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Investigation of Pollution Level of Traces Metals Elements in Agricultural Soil of Oubritenga Province of Burkina Faso

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Abstract

The purpose of this study was to investigate the pollution level of trace metals As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se and Zn in agricultural soil around the water reservoir. A total of 36 soil samples were collected both during off-season agriculture and pluvial agriculture from April to October 2022. The samples were analyzed for trace metals according to the standard methods of the US EPA 2007 with a microwave plasma atomic emission spectrometer (MP-AES), Agilent Model 4210. The pollution level was assessed using contamination factor (*Cf*) and modified contamination degree (*mCd*). During the off-season, the concentration of trace metals followed in descending order as Mn > Cr > Cu > Pb > Zn. As, Cd, Co, Hg, Ni, Sb and Se were below the detectable limits. In pluvial season, the concentration of traces of metal follows the order Mn > Cr > Zn > Cu > Ni > Pb > Hg > As. Cd, Co, Sb and Se remain below the detectable limits. The concentrations of Cr, Mn and Zn were lower in the off-season agriculture than in pluvial agriculture. For Cu and Pb, the concentrations were higher in the off-season than in pluvial agriculture. The *Cf* ranges from 0.24 to 11.70 depending on the considered trace metal. The *Cf* values of As, Ni, Pb, Zn and Mn indicated that the agricultural study soil was lowery contaminated by these trace metals. The agricultural study soil was moderately contaminated by Cr and Cu, and highly contaminated by Hg. Globally the agricultural study soil presents a moderate degree of contamination (*mCd* 2.25) by the eight trace metals studied. This result provides information on understanding the risks of trace metal contamination of agricultural soil. It is important to anticipate the control of soil contamination through regular monitoring of toxic metals in agricultural soils, control the quality of chemicals used in agriculture and regulate their use.

Keywords

Chemicals Products, Trace Metals, Pollution Index, Soil Contamination, Off-Season, Burkina Faso

1. Introduction

Trace metals generally refer to metals and metalloids associated with pollution and toxicity but also to the essential elements for human health [1] [2]. All trace metals are not always toxic because these elements are naturally present in the soil and in all living organisms, at the concentrations that vary according to the environment and the organisms [3]. The pollution effect of trace metal result is mainly from human activities such as industries, domestic wastes, agrochemical products (fertilizers and pesticides), and transport [4] [5] [6]. The trace metals are not biodegradable, some mineral and biological processes allow the accumulation of these elements and to a certain degree, they may be considered hazardous for agriculture [7] [8].

In Burkina Faso, the agriculture employs over 86% of the rural population and constitutes the main source of food and income for the population [9]. Measures to adapt to climatic variability and the search for food security have led farmers to expand their agricultural areas and to practice continuous crop cycles during the rainy seasons (pluvial agriculture) and dry seasons (off-season agriculture). Off-season agriculture is practice near the water reservoir due to favorable hydrometeorological conditions [10]. Excessive exploitation of soils leads to their degradation and a decrease in their productivity. To remedy these effects, farmers increase the use of agrochemical products (fertilizers and pesticides). These products are generally used without respecting the use of fertilizers and pesticides and the consequence is the imbalance of the ecosystem and the production of chemical pollutants that can affect the physico-chemical and biological quality of the environment [11] [12]. The principal function of the soil is to act as a filter, a purifier of a large number of pollutants, but this capacity is limited and the soil becomes negatively affected by these different pollutants [13]. Trace metals are among the chemical pollutants in soils from the use of certain fertilizers and agricultural chemicals. Some trace metals such as Co, Cu, Fe, Mn, Mo, Ni, V and Zn are essential to organisms in minute quantities, but they can accumulate in soils for long periods of time and become hazardous to the environment and human health because they are not biodegradable [7] [14]. Other trace metals such as arsenic (As), lead (Pb), mercury (Hg) and cadmium (Cd), on the other hand, have significant toxicity on human health [14]. The consumption of food grown on soil contaminated with these elements presents a risk to human health. The objective of this study is to investigate the pollution level of trace metals (As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se and Zn) in agricultural soil by using contamination factors and modified contamination degree.

