pb, Fe-Cr, and Fe-Mo were showed significant differences in their concentrations in the study region, top-soil. In the top-soil, pH was high positively correlated with silt (r=0.760), whereas in the sub-soil, pH was highly positive correlated with EC (r= 0.755). The extraction of trace elements from soils of North Darfur for industrial use (especially, Fe, Cr and Cu) should be investigated.

Keywords: Soil Physico-Chemical Parameters, Trace Elements, Clay Loam Soil, West Al-Fashir, North Darfur, Western Sudan

1. Introduction

Soil is a natural body, differentiated into horizons of minerals and organic constituents, usually unconsolidated, of variable depth, which differs from the parent material below the morphology, physical properties and constitution, chemical properties and composition and biological characteristics.

Different soils have varying potential to support different land use types. The productivity of a soil depends largely on its physico-chemical properties. These properties are as a result of the interaction among the soil forming factors. Where the relative influence of these factors differs, it will give rise to different kinds of soils with different productivity potential. Therefore in order to derive the maximum benefit from a soil, it is necessary to know its physical and chemical properties.

Metals are persistent pollutants that can be biomagnified in the food chains becoming increasingly dangerous to human and wildlife. Assessing pollutants in different components of

the ecosystem has become an important task in preventing risk to natural life and public health. Trace metals enter into the environment mainly via three routes: (i) Deposition of atmospheric particulate (ii) Disposal of metal enriched sewage sludge and sewage effluents and (iii) By-products from metal mining process. Trace metal concentration in the soils is a major concern because of their toxicity and threat to human life and the environment [1]-[3]. Trace metal studies are necessary to evaluate both soil/sediment and ground water contamination. Trace metals and other heavy elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and air. Trace and heavy elements are released into the environment from the natural weathering of rocks and minerals and from various sources related to human activity. Although the concentration of these elements occurring naturally in the environment is generally small, they may directly or indirectly affect the chemical composition of food-stuff and animal feed, potable water supplies and airborne particulates and dust [4], [5].

The objectives of this study were to: (1) Assess levels of trace and heavy elements in study region in North Darfur soils and to provide information regarding accumulation of these metals. (2) To evaluate the concentrations of selected trace and heavy elements in top and subsoils of the study region. (3) To determine the most important soil factors (chemical and physical) which influence trace and heavy elements concentrations in soil.

2. Materials and Methods

2.1. Soil Sampling

Soil samples were collected from West AL-Fashir, North Darfur, Western Sudan at the 0-20 cm depth (Top-soil) and the Sub-soil (approximately the 20-40 cm depth).

2.2. Analysis of Soil Physico-Chemical Properties

2.2.1. Soil Physical Analysis

(i) Particle Size Distribution:
The two common procedures used for particle size analysis or mechanical analysis are the 'hydrometer' method. [6].

(ii) Apparatus

Soil dispersing stirrer: A high-speed electric stirrer with a cup receptacle.
'Hydrometer' with Bouyoucos scale in g/L (ASTM 152H).

(iii) Reagents
(1) Dispersing solution
40g sodium hexametaphosphate {(NaPO$_3$)$_{13}$}, and 10g sodium carbonate (Na$_2$CO$_3$) were dissolved in DI water, and bring to 1mL volume with DI water.

(2) Amyl Alcohol

(iv) Procedure
Forty grams of each of the soil samples were weighed and introduced into a 600ml beaker. Sixty mL of the dispersing solution were added to the weighed soil sample. The content of the beaker were covered with a watch glass, and leave overnight. Contents of the beaker were quantitatively transferred to a soil stirring cup, and the cup was filled to about three quarters of its capacity with water. The suspension was transferred into a 1 L calibrated cylinder (hydrometer jar) and was then brought to volume. The suspension was stirred at high speed for three minutes using the special stirrer and the stirring paddle was rinsed into the cup, and allowed to stand for 1 minute.

Silt, clay and sand readings: The suspension was mixed in the hydrometer Jar using the paddles, which was then withdrawn, and the hydrometer was inserted and the hydrometer reading was recorded as solution readings (R_{sc}).

(1) Determination of Blank
Sixty mL dispersing solution was diluted to 1L hydrometer jar with water and was mixed well, and hydrometer was inserted, and hydrometer reading was taken, R_b.

The blank reading was re-determined for temperature changes of more than 2°C from 20°C.

