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Environmental Monitoring of Heavy Metals Status in Semiarid Lands of Northeastern Algeria

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ENVIRONMENTAL MONITORING OF HEAVY METALS STATUS IN SEMIARID LANDS OF NORTHEASTERN ALGERIA

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ABSTRACT

With the rapid development of industry, heavy metal contamination is becoming among the most important environmental problems causing worldwide concern. The purpose of this study was to evaluate the level of soil heavy metal pollution in the semi-arid areas of Northeast Algeria. To evaluate the ecological state of soils, we investigated fifteen sites. The level of heavy metals (HMs) toxicity and soil characteristics likr pH, electrical conductivity, organic matter, calcium carbonate, calcium, sodium, magnesium, phosphorus, nitrogen, and potassium were assessed during this study. The results showed that the mean values of heavy metals were as follows in ppm: Zn (41.197 ± 37.328), Fe (1.281 ± 0.459), Cu (23.407 ± 27.905), Pb (68.567 ± 43.412) and Cd (4.463 ± 1.823). Almost all of the soil was unpolluted by Fe and Zn, and a few were slightly polluted by Pb and Cu. High Cd concentration determined throughout this analysis is alarming. This study offers a thorough examination of soil heavy metal pollution in Northeastern Algeria to obtain soil pollution proportions of great significance for the comprehensive evaluation and control of soil pollution.

Keywords: Heavy metals, soil characteristics, physicochemical soil parameters, semi-arid, northeastern Algeria.

INTRODUCTION

The concentration of toxic heavy metals in the environment has dramatically increased as a result of the rapid industrialization and urbanization processes (Shah et al., 2023; Ma and Jia, 2022). Globally, environmental contamination is a major concern (Singh and Naaz, 2023; Yang et al., 2018). The principal sources of heavy metals are anthropogenic and natural substances (Mitra et al., 2022). Heavy metal contamination includes some natural sources such as the decomposition of metal-bearing rocks, eruption of volcanoes, and some human activities such as increased urbanization, industrial waste discharges, agricultural practices, and mining processes (Li et al., 2022; Shah, 2021; Hahn et al., 2019). Even in low quantities, heavy metals are quite dangerous to human health (Anitha et al., 2023). Heavy metals including cadmium (Cd), copper (Cu), lead (Pb), Iron (Fe), Zinc (Zn), and others are known to cause long-term effects on biotic systems. It's crucial to timely identify, diagnosed, and monitor environmental toxins (Elbasiouny et al., 2023; Kamdar and Solanki, 2023 and Zwolak et al., 2019). The capacity

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to estimate the spatial distribution of heavy metals is crucial for determining pollution sources and possible hazards to both people and the environment (Omićević et al., 2023).

Over the past three decades, there has been a huge increase in soil toxic heavy metal pollution, mainly because of fast unplanned development and intensive farming techniques (Chakraborty et al., 2022). The fertility of the soil is decreased when significant quantities of heavy metals accumulate (Mishra et al., 2022). Heavy metal contamination of the soil can harm crops, penetrate the food chain, and have an impact on human health (Pouresmaieli et al., 2022; Hou et al., 2018; Antoniadis et al., 2017 and Manzetti et al., 2014). Consequently, soil pollution levels must be monitored through annual soil sampling to analyze the activities of soil carefully using laboratory equipment (Hussain et al., 2022).

Semi-arid environments are characterized by low levels of soil nutrients and organic matter, poor soil structure, excessive salinity, a lack of water, excessively high temperatures, and desiccation (Aburas et al., 2022; Ayangbenro and Babalola, 2021 and Hernández et al., 2015). In this study, the Morsott area of Northeast Algeria was chosen, to detect soil heavy metals contaminations. Therefore, was provided with the most recent heavy metal concentrations and pollution levels from the samples that were taken in the area. The results can provide important ideas about soil contamination and ecological risks posed by HMs, in preparation for future heavy metal pollution assessments and soil remediation.

MATERIALS AND METHODS

Study Area

The study area is located in the municipality of Morssot which is located 50 kilometers (km) north of Tebessa city in the semi-arid region of Northeast Algeria with coordinates lat. 35°63" N to 35°64 "N, long, 7°98" E to 7°97" E (Figure 1).