2. Materials and Methods

2.1. Materials

2.1.1. Characteristics of the Study Area

The study was conducted on agricultural soil around the water reservoir in municipality of Nangreongo, in Oubritenga Province at central region (Lat. 12˚30'N; Long. 1˚05'W), Burkina Faso (**Figure 1**). This site is located at 50 km at the east of Ouagadougou. The water reservoir is the most important water supply at this central region. This site is characterized by the semi-arid climate with the mean annual precipitation of 726 mm. There are two main seasons, the dry season extends from November to May, and the rainy season, which corresponds to the peak period of agricultural activities, extends from June to October [15]. The main soil is Ferric Lixisols [16].

There are two main types of agricultural activities in the area; pluvial agriculture, which takes place during the rainy season and off-season agriculture which is practiced during the dry season. During the off-season agriculture the soil are irrigated with water from the water reservoirs. The main crop are sorghum, maize, sesame and millet during pluvial agriculture. For off-season agriculture the main crop are market garden products such as onions, tomatoes, cucumbers, cabbages. The agriculture in this area is characterized by an archaic exploitation using chemical fertilizers for soil fertilization and pesticides for crop protection.

2.1.2. Soil Sampling

The soil samples were collected from April to October 2022, in two periods, during the off-season agriculture (dry season) and during the pluvial agriculture (rainy season). The samples were collected as to cover a uniform area of the soil.

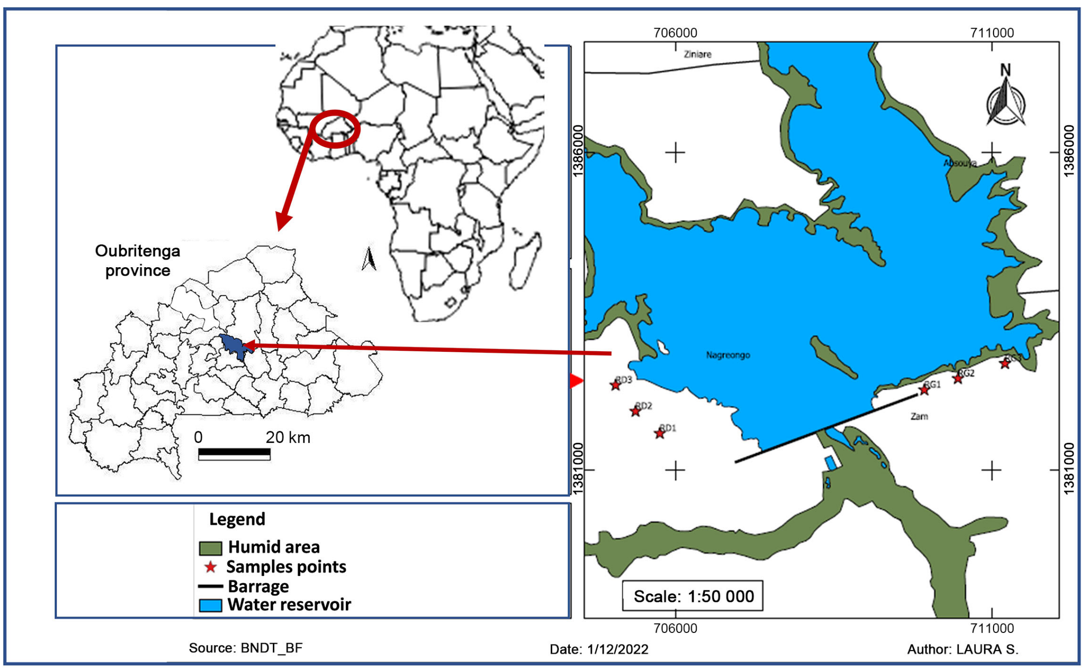

Figure 1. Location of the study sites in Oubritenga province.

The soil samples were randomly collected at three (3) replicate points per field, from 6 fields, following a zigzag pattern. The samples were collected using with a 118.8 cm^3 cylinder (5.5 cm diameter and 5 cm height) at the depth of 0 - 20 cm. The three replicate samples were combined into a composite sample of approximately 500 g. A total of thirty-six (36) samples for twelve (12) composites soil samples were placed in a plastic bag and labelled. Before analysis, the samples were air-dried, and oven dried at a temperature of 105˚C. The dried soil samples were then ground and sieved to obtain a fine soil fraction. The analyses were performed in the private laboratory SENEXEL in Ouagadougou. The samples were used to determine the concentration of traces metals.