(2) Determination of Silt plus clay
Suspension in the 'hydrometer' jar was mixed, using a special paddle carefully, withdraw the paddle was withdrawal, and immediately the 'hyderometer' was inserted. Any froth was dispersed with one drop of amyl alcohol, and hydrometer reading was taken 40 seconds after withdrawal the paddle. This gives reading, R_{sc}.

(3) Calculations
Percentage silt plus clay in soil

$$\%[Silt + Clay](w/w) = (R_{sc} - R_b) \times \frac{100}{Oven-drySoil} \quad (1)$$

Where: R_{sc} = solution readings, R_b = blank readings, weight of sand follows from:

$$Sand\ weight(g) = [Beaker + Sand\ (g)] - [Beaker\ (g)] \quad (2)$$

(v) Soil Texture
Once the percentage of sand, silt, and clay is measured, the soil may be assigned a textural class using the Table of textural soil types in (Forest Service Handbook. Washington, DC, 1960, Department of Agriculture, US) [7]. Within the Table of textural soil type various soil textures which depend on the relative proportions of the soil fraction.

2.2.2. Chemical Analysis of the Soil
The pH of the soil was measured in a soil water suspension (1: 2, soil: water). Organic carbon content (%) of the soil was determined by Wakley and Black method [8]. using 1g soil. Organic matter (%) was determined by multiplying the value of organic carbon by 1.724 (van bemmelen factor).

Saturation Percentage (SP) was determined on a soil paste made with distilled water, pH and Electrical conductivity

(EC) were determined from saturated soil extract. Organic Carbon (OC) was determined [9].

(i) Preparation of Saturated Soil Paste and Extract

(1) Preparation of saturated soil paste:

To an accurate weight of the dried soil sample (250g) distilled water was added, while stirring with the spatula. The paste was then left to stand for an hour and the criteria for saturation were again checked. Free water should not collect over the paste surface nor should the paste stiffens markedly or loses its glistening appearance on standing. The quantity of water added to saturate the paste was recorded.

(2) Preparation of the saturated soil extract:

The saturation extract was obtained by transferring the saturated soil paste to the Buchner funnel with the filter paper in place and suction was applied using the vacuum pump. The extract was received in the air-tight stoppered bottles. The vacuum was stopped when air started to pass through the filter paper.

(ii) Determination of the pH

The pH was determined by first calibrating the pH meter with two standard buffer solutions and directly immersing the electrodes in the saturated soil paste [10].

(iii) Determination of the Electrical Conductivity

The Electrical conductivity was determined directly by immersing the electrodes of the solubridge in the saturated soil extract [10].

(iv) Determination of Moisture Content

Soil moisture content was determined by oven drying method [11]. 10 g of soil sample was taken. The samples were oven dried at 105 C for 24 hrs. Dry weight of the sample was taken till it showed its constant weight. The loss in weight corresponds to the amount of water present in the soil sample. The formula below was used to calculate the percentage of moisture content in each of the soil sample.

$$\text{Moisture content (MC)}\% = \text{Loss in weight on drying (g)/Initial sample weight} \times 100 \tag{3}$$

The corresponding moisture correction factor for analytical results or the multiplication factor for the amount of sample to be weighted in for analysis was calculated as:

$$\text{Moisture Correction Factor} = 100 + \% \text{ Moisture content} / 100 \tag{4}$$

(v) Determination of Organic Carbon

The soil organic carbon analysis was performed according to standard procedure [7].

Reagents for organic carbon determination were prepared as follows:

Solution A: Potassium dichrome (1N) was prepared by dissolving 49.4g potassium dichloride in distilled water and dilute to one litre.

Solution B: Condensed sulphuric acid contain silver sulphate was prepared by dissolving 25 g silver sulphate in one litre condensed acid.

Solution C: Ferroin indicator (Ortho-phenanthroline Ferrous sulphate, 0.024M) was prepared by dissolving 14.85g indicator and 6.95 g Ferrous sulphate in distilled water and dilute to one litre.

Solution D: Ferrous sulphate (0.5 N) was prepared by dissolving 140 g $FeSO_4.7H_2O$ in water and 15 ml H_2SO_4 was added then the solution was diluted to one litre with distilled water.