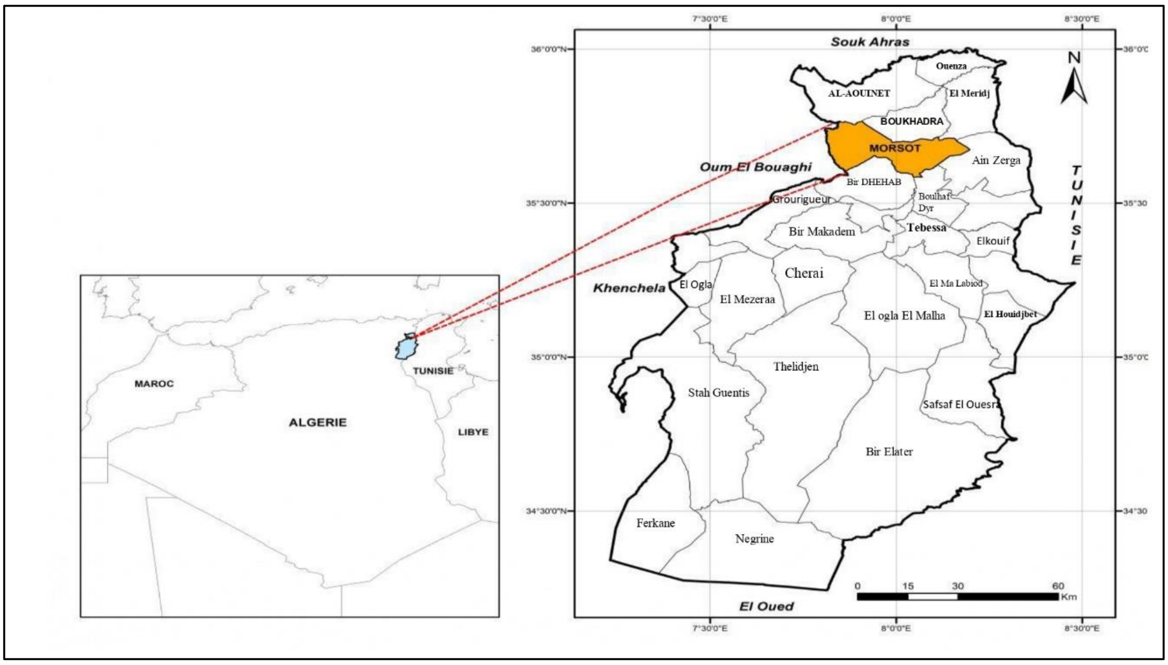

Figure 1: Location of the study sites in the Morsott regions of northeastern Algeria.

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The region is bounded to the west by Djebel Mesloula and east by Djebel Boukhadra, to the north by Djebel Guelb El Gounatas, and to the south by Bir Dhehab and Boulhaf Dyr. The study area receives between 350 and 400 mm of precipitation annually, making it a semi-arid region. The summertime temperature can reach 45 °C (Fehdi et al., 2009).

Soil Sampling and Analysis

The study area is characterized by the presence of many active and abandoned mines. Therefore, it is hypothesized that the area is contaminated a heavy metals. During the period of February to June 2021, a total of 15 topsoil samples to a depth of 30 cm were collected, to assess the properties of the soil, with repetitions monthly for each region. The soil samples were dried in the air. These parameters comprised acidity pH, electrical conductivity (EC), organic matter (OM), calcium carbonate ($CaCO_3$), calcium (Ca), sodium (Na), magnesium (Mg), Phosphore (P), Nitrogen (N), potassium (K) and finally heavy metals concentrations, lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), iron (Fe).

The pH measurements were made with a (1/5) soil/water ratio, The EC is measured in the same manner as pH with a (1/5) soil/water ratio (Mathieu and Pieltain, 2003). Organic matter is determined by determining the amount of organic carbon. Organic carbon was determined according to Anne's method by oxidation of carbon with excess potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid medium (heat source). The amount of dichromate not consumed was determined by Mohr's salt. The organic matter (OM) content was estimated by multiplying the percentage of carbon by 1.72 (Bonneau and Souchier, 1994). The method was performed by placing 2 g of soil into a beaker with 10 mL of HCl that had been diluted to 1/3 of known weight (W_1), The solution was weighed again after stirring to determine its weight (W_2), and The volume of CO_2 released was used to compute the proportion of $CaCO_3$ (W_1-W_2), $CaCO_3$ (%) = CO_2 × 2.274 × 100/soil weight (Baize, 2018). The soil texture particle size was determined using an electric sieves machine in accordance with the NF P94056 standard. The concentrations of N, P, K, Mg, Ca, and Na were measured at the level of Fertilizers of Algeria FERTIAL SPA/Groupe Villar Mir-Annaba.

The concentrations of heavy metals Pb, Zn, Cd, Cu, and Fe of the powdered soil samples were determined by a spectrophotometer type AAnalyst™ 400 AA according to the AFNOR method by ICP-AES (Inductively Coupled-Plsama/AtomicEmission-Spectrometry) at the SEMIPHOS laboratory (Djebel Onk- Bir El Ater-Tebessa).