2.2. Methods

2.2.1. Traces Metals Analyses

Traces metals were determined according to the standard methods of the US EPA 2007 with a microwave plasma atomic emission spectrometer (MP-AES), model Agilent 4210. The studied traces metals were, arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se) and zinc (Zn). For the analyses of Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se and Zn, 25 g of dried samples are subjected to acid digestion in a microwave oven with a solution of 2.5 mL concentrated nitric acid HNO_3, 7.5 mL concentrated chloridric acid HCl and 0.5 mL of hydrogen peroxide H_2O_2. The digested samples are filtered with a Whatmann paper. The filtrate was diluted, in a centrifuge tube, with 50 mL of deionized water. The blank samples (analytical standards) were prepared following the same procedure, with deionized water, 1% HNO_3 and 1% HCl. Three replicates' measurements were made for each sample and the final concentration value for the sample was the average of the three measurements.

The arsenic (As) was measured by pre-reduction of arsenic with potassium iodide (KI), followed by hydride generation. The pre-reduction consisted of continuous stirring of mixture 25 mL of homogenized filtrate with 5 ml of HCl (10% v/v) and 2 ml of KI (25% m/v) in 50 ml centrifuge tube. The mixture was heated in a water bath at 50˚C to 70˚C for 10 minutes. Hydride generation was performed with mixture of sodium borohydride, $NaBH_4$ (0.6% w/v) and sodium hydroxide solution, NaOH (0.5% w/v).

2.2.2. Indices of Contamination

The contamination indices, mainly the contamination factor (Cf), the modified contamination degree (mCd), were calculated using the traces metals concentrations values in the soils of this study and the background concentration values of traces metals. The background concentration corresponds to the concentration of trace metal in the soil without anthropogenic input [17]. Due to lack of local or regional geochemical background data in uncontaminated soils for this study site, the global average background concentration values for each traces metals reported by Alloways [18] were used.

Contamination factor (*Cf*)

The *Cf* was calculated as the ratio of the concentration of observed trace metal (*Ci*) to the background concentration value (*Cb*) of the corresponding trace metal as follows:

$$Cf = Ci/Cb$$

Cf ≤ 1 indicates low contamination, 1 < *Cf* ≤ 3 indicates moderate contamination, and 3 < *Cf* ≤ 6 indicates considerable contamination, *Cf* > 6 indicates very high contamination [17] [19].

Modified contamination degree (*mCd*)

The modified contamination degree (*mCd*) determines the degree of overall contamination by several trace metals in a surface layers [20]. The *Cd* was calculated as the sum of all contamination factors (*Cf*) divided by the number of analyzed traces metals.

$$mCd = \sum Cf/n$$

With *n*, the number of measured trace metal. The modified degree of contamination is classified as nil to very low degree of contamination if *mCd* < 1.5, low degree of contamination if 1.5 ≤ *mCd* < 2, moderate degree of contamination if 2 ≤ *mCd* < 4, high degree of contamination if 4 ≤ *mCd* < 8, very high degree of contamination if 8 ≤ *mCd* <16, extremely high degree of contamination if 16 ≤ *mCd* < 32, and ultra-high degree of contamination if *mCd* > 32 [20] [21].

2.2.3. Statistical Analysis

The data were statistically analyzed using International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) Statistics V18.0 software. SPSS is the statistical tool. The descriptive analyses such as minimum; maximum; mean; median; variance, were represented in the form of tables and histogramme diagrams.

3. Results

3.1. Content of Traces Metals in Soil

The trace metal concentration measured in agricultural soils around the water reservoir during the off-season agriculture (dry season) and the pluvial agriculture (wet season) are presented in **Table 1**. The average of the two periods gives the concentration of traces metals on agricultural soil. The detection limit of arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se) and zinc (Zn) were, respectively, 1, 5, 10, 10, 5, 0.03, 10, 10, 2, 1, 1 and 5 µg/g.

During the off-season agriculture, the concentration of As (<1 µg/g), Cd (<5 µg/g),, Co (<10 µg/g), Hg (<0.03 µg/g), Ni (<10 µg/g), Sb (<1 µg/g) and Se (<1 µg/g) were below the detection limit (**Table 1**). In contrast, during pluvial agricultural, the concentration of As (1.12 µg/g), Hg (1.17 µg/g) and Ni (10 µg/g) were measured in agricultural soils. While the concentration of trace metal Cd,

Table 1. Concentrations of traces metals (μg·g^{-1}) (As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se and Zn) for off-season agricultural and pluvial agriculture soil around water reservoir and standard permissible concentrations value of traces metals in agricultural soil (AFNOR U44-41).