Procedure:

Three grams of soil sample were weighed accurately into Erlenmayer flask (500 ml). 10 ml of solution A (Potassium dichromate, 1N) were added followed by 10 ml of solution B (sulphuric acid + silver sulphate). The sample was shaken, boiled + silver sulphate). The sample was shaken, boiled until the temperature reached 150 C for 1 minute, with continuous shaking. The flask was then cooled. 200 ml of distilled water were added followed by 5 drops of solution C (Ferroin indicator). The mixture was titrated with solution S (Ferrous sulphate) until the colour was change (from green to red).

Caluculation:

$$\% \text{ Organic carbon} = \frac{V_1 - V_2 \times N \times 0.003 \times 100 \times C}{W}$$

Where:

W = weight of sample

V_1 = Blank Titre value

V_2 = Titre value of the sample

N = Normality of $K_2Cr_2O_7$ (1 N)

C = Correction Factor (1.334, 1.724)

2.2.3. Determination of Trace Elements

One gram soil sample was decomposed with a HF-$HClO_4$-HNO_3 mixture followed by Atomic Absorption Spectrophotometry (AAS) for chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, zinc and cadmium [12], [13].

2.3. Statistical Analysis

Statistical analysis, such as descriptive statistics, correlation coefficients as well as t-test and regression equations were performed using SPSS 20.0 Software for Windows.

3. Results and Discussion

This research work provides documentation of the relationship between physico–chemical properties and heavy elements in soils of North Darfur. Tables 1-6 shows the descriptive statistics for the recorded trace and heavy elements contents in the Top- and Sub-soils of the study

region in North Darfur. Means and standard deviation used to describe central tendency and variation of the data. In addition to standard error values. Skewness and Kurtosis are also presented which can, to some extent, enable computing of the uniformity of the distribution which, in this particular case, was calculated (0.05 significance level). The values for

asymmetry kurtosis between -2 and +2 are considered acceptable in order to prove normal univariate distribution. S= Skewness/SE (Skewness), K=Kurtosis/SE (Kurtosis). Kurtosis value of 3 for a normal, while values exceeding 5 indicates data are nonnormality distributed.

Table 1. *Descriptive statistics – Topsoil.*

Parameters	pH	E. C	O. C	M. C	Clay	Silt	Sand
Mean	7.368	0.249	0.081	0.319	9.261	1.386	89.353
SD	0.357	0.078	0.007	0.071	1.374	0.074	1.404
Skewness	-1.066	0.297	-0.492	0.395	-0.395	-0.280	0.339
Kurtosis	2.999	1.335	2.535	1.509	1.552	2.830	1.613

Parameters	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Zn
Mean	37.910	3126.703	2901.027	2516.160	3366.796	782.643	739.416	2951.725	685.557	2202.979
SD	103.013	8706.353	8053.126	7006.497	2779.236	2035.657	2035.832	8211.718	1882.701	6100.520
Skewness	2.120	2.121	2.121	2.121	-0.429	2.119	2.120	2.121	2.120	2.120
Kurtosis	5.371	5.373	5.373	5.373	1.127	5.369	5.372	5.373	5.371	5.372

Table 2. *Descriptive statistics – Subsoil.*

Parameters	pH	E. C	O. C	M. C	Clay	Silt	Sand
Mean	6.523	0.211	0.093	0.357	10.258	1.76	87.983
SD	0.334	0.042	0.020	0.070	0.669	0.723	1.054
Skewness	0.122	0.228	1.207	-0.771	0.644	0.993	-0.645
Kurtosis	2.169	1.492	3.034	2.043	2.144	2.048	1.824

Parameters	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Zn
Mean	0.319	0.05	16.166	2.867	5629.375	85.119	6.054	6.054	3.337	15.174
SD	0.093	7.418	4.004	0.529	862.973	60.015	0.740	7.740	2.800	9.203
Skewness	0.6742	0.935	0.821	0.501	-0.380	-0.335	-0.128	-0.128	-0.257	0.601
Kurtosis	2.5030	0.875	2.558	1.764	2.195	1.725	1.334	1.334	1.167	2.730

The results of physico-chemical analysis (viz. pH, EC, O. C, M. C, soil texture: clay, silt and sand) and selected trace /heavy element concentrations of soil samples collected from top and subsoil layers of the study region are provided in Tables 1-6.