Statistical Analysis

Statistical analyses and control charts were performed for all data using ExcelStat 2014 and R Version 4.1.3 statistical software. In the case of normal data and homogeneous parametric tests, the Analysis of Variance (ANOVA) and Tukey test were used. Nonparametric tests and specifically, the Kruskal-Wallis test were used for non-normal data. The level of significance was considered less than 5 %. Principal component analysis (PCA) was used to analyze the relationship among soil physicchemical properties.

RESULTS

Soil properties and the Concentration of Heavy metals in 0–30 cm soil depth in the semi-arid region

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are shown in Table 1. Values of the gravel were ranged between 38,810 and 85,860 % is the most abundant soil fraction. Soil coarse sand averaged 14.067 ± 7.151 %. The mean Silt in the soil samples analyzed was 3,983 ± 4,426 %. The percentage of clay in the samples was low varying from 0, 26 % to 14, 50 %. Based on these findings, the soils are characterized as Gravel in general. The study area was particularly dominated by vegetation cover with a mean of 49.067 ± 9.091 %, followed by bare soil at 22.333 ± 6.455 %.

Table 1: Characteristics, Minimum, Maximum, and mean values (± standard deviation) of environmental factors (values represent the average of 15 observations).

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Moyenne	Ecart-type
Plant litter %	15	0	15	2.000	31.000	18.733	7.516
Coarse materials %	15	0	15	9.000	28.000	17.533	6.917
Bare soil %	15	0	15	9.000	36.000	22.333	6.455
Vegetation cover %	15	0	15	35.000	67.000	49.067	9.091
pH	15	0	15	7.180	7.960	7.455	0.250
EC µS cm-¹	15	0	15	449.000	2090.000	947.667	438.957
OM %	15	0	15	0.570	1.790	1.277	0.348
Gravel %	15	0	15	38.810	85.860	62.742	14.094
Coarse sand %	15	0	15	2.830	29.920	14.067	7.151
Medium sand %	15	0	15	1.660	15.100	6.583	3.939
Fine sand %	15	0	15	1.000	19.280	8.992	5.093
Silt %	15	0	15	0.180	15.470	3.983	4.426
clay %	15	0	15	0.260	14.500	3.492	3.864
Zn (ppm)	15	0	15	2.500	138.700	41.197	37.328
Pb (ppm)	15	0	15	10.000	140.000	68.567	43.412
Cd (ppm)	15	0	15	2.000	6.450	4.463	1.823
Fe %	15	0	15	0.650	1.700	1.281	0.459
Cu (ppm)	15	0	15	11.500	121.000	23.407	27.905
CaCo3 %	15	0	15	12.850	36.240	23.361	6.691
N %	15	0	15	0.070	1.100	0.161	0.260
P (ppm)	15	0	15	15.320	36.210	25.987	6.818
K (ppm)	15	0	15	175.320	495.320	303.668	108.400
Mg (ppm)	15	0	15	59.960	145.360	92.808	30.109
Ca (ppm)	15	0	15	1213.300	8793.250	6890.572	2809.274
Na (ppm)	15	0	15	84.360	942.130	509.938	346.052

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In addition, Plant litter averaged 18.733 ± 7.516 % while the ratio of the coarse materials was 17,533 ± 6,917 %. These results were confirmed by (Souahi et al., 2022; Prakash et al., 2019; Boudjabi and Chenchouni, 2021; Mouvet et al., 2020; Kompała-Bąba et al., 2019).

Regarding the main physicochemical properties (Figure 2), the mean value of pH (7.455± 0.250) of the soil in the study area was found to be considered Low alkaline pH (7.4 - 7.8) as per the rating of Doucet (2006).