	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Se	Zn
	μg/.g											
Off-season agriculture												
Mean	<1	<5	<10	97.4	20.5	<0.03	306.2	<10	12.4	<1	<1	6.8
S.E.				22.7	1.5		40.1		2.0			0.4
Min.	<1	<5	<10	57.5	15.8	<0.03	213.8	<10	6.1	<1	<1	6.5
Max.	<1	<5	<10	202.0	25.5	<0.03	435.1	<10	20.1	<1	<1	7.0
Pluvial agriculture												
Mean	1.12	<5	<10	106.5	13.5	1.17	582.5	10	3.5	<1	<1	31.8
S.E.	0.03			21.1	1.5	0.03	85.1		0.3			3.5
Min.	1.00	<5	<10	44.4	7.3	1.14	210.3	<10	3.3	<1	<1	20.3
Max.	1.00	<5	<10	193.0	18.6	1.20	810.2	10	3.7	<1	<1	40.5
AFNOR U44-41	100	2	30	150	100	1	-	50	100	-	-	300

S.E.: standard error; Min.: minimum; Max.: maximum; AFNOR U44-41: standard permissible concentrations of traces metals in agricultural soil [22].

Co, Sb and Se remain below detection limit. The concentrations of Cr (97.4 μg/g), Mn (306.2 μg/g) and Zn (6.8 μg/g) were lower in the off-season agriculture compared to the pluvial agriculture, 106.5 μg/g for Cr, 582.5 μg/g for Mn and 31.8 μg/g for Zn. For trace metal Cu and Pb, the concentrations were higher in the off-season (Cu 20.5 μg/g, Pb 12.4 μg/g) than in pluvial agriculture (Cu 13.5 μg/g, Pb 3.5 μg/g).

During the off-season the metal with the highest concentration is Mn, followed in descending order as Mn > Cr > Cu > Pb > Zn. As, Cd, Co, Hg, Ni, Sb and Se were below the detectable limits. In pluvial season, the concentration of traces metal follows the order Mn > Cr > Zn > Cu > Ni > Pb > Hg > As. Cd, Co, Sb and Se remain below the detectable limits.

3.2. Indices of Contaminations

The mean concentration of trace metal in agricultural soils were classified in decrease order as follow Mn (444.4 μg/g) > Cr (102.5 μg/g) > Zn (25.5 μg/g) > Cu (17.3 μg/g) > Ni (9.9 μg/g) > Pb (9.8 μg/g) > Hg (1.2 μg/g) > As (1.1 μg/g) (**Figure 2**). The concentration of all these traces metals were lower than the standard permissible concentration in agricultural soil, according to the French standard AFNOR U44-41, except for Hg of which the average concentration was slightly high than the standard permissible concentration (**Table 1**).

The concentrations of ETMs measured in this study were compared with the background value (**Figure 2**). The background concentration [18] corresponds to the concentration of trace metal in the soil without anthropogenic input [17].

The levels of the trace metals As (1.1 μg/g), Ni (9.9 μg/g), Pb (9.8 μg/g) and Zn (25.5 μg/g) measured in this study were lower than the background values. While the concentration of Cr (102 μg/g), Cu (17 μg/g), Hg (1.17 μg/g) and Mn (444 μg/g) were higher than the background values.

The contamination factor (*Cf*) for each trace metal and modified contamination degree was presented in **Figure 3**. The *Cf* ranges from 0.24 to 11.70 depending on the considered trace metal. The *Cf* values for As (0.24), Ni (0.55), Pb (0.39), Zn (0.41) and Mn (1.06) indicated that the agricultural study soil were lowery contaminated ($Cf \leq 1$) by As, Ni, Pb and Zn. The agricultural study soil was moderately contaminated ($1 < Cf \leq 3$) by Cr (2.44) and Cu (1.24). Mercure Hg (11.70) presents a very high contamination of agricultural soil of this study.

Globally the agricultural study soil presents a moderate degree of contamination by the eight trace metals studied, as *mCd* (2.25) was between $2 \leq mCd < 4$.