The top soil of this region is predominantly loamy sand. The soil pH varies within the acidic or slightly neutral and range between 6.62 – 7.72. The EC values were found to vary between 0.155-0.360. OC is very low (mean 0.081± 0.007). MC range between 0.230 – 0.430%.

Average trace and heavy element concentrations decreased according to:

Fe-Co-Ni-Cr-Zn.

The subsoil of this region is predominantly loamy sand. The soil pH varies within the range 6.02-7.10. The EC values were found between 0.162-0.275. OC is very low (mean 0.093±0.020). MC range between 0.230-0.430%.

Average trace and heavy element concentrations decreased according to:

Fe -Mn-Cr-Zn.
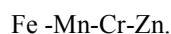
It is clear from the data obtained in this study that the Cr concentration exhibits no correlation with increase or

decrease of soil depth. The amount of Cr in both top and sub-layers are highly variable. Chromium ranging from 2901.027 to 16.166 ppm. Some of the highest Cr contents are reported for loamy and clay soils of Chad (100-300 mg/Kg) and New Zealand (70-1100 mg/Kg) [14].

The abundance of Fe is likely to be increased in heavy loamy soils and some organic soils.

The worldwide mean value of Co in surface soils is calculated as 10 mg/Kg. Usually, higher levels of Co are in heavy loamy soils (Cambisols) and sometimes in organic soil (Histosols). Higher Co contents of surface soils are found in arid and semi-arid regions [15].

Soils throughout the world contain Ni in the very broad range, however its mean concentrations, as reported for various countries are within the range 13-37 mg/Kg. Soils of South Africa contain Ni within the range of 3.43 – 159 mg/Kg, and the maximum permissible level in agriculture soils is 50 mg/Kg [16].

Cu contents are closely associated with soil texture and usually are the lowest in light sandy soils and the highest in loamy soils. Also, the clay fraction contributes significantly to the Cu contents of soils. The baseline levels for Cu in soils of Brazil is given (in mg/Kg) as 0.1 and 8.7 for sandstone and limestone soil, respectively [17]. The concentration of Cu in surface soil from major agricultural production areas of the

United State varies from < 0.6 to 495 mg/Kg (geometric mean, 18 mg/Kg). It is clear from the data drawn in this study, there is no systematic increase or decrease of Cu with the increase or decrease of depth. The increase of the Cu concentration in the soils can be attributed to the weathering of sulfides in the surrounding mountains areas around the region. The concentration of Cu in the study region (Top-soil) reaching to alarming level, and this should be evaluated in detail.

The t-test showed that, elemental pairs: Ni-Cd, Cd-cr, Mn-Cr, Pb-Cd, Cu-Cr, Cu-Cd, Cu-Mn, Zn-Cd, Fe-Mn, Fe-Pb, Fe-Cr, and Fe-Mo were showed significant differences in their concentrations in the study region, top-soil. Elemental pairs: Ni-Mo, Ni-Co, Cd-Co, Pb-Co, Pb-Ni, Cu-Ni, Cu-Pb, Zn-Cd, and Zn-Cr were showed no significant differences (Table 3) in their concentrations in the study region, sub-soil.

Table 3. T-values at significance level (p<0.05) of heavy and trace elements in study region.

Elemental pair	Top soil		Subsoil	
	t-value	Significance level	t- value	Significance level
Cr-Mo	0.958	NS	7.024	S
Cr-Co	0.991	NS	11.384	S
Mo-Co	0.742	NS	4.009	S
Ni-Mo	1.460	NS	1.270	NS
Ni-Co	1.844	S	1.387	NS
Ni-Cd	2.887	S	4.303	S
Ni-Cr	0.991	NS	7.024	S
Cd-Co	1.601	NS	1.282	NS
Cd-Cr	6.153	S	19.546	S
Cd-Mo	0.973	NS	21.753	S
Mn-Mo	0.042	NS	3.726	S
Mn-Ni	0.725	NS	3.726	S
MnCo	0.742	NS	4.009	S
Mn-Pb	0.099	NS	3.850	S
Mn-Cr	2.521	S	3.253	S
Pb-Co	0.127	NS	0.168	NS
Pb-Cd	4.427	S	5.233	S
Pb-Cr	0.955	NS	7.427	S
Pb-Mo	0.055	NS	2.654	S
Pb-Ni	0.761	NS	2.654	NS
Cu-Mo	0.689	NS	10.003	S
Cu-Ni	0.114	NS	10.003	NS
Cu-Co	0.155	NS	17.197	S
Cu-Pb	0.714	NS	0.392	NS
Cu-Cr	3.233	S	5.329	S
Cu-Cd	4.506	S	3.709	S
Cu-Mn	2.834	S	3.577	S
Zn-Co	0.246	NS	4.679	S
Zn-Pb	0.672	NS	3.498	S
Zn-Mn	0.625	NS	3.261	S
Zn-Cd	1.927	S	1.649	NS
Zn-Cr	0.999	NS	0.292	NS
Zn-Mo	0.644	NS	2.807	S
Zn-Ni	0.207	NS	2.807	S
Zn-Cu	0.095	NS	3.776	S
Fe-Mn	2.122	S	21.914	S
Fe-Ni	0.135	NS	22.299	S
Fe-Co	0.0743	NS	22.323	S
Fe-Pb	2.259	S	22.310	S
Fe-Zn	0.491	NS	22.262	S
Fe-Cu	0.319	NS	22.311	S
Fe-Cr	3.374	S	6.641	S
Fe-Mo	2.157	S	22.299	S