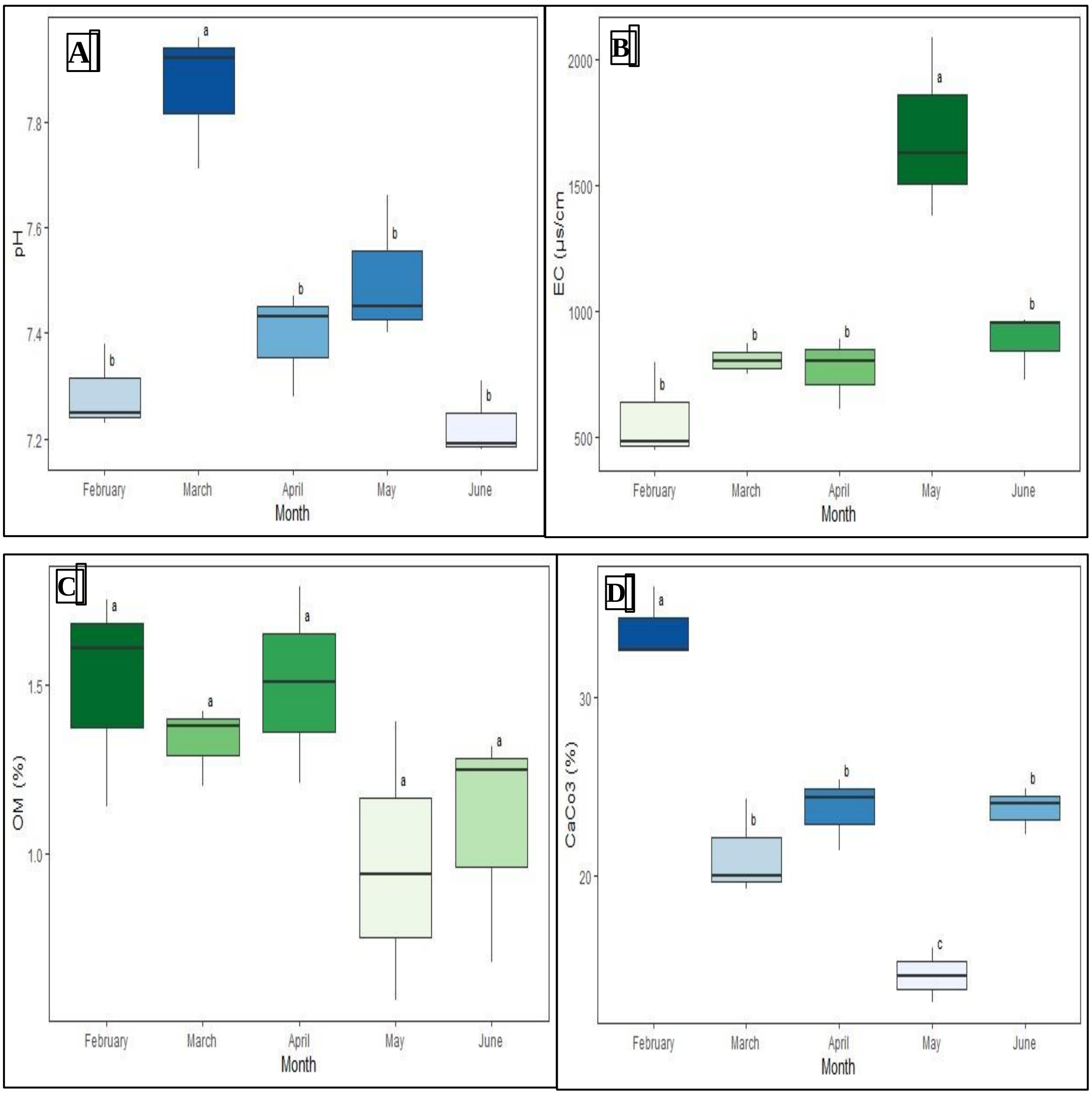

Figure 2: Boxplots showing the differences in soil physicochemical properties in Northeast Algeria. Testing the variation of soil pH (A), electrical conductivity (B), organic matter (C), and total CaCO3 (D). Different letters indicate significantly different mean soil parameters.

The soil pH levels that were the highest were found in the month of March. While the pH levels in soils from the month of June. The mean value of EC in the study area was 947.667 ± 438.957 µS cm-¹ According to Durand (1983), the EC of the soils is slightly salty. The analysis boxplot (Figure 2) of EC between the five months showed a significant variation.

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Where, the EC in May was significantly higher than it was in February. April. or June, with the lower EC in February month. The mean Soil organic matter (OM) concentration of the study area is 1.277 ± 0.348 percent. Soils are regarded as being very poor in OM. The month with the lowest OM content was May, whilst the maximum was in the month of February. The mean total CaCO3 content of the analyzed soil was 23.361 ± 6.691 % which indicates that it was moderately calcareous as stated by Durand (1983). Figure 2 shows that the increase in CaCO3 was higher in both February. Finally, the lowest CaCO3 levels were found in May.

As shown in figure 3 one of the main mineral components is Ca. accounting for 1213.300 to 8793.250 ppm. The average Na Concentration is 509.938 ± 346.052 ppm, which is less abundant than Ca. Na concentration increases in the month of April and is low in the month of February. N Percentage ranges from 0.070 to 1.100 % and is relatively higher in the month of June. K Concentration has the largest range in the month of February 495.320 ppm to 175.320 ppm in the month of March. The content of other minerals suchas Mg. and P is very low 92.808 ± 30.109 ppm average and 25.987 ± 6.818 ppm averages respectively. Our results are consistent with several articles (Camponi et al., 2023; Arumugam et al., 2022; Lyu et a., 2023; Alsanius et al., 2020).