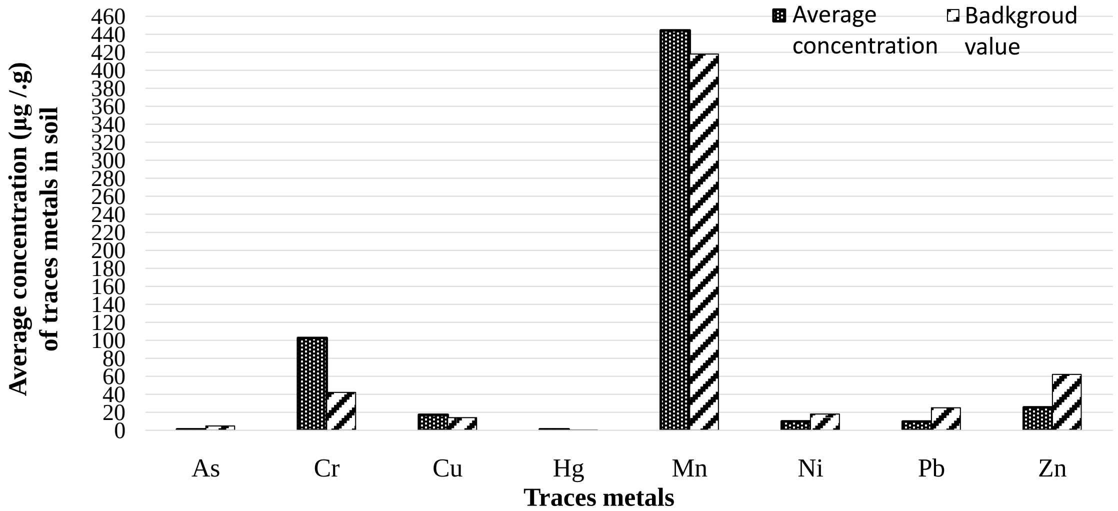

Figure 2. Mean concentration of trace metal in agricultural soils of this study and background value.

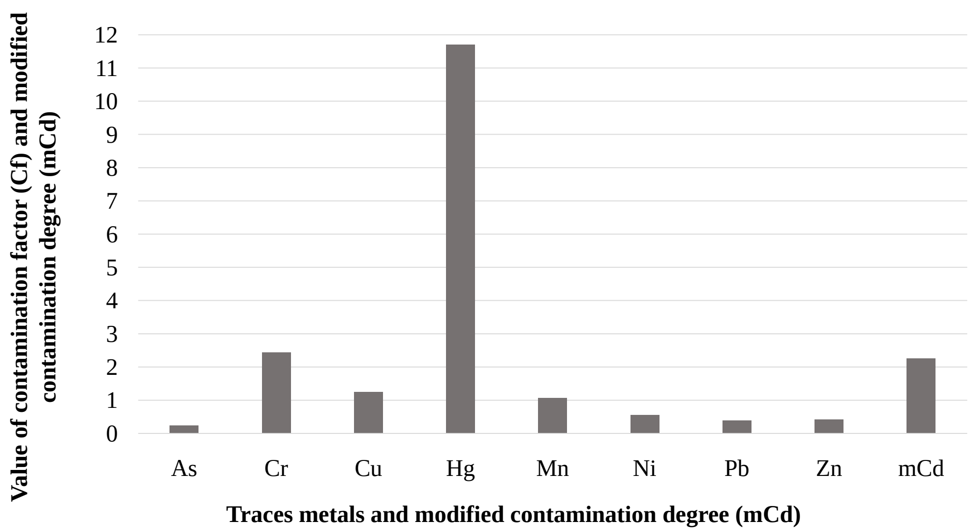

Figure 3. Contamination factor (*Cf*) for each trace metal and modified contamination degree.

4. Discussion

This study provides information on understanding the risks of trace metal contamination of agricultural land due to the misuse of chemicals products such as fertilizers, pesticide. Our results show the absence of some trace metal in agricultural soil, these metals were cadmium (Cd), cobalt (Co), antimony (Sb) and selenium (Se).