The high correlation coefficient (near +1 or -1) means a good relation between two variables, and its concentration around zero means no relationship between them, it can be strongly correlated, if r more than 0.7, whereas r values between 0.5 to 0.7 shows moderate correlations between two different parameters. In order to test the degree of association between trace and heavy elements and some other properties in studied region soils, a Pearson s correlation was carried out. Correlation coefficient was used for the investigation of statistical significant correlations at level, for P < 0.05.

In the top-soil, pH was positively correlated with silt (r=0.760), clay (r=0.075), MC (r= 0.155), Cd (r=0.089), Co (r=0.093), Cr(r= 0.092), Cu (r=0.092), Mn (r=0.084), Mo (r= 0.0917), Ni (r= 0.092), Pb (r=0.092) and Zn (r=0.092); and negatively correlated with EC, OC, sand and Fe whereas in the sub-soil, pH was positively correlated with EC (r= 0.755), Mn (r= 0.439), clay (r= 0.211), silt (r=0.318), Cr (r= 0.246), Cu (r=0.074), Fe (r= 0.134), Ni (r= 0.105), Pb (r= 0.061), and

Zn (r= 0.004); and no correlation with Co. PH was negatively correlated with OC, sand, MC, Cd and Mo.

In the top-soil of study region, clay was positively correlated with OC, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, and Zn; and negatively correlated with EC and MC. Silt was positively correlated with Mo, EC, MC, Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn; and negatively correlated with OC and Fe. Sand was positively correlated with EC, OC and MC; and negatively correlated Cd, CO, Cr, Cu, Fe, Mn, Mo, Ni, Pb and Zn; whereas in the subsoil of this region, clay was positively correlated with OC, Cd, Cu, EC, Fe, Mn, Mo, Ni, and Zn; and negatively correlated with MC, and Pb. No correlation with Co. Silt was positively correlated with Zn, EC, OC, MC, Cu, Pb, no correlation with Co and negatively correlated with Cd, Cr, Fe, Mn, Mo and Ni. Sand was positively correlated with MC, Co, Fe, Mn, Mo and Ni; and negatively correlated with EC, OC, Cd, Cr, Cu, Pb and Zn.

Table 4. *Correlation coefficients of the soil pH with the some other soil properties in study region.*

	Topsoil		Subsoil	
	R	Correlation	R	Correlation
EC	-0.150133	−ve	0.754629	High +ve
OC	-0.018447	-ve	-0.367806	-ve
Clay	0.074903	Weak +ve	0.211231	Weak +ve
Silt	0.760024	High +ve	0.31825	Weak +ve
Sand	-0.113275	-ve	-0.352314	-ve
MC	0.158232	Weak +ve	-0.385585	-ve
Cd	0.08934	Weak +ve	-0.138198	-ve
Co	0.092512	Weak +ve	0.00	No correlation
Cr	0.09221	Weak +ve	0.245837	Weak +ve
Cu	0.092456	Weak +ve	0.074285	Weak +ve
Fe	-0.125133	-ve	0.133792	Weak +ve
Mn	0.08396	Weak +ve	0.438957	Moderate +ve
Mo	0.091679	Weak +ve	-0.051719	-ve
Ni	0.092414	Weak +ve	0.105461	Weak +ve
Pb	0.091727	Weak +ve	0.060627	Weak +ve
Zn	0.092205	Weak +ve	0.004437	Weak +ve