Figure 4 displays the average HMs concentrations found in the soil samples. The Zn concentration was in the range of 41.197 ± 37.328 ppm on average. The Fe Percentages were in the range of 0.650 to 1.700 % .The average concentration of Zn and Fe in the soil did not exceed the risk value in the environment based on the evaluation of AFNOR N F U 44-041. The mean Cu value is 23.407 ± 27.905 ppm. Figure 4 shows that the increase in Pb and Cu is higher both in April and June respectively where were exceeded the risk value. The Pb and Cu concentrations in other months were lower than the risk values at all sampling sites. Whereas the Concentration of Cd exceeded the risk value, which was 4.463 ± 1.823 ppm average twice as much as that of the risk value in the environment. In general, the soil was lightly contaminated by Cu and Pb, but Cd was outside the allowed range for agricultural soils according to the evaluation by AFNOR N F U 44-041.

The loadings Principal Component Analysis for F1 and F2 (Figure 5) presented four distinct clusters. One formed by N, silt, Cu. Fine sand. Plant’s litter and EC. represents a set of interrelated attributes. The second represents a group of interconnected characteristics and is produced by Fe, medium sand. Na pH, and Mg. The Third cluster is formed by Ca. P. K. Pb. and $CaCO_{3.}$ Finally, the fourth group consisted of OM. Bare soil. There were differences in the levels of soil organic matter, total nitrogen, phosphate, and potassium among various soil texture types (Wang et al., 2018).

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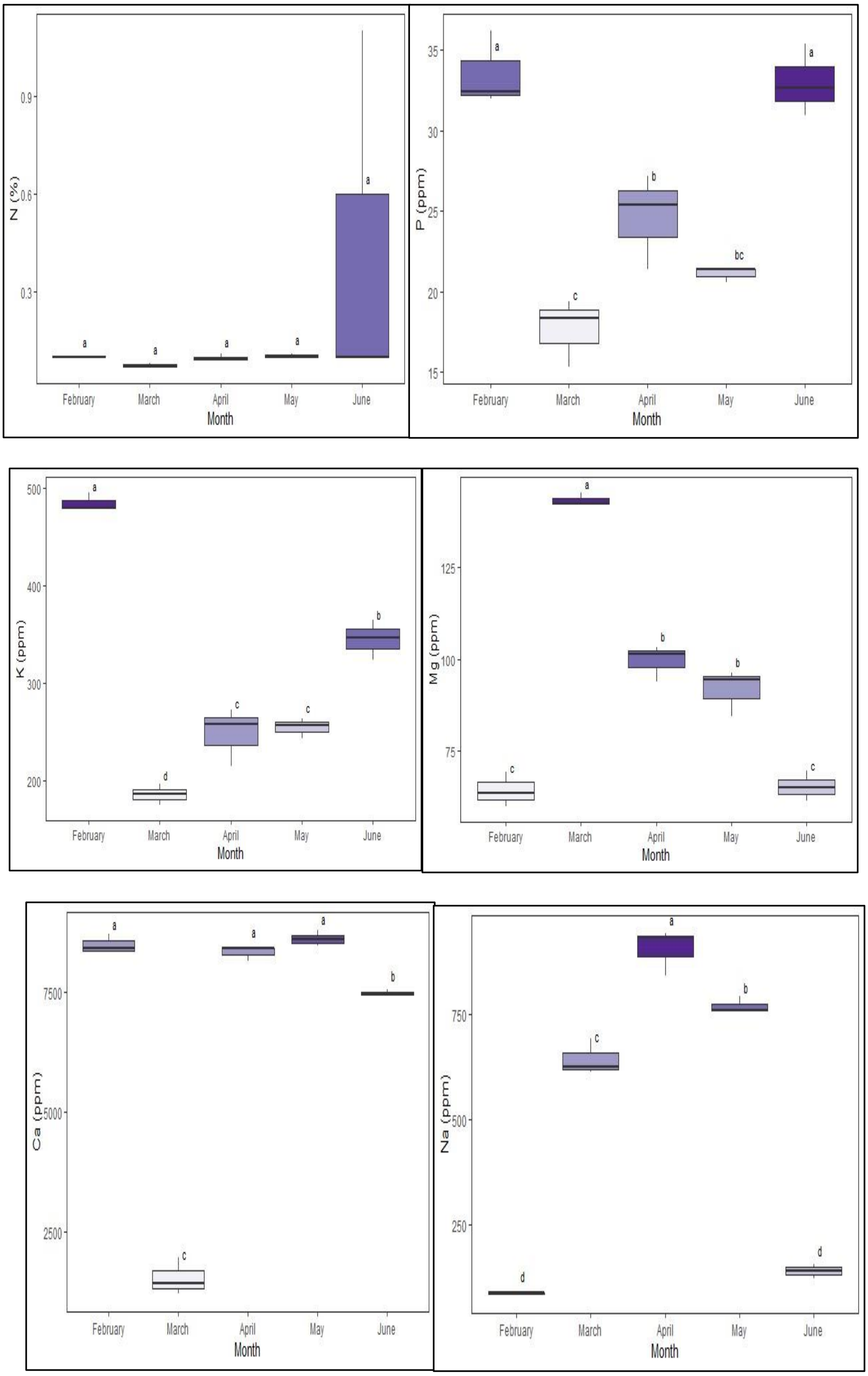