The trace metals, As, Pb, Cd, Cr, Cu, Hg, Ni, and Zn, considered in this study have a greatest concern for human health, for which some of them are toxic (As, Cd, Pb, Hg) and other essential (Zn, Se) [23] [24]. The low level of As, Pb, or the absence of certain trace metals such as Cd, can be explained by the absence of industrial activity in this area [23]. The concentration of As, Cu, Hg, Ni, Pb, Zn in this study were extremely lower than that reported by Rahman [25] This comparation show the high impact of industrial activities as show in the study of Rahman [25].

The concentration of trace metals in this study was compared to the values reported in the world. The mean concentration of Cu, Pb, Zn and Ni were lower than the mean value found agricultural soil in China [26], and higher than the mean value in agricultural soil in Tanzania [27]. The concentration of Pb and Zn in this study was lower than the mean value reported in soil in Nigeria [28].

The variation of concentration of traces metals between off-season and pluvial season were impact by the type of crop cultivated consequently, the type of chemicals products used. The chemicals products used in the agricultural soil of this study would not contribute to the concentration of traces metal such as cadmium (Cd), cobalt (Co), antimony (Sb) and Selenium (Se).

The average concentration of the trace metals varies according to the considered trace metal the period of soil sampling. These results were in accordance with those of several authors such as Smouni *et al.* [29], Ye *et al.* [30] who have shown that the concentration of trace metal varies depending on the trace metal, the sampling site and soil type.

Arsenic is naturally present in the soil but has a contaminating effect following the use of wood preservatives and pesticide [23] [24]. Pb is introduced into the soil mainly through leaded gasoline, lead-based paints, lead mining and smelting [23] [31]. The low soil contamination in this study by Zn is consistent with most soils in the world that are generally deficient in Zinc [23]. The main causes of the presence of Cd in the soil are the industrial activities or the fertilization with sewage sludge [23]. The poorly treated wastewater from discharged of ceramics, steel alloys are the main source of Ni [25]. The agricultural soil in this study is not affect by those activities, consequently Cd, Co Ni, Sb and Se were not determined in this study.

Despite the absence of anthropogenic contamination from gold mining, coal burning, or chlorine production, the concentration of Hg measure in this study would probably due to the use of fungicide [25]. As it is the main pesticide use to control fungi that damage plants such as mildew. The mildew especially present in the wet period justify the high concentration of Hg during the pluvial season and the absence of Hg in the off-season.

Both in off-season and pluvial season, Mn remains the most important with higher concentration compared to other trace metal. This can be explained as Mn is the commonly found elements in the lithosphere [25].

The pollution index (contamination factor *Cf*, modified contamination degree *mCd*) was used to investigate the pollution level of traces metals in agricultural soil in this study. The calculation of the contamination factor shows that the agricultural soil in this study was less contaminated by As, Ni, Pb, Zn, Mn, moderately contaminated by Cr, Cu, and highly contaminated by Hg.

The *mCd* in this study presents a moderate degree of contamination by the eight trace metals studied.

The concentration of the trace metals was lower than the standard permissible concentration in agricultural soil, according to the French standard AFNOR U44-41. These results were in accordance of the studies of [30]. On the other hand, the average concentration Hg was slightly high than the standard permissible concentration. This indicates that Hg is the most polluted metal among the eight studied trace metals. The concentration of trace metal in the soil corresponds to its content naturally present in the soil and the contributions from anthropic activities [22]. The concentrations above background values indicate that in addition to the naturally occurring concentration there are also concentrations due to anthropogenic activities.

5. Conclusion

The study aims to investigate the pollution level of trace metal in agricultural soil of Ou Oubritenga province in Burkina Faso. The trace metals, As, Pb, Cd, Cr, Cu, Hg, Ni, and Zn, considered in this study have the greatest concern for human health. The result indicates a moderate degree of contamination by the eight trace metals studied. The concentration of the trace metals was lower than the standard permissible concentration in agricultural soil, according to the French standard AFNOR U44-41, except for Hg for which the average concentration was slightly high than the standard permissible value. The results show the absence of some trace metals in agricultural soil, these metals were cadmium (Cd), cobalt (Co), antimony (Sb) and selenium (Se). This study provides information on understanding the risks of trace metal contamination of agricultural land due to the misuse of chemical products, such as fertilizers and pesticides. As the study was conducted on agricultural soil around the water reservoir that is used for water distribution, it is important to anticipate the control of soil contamination. These actions could be through regular monitoring of toxic metals in agricultural soils, controlling the quality of chemicals used in agriculture and regulating their use.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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