Table 5. *Correlation coefficients of the soil texture with the some other soil properties in study region – Topsoil.*

	Clay		Silt		Sand	
	R	Correlation	R	Correlation	R	Correlation
EC	-0.240224	-ve	0.234298	Weak +ve	0.222771	Weak +ve
OC	0.256458	Weak +ve	-0.260991	-ve	0.264707	Weak +ve
MC	-0.152189	-ve	0.28585	Weak +ve	0.133905	Weak +ve
Cd	0.229471	Weak +ve	0.076106	Weak +ve	-0.228572	-ve
Co	0.232137	Weak +ve	0.076384	Weak +ve	-0.231196	-ve
Cr	0.232078	Weak +ve	0.076066	Weak +ve	-0.231122	-ve
Cu	0.232086	Weak +ve	0.076286	Weak +ve	-0.231141	-ve
Fe	0.381215	Weak +ve	-0.183808	-ve	-0.363406	-ve
Mn	0.250694	Weak +ve	0.075779	Weak +ve	-0.249324	-ve
Mo	0.233623	Weak +ve	0.76504	High +ve	-0.232657	-ve
Ni	0.232222	Weak +ve	0.076278	Weak +ve	-0.231274	-ve
Pb	0.234278	Weak +ve	0.076885	Weak +ve	-0.233318	-ve
Zn	0.233585	Weak +ve	0.076819	Weak +ve	-0.232636	-ve

Table 6. *Correlation coefficients of the soil texture with the some other soil properties in study region – Subpsoil.*

	Clay		Silt		Sand	
	R	Correlation	R	Correlation	R	Correlation
EC	0.330146	Weak +ve	0.016952	Weak +ve	-0.221049	-ve
OC	0.658383	High +ve	0.337351	Weak +ve	-0.649056	-ve
MC	-0.516761	-ve	0.141207	Weak +ve	0.230924	Weak +ve
Cd	0.665915	High +ve	-0.246905	-ve	-0.253026	-ve
Co	0.0	No correlation	0.0	No correlation	0.000002	Weak +ve
Cr	0.807279	High +ve	-0.28979	-ve	-0.313276	-ve
Cu	0.417898	Moderate +ve	0.053927	Weak +ve	-0.302078	-ve
Fe	0.224534	Weak +ve	-0.30708	-ve	0.068233	Weak +ve
Mn	0.089558	Weak +ve	-0.385247	-ve	0.207476	Weak +ve
Mo	0.339965	Weak +ve	-0.475669	-ve	0.110667	Weak +ve
Ni	0.339965	Weak +ve	-0.475669	-ve	0.110667	Weak +ve
Pb	-0.190651	-ve	0.241959	Weak +ve	-0.045052	-ve
Zn	0.031523	Weak +ve	0.491029	Moderate +ve	-0.356849	-ve

The statistical parameters of the calibration curve – slope, intercept and correlation coefficients – were calculated by linear regression analysis. Correlation analysis with the results from the studied region (top-soil), gave a best fit linear relationship between pH and MC content with a slope 0.80114 and Y-intercept of 7.112. Correlation analysis with the results from sub-soil, gave a best fit linear relationship between clay and Cu content with a slope 0.529 and also gave a best fit linear relationship between silt and MC content with a slope 1.477.

In line with the present-day ecological and toxicological data, trace metals form the following succession according to their hazard degree in soils: Cd>Ni>Cu>Cr>Pb>Zn which considered to be moderate to strongly hazardrous element [18].

4. Conclusion

Monitoring of trace and heavy elements in soil provides efficient way to assess the qualitative and quantitative differences in element concentrations at distinct location. It can be concluded that the physico-chemical analysis of soil samples under study showed variable concentration of various parameters. Levels of trace elements studied are generally no within the range for soils on a world-wide basis. Some trace elements examined in this study that are potentially may toxic to biological systems. The heavy elements detected in sampling sites could contaminate surface and ground water. Hence steps should be taken to check the flow and accumulation of these heavy elements to avoid any harm to human existence. The extraction of trace elements from soils of North Darfur for industrial use (especially, Fe, Cr and Cu) should be investigated.

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