Figure 3: Soil nutrients among different months. Whiskers are the standard deviations. Different letters indicate significant differences. Calcium (Ca). Sodium (Na). Magnesium (Mg). Phosphore (P). azote (N). and potassium (K).

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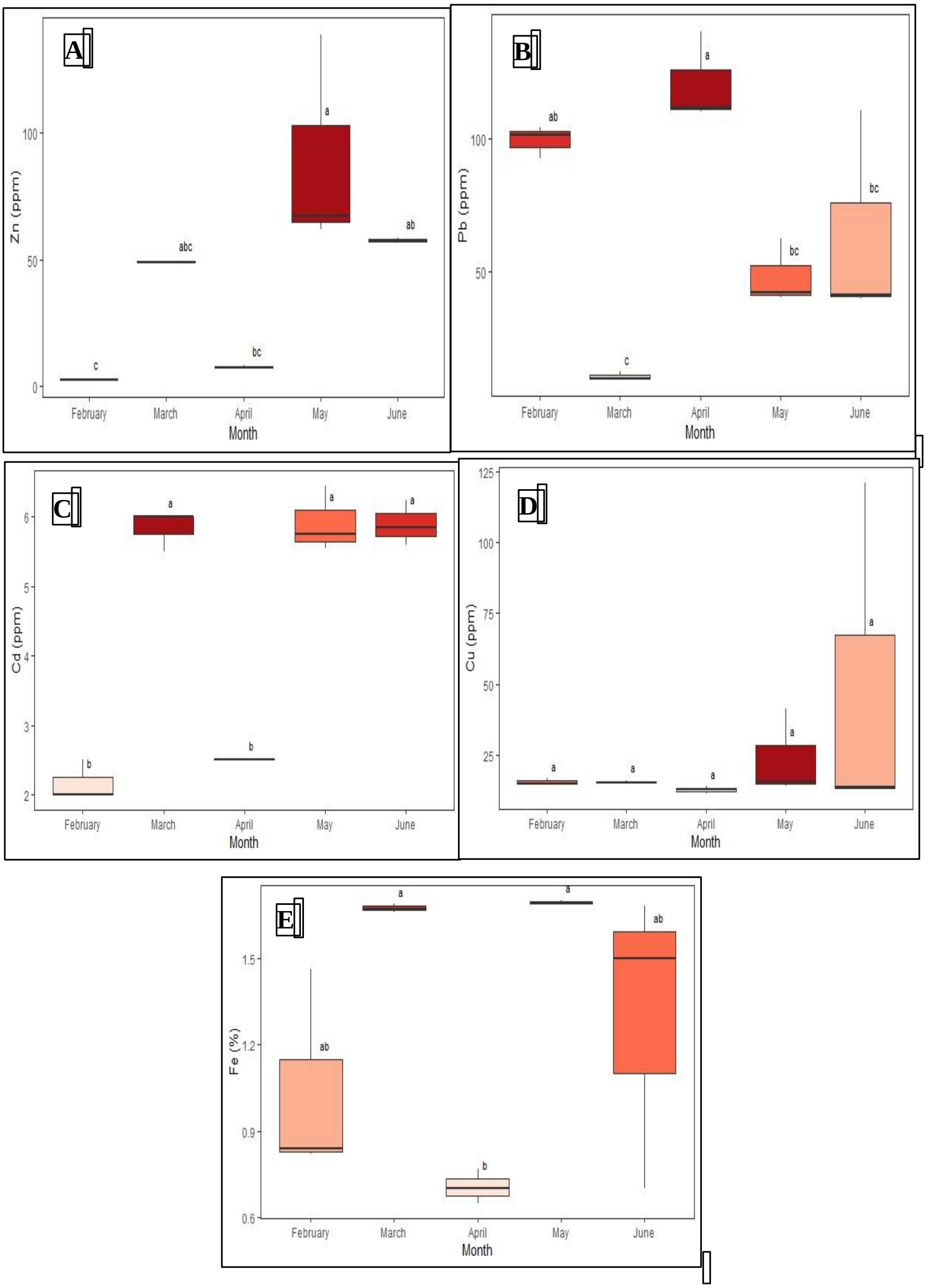

Figure 4: Boxplots displaying monthly variations of soil Heavy metals parameters in the northeastern Algeria. Testing the variation of soil, Zn (A), Pb (B), Cd (C), Cu (D), Fe (E). Different letters indicate significantly different mean soil parameters.

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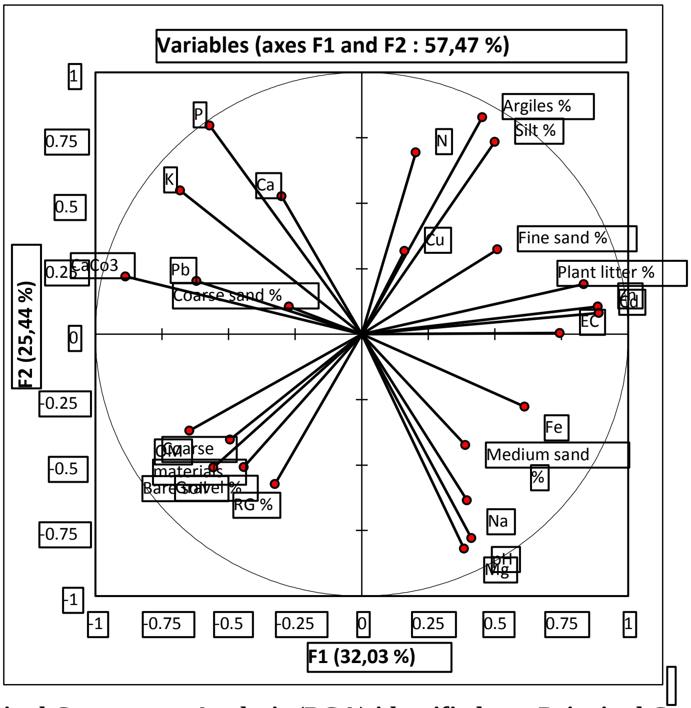

Figure 5: The Principal Component Analysis (PCA) identified two Principal Components (F1 and F2), which together explained 57.47 % of the variance of the properties of the soil.

DISCUSSION

The management and usage of land can have a significant impact on a variety of soil qualities (Mihelič et al., 2020). Consequently, indirectly changing soil quality can enhance or limit the production of agricultural lands. Since soil chemistry is the foundation of soil fertility and gives the necessary knowledge to comprehend the variations in soil fertility and their response to fertilization. Understanding soil chemistry is of utmost importance (Sofo et al., 2022). On occasion, the chemistry of the soil can directly affect its physical characteristics (Delgado and Gómez, 2016).

The texture of the soil is an important factor, the soil management techniques are largely influenced by the texture (Yustres et al., 2021; Imamul et al., 2013) Soil texture more precisely the size distribution of soil particles have a substantial impact on inter-particle pore space (Wang et al., 2023). It is essential to remember that the granulometric structure of the soil affects its other physicochemical characteristics (Van der et al., 2013). Classes of soil texture affect the soil's physicochemical biological characteristics (Kaya et al., 2022). Soil texture is one of the most important properties in the soil, which controls root development, nutrition availability, water retention, and penetration (Naorem et al., 2021; Ahmad et al., 2017). Additionally, agricultural planning and management require a high-resolution geographic distribution of soil texture since texture classes affect the amount of water that is available in the soil (Keshavarzi et al., 2022).

The physicochemical characteristics of the soil greatly affect soil quality (Naga Raju et al., 2017). The physical and chemical characteristics of soil are mostly determined by the electrical

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conductivity (EC) and pH value, which can indicate the amount of soil acidity and alkalinity in the semi-arid region (Lei et al., 2016). pH is an important and variable development component in both agricultural and natural soils (Parvin et al., 2019). Knowing how much soil pH is the most important to manage soil fertility (Herriyance and Rivaldo, 2021; Kumar et al., 2014). It directly affects nutrient bioavailability and assesses the acidity or basicity of the soil (Maphuhla et al., 2019). The electrical conductivity of the soil is affected by a number of variables, including pH, soil moisture, and soil porosity (Souahi et al., 2015; Zhou et al., 2012). It is a sign of soil deterioration processes like salinity (Viana et al., 2021). The lifeblood of the soil and organic matter is essential for sustainability and high environmental standards (Rahman et al., 2020). Organic matter in the soil improves soil fertility (Miltner et al., 2021). Poor soil structure and low organic matter reduce the water-holding capacity of the soil, which is also associated with loss of fertility (Hobley et al., 2018). The movement of organic matter in the environment and the cycling of other nutrients like nitrogen, phosphorus, and others are all closely related (Spaeth, 2020). These results agreed with (Mebrate et al., 2022; Eid et al., 2021; Khan et al., 2021; Kaur et al., 2021; Basweti et al., 2018)

Pollutants of various chemical compositions and specific gravities may enter natural soils as a result of various daily human activities, soil pollution is a common occurrence in the environment that significantly alters the properties of soil (Ganiyu et al., 2019). Risk assessment of contaminated soils is routinely based on physical (pH. soil texture, etc.) and chemical (sodium, potassium, magnesium, nitrates, and phosphates etc) analysis (Ashraf et al., 2014). The population of soil microorganisms and the physicochemical characteristics of the soil are negatively impacted by toxic heavy metals released from these sources, which lowers soil fertility and agricultural productivity (Patil et al., 2023). Heavy metal migration in the soil is influenced by a variety of variables, such as reduction-oxidation, the acid-basic nature of the soil, the amount of organic matter present, the makeup of the granules, the water and heat regime, geochemical properties, and others (Petruk et al., 2016). Due to metals' propensity to form soluble or insoluble complexes with organic matter, the organic content of the soil has a significant impact on metal mobility and bioavailability. Cation exchange capacity (CEC) measures the negative charges on soil surfaces and can indicate whether they are pH-dependent or long-lasting. Through exchange processes, heavy metals can replace alkaline cations on these surfaces (Petruzzelli et al., 2015). The physical characteristics of the soil, including its texture, pH, electric conductivity, and organic matter content, have an impact on the accumulation of heavy metals in the soil (Eze et al., 2018). Previous studies showed that distributions of Zn, Cu, Pb, and Cd are related to the soil's properties (Zeng et al., 2021). These results are consistent with those obtained by Gui et al., 2023 who noted that the main cause of the accumulation of HMs in soil and the high level of soil contamination in the study area is the long-term emissions of toxic fume and dust from mining and smelting processes. Similarly to our results, other studies have also shown Soil contamination with heavy metals (Li et al., 2023; Zhang et al., 2023; Tian et al., 2022; Khan et al., 2021; Kouchou et al., 2020; Zhai et al.,

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2009; Tumanyan et al., 2017; Bian et al., 2016).

Heavy metals are the most toxic pollutants (Srivastava et al., 2022). The wide distribution of heavy metals in the environment is of great concern because of their highly toxic properties. Yet, some metals are essential for normal plant growth (Beduk et al., 2022). Toxic heavy metals are non-essential hazardous environmental pollutants that pose intractable health problems in humans and animals. Exposure to zinc, iron, lead, and cadmium is ubiquitous and unavoidable due to food contamination, mining and industrial mobilization (Famurewa et al., 2022; Bortolot and Baron, 2022; Selvi et al., 2019). They are not biodegradable and can persist in the environment for long periods of time, making soils unsuitable for cultivation (Shah and Daverey, 2020). Toxic metals are among the major environmental pollution threats, as they pose a risk to human health through various exposure routes and to the environment (Allajbeu et al., 2021). Pb and Cd is one of the riskiest non-essential heavy metals for plants because of its high-water solubility and interference with a number of physiological and biochemical processes (Kaur et al., 2022; Souahi et al., 2021).

CONCLUSION

This study provides a comprehensive assessment of soil heavy metal pollution in Semi-Arid Lands of Northeastern Algeria (Morsott). The following conclusions can be reached in the context of the results and discussions. The soil was almost unpolluted of Fe and Zn contamination, with a few having little Pb and Cu contamination and high Cd contamination. Although Northeastern Algeria's heavy metal contamination was generally at a low-risk level but must continue to pay attention to the dangers of heavy metals to human health and their introduction into the soil particularly cadmium (Cd).

AUTHORS CONTRIBUTION

Rania Gacem: conducted fieldwork and collected data, editing the original draft. Hana Souahi: analyzed data, Methodology, conceptualization, and Formal analysis. Chemseddine Fehdi: Resources, Conceptualization, Supervision. Abderrezzeq Chebout: conceived the study, Data curation, Validation, Writing and review

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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