ISSN (Online): 2091-2609
DOI Prefix: 10.3126/ijasbt
International Journal of Applied Sciences and Biotechnology (IJASBT)

Research Article

Assessment of Heavy Metal Contamination Levels in Market Gardening Soils Used to Grow Onions (*Allium cepa*) in the City of Abéché (Eastern Chad)

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Article Information

Received: 25 January 2023
Revised version received: 26 March 2023
Accepted: 27 March 2023
Published: 31 March 2023

Cite this article as:
H. Abdou et al. (2023) Int. J. Appl. Sci. Biotechnol. Vol 11(1): 42-53. DOI: 10.3126/ijasbt.v11i1.53700

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Abstract

The main objective of this study was to assess the level of metal contamination of the soils used in the cultivation of onions in the city of Abéché. Thus, 04 plots were carried out and monitored for a period of five years (05 years). Two traditional plots were chosen in the Arkou site; and two control plots were carried out in the Bagarine site. Soil samples were taken annually (2016 to 2020) after harvesting on a thickness of 0 and 20 cm. In each plot, thirteen (13) samples were taken. After quartering, one (01) representative sample from each plot was retained. The samples were analyzed by optical emission spectrometry at the Food Quality Control Center Laboratory (FQCCL) in Ndjamena. The determination of heavy metal concentrations revealed relatively low levels for Ni, Zn, Cu, Cr and Fe. These levels are generally lower than the reference values for all the plots. Geoaccumulation indices (Igeo) and Contamination factor (Cf) revealed pollution indices. Pb and Cd show contaminations in traditional plots. The correlations ($P < 0.05$) observed in our study area are positive and significant. This study shows that the use of chemical inputs are sources of soil contamination by heavy metals.

Keywords: soils, heavy metals, geoaccumulation index, contamination factor and Abéché

Introduction

Market gardening in the Sahelian zone has undergone profound changes in recent decades. The low and fluctuating rainfall, the decline in soil fertility and the damage caused by a range of crop enemies (insects, diseases) have led to the increased use of phytosanitary products, including fertilizers. The increased use of these fertilizers raises questions about the problem of environmental protection and soil conservation (Tabi *et al*., 1990). Population growth that and the increased use of chemical and organic fertilizers are generally blamed for soil degradation (Gruhn *et al*., 2000). In recent decades, the use of chemical phosphate fertilizers has become one of the inevitable solutions to provide the necessary nutrients to plants and increase agricultural production (Chen *et al*., 2007). However, excessive fertilization through and inappropriate use of mineral fertilizers and pesticides can contribute to the increase of metallic trace elements (MTE) in the soil (Traore *et al*.., 2010). The use of inputs can have negative effects on the environment. Various studies have shown that heavy metals are potentially toxic to humans, animals, and crops grown on contaminated soils (Hussain and Bordoloi, 2019).

Several studies on soil pollution have been conducted in recent years around the world. The work of Baize (2000) on French agricultural soils showed high levels of MTE. Similarly, in Poland, the study on the determination of metallic contamination of agricultural soils in industrial areas showed that the concentration of MTE is higher than that of the earth's crust (Loska *et al*., 2004). The results of work by (Ouakki *et al*., 2001) highlighted the contamination of certain edible crops by Cd and Pb.

In Africa, more specifically in Ngaoundéré in Cameroon, the work of Adjia *et al*. (2010) showed that certain market garden products grown in the city of Ngaoundéré were contaminated by metals including Pb and Cd, due to the amendment of market garden soils with household waste combustion debris from urban dumps. As well as the work of Temgoua *et al*. (2015) on market garden crops in Dschang which showed high levels of heavy metals in soils and plants. We can mention the works of (Ekengelé *et al*., 2016) in the evaluation of metals contamination of soils, exposed to the burning of car tires and the total levels of Zn, Ni, Cu, Cr, Pb and Cd were found to be significantly high in Ngaoundere compared to the reference values used.

And in Chad, specifically in Abéché, no study has so far focused on the risk of contamination of agricultural soils by heavy metals. Capital of the province of Ouaddaï, Abéché has an estimated population of one million inhabitants according to the final results of RGPH2 2016, with a density of 33 inhabitants/Km2. These results reveal an acceleration of the country's population growth. The main activity of the population is agriculture and animal husbandry. Garlic and onion production in Abéché accounts for about 90% of Chad's total production (Africare, 1989). In recent years, the agricultural campaign of the city of Abéché has been in deficit with a difference of 39.57% (WHO, 2017). To increase soil fertility, farmers resort to the use of fertilizers from various sources. Repeated use of chemical inputs is the source of soil contamination by heavy metals (Webber *et al*.1981). Discharged into the environment, heavy metals mainly accumulate in the soil. Soils then behave as reservoirs of pollutants, and are important vectors for the transfer of heavy metals from the environment to the body (Sirven *et al*., 2006). Given the need to use chemical inputs to improve agricultural production, it is important to assess the impact this has on the soil. The main objective of this study is to assess the level of heavy metal contamination of the soils used in the cultivation of onions in the city of Abeche.

Materials and Methods

Study Sites

During our study, we chose two traditional plots in the Arkou site. Then, we carried out two experimental fields in the market gardening site of Bagarine (Fig. 1). The choice of these 2 sites is based on the fact that the soils are fertilized with chemical fertilizers (NPK and Urea).

Location of the Study Area

The two sites of Bagarine and Arkou are respectively located about 3 km and 5 km from the town of Abéché. The Bagarine site is located between 13°51'900 North latitude and 20°41'081 East longitude. The Arkour site is located between 13°52′160 North latitude and 20°51’150 North latitude East longitude (Fig. 1).

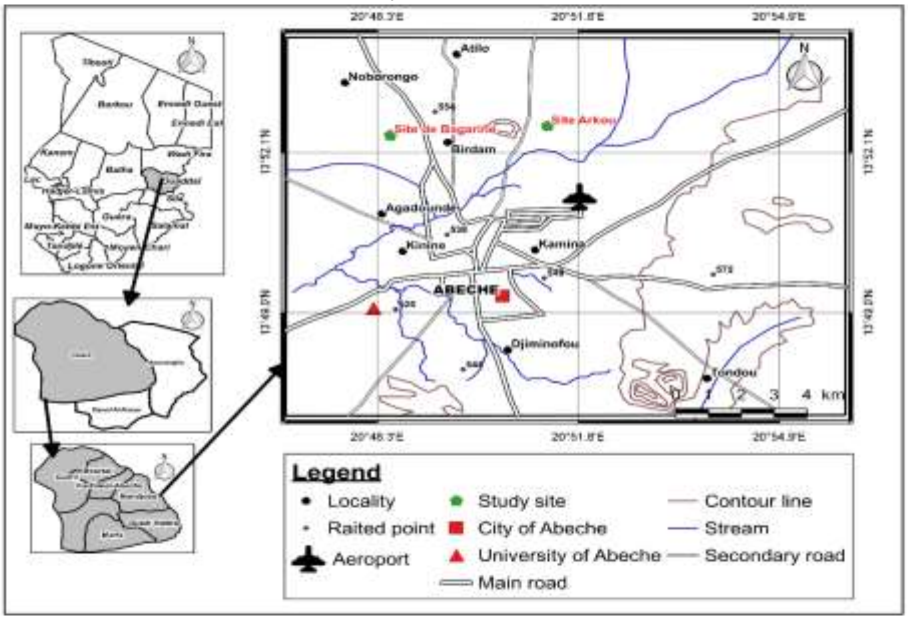

Fig. 1: Location map of the study area (source Hamadou, 2019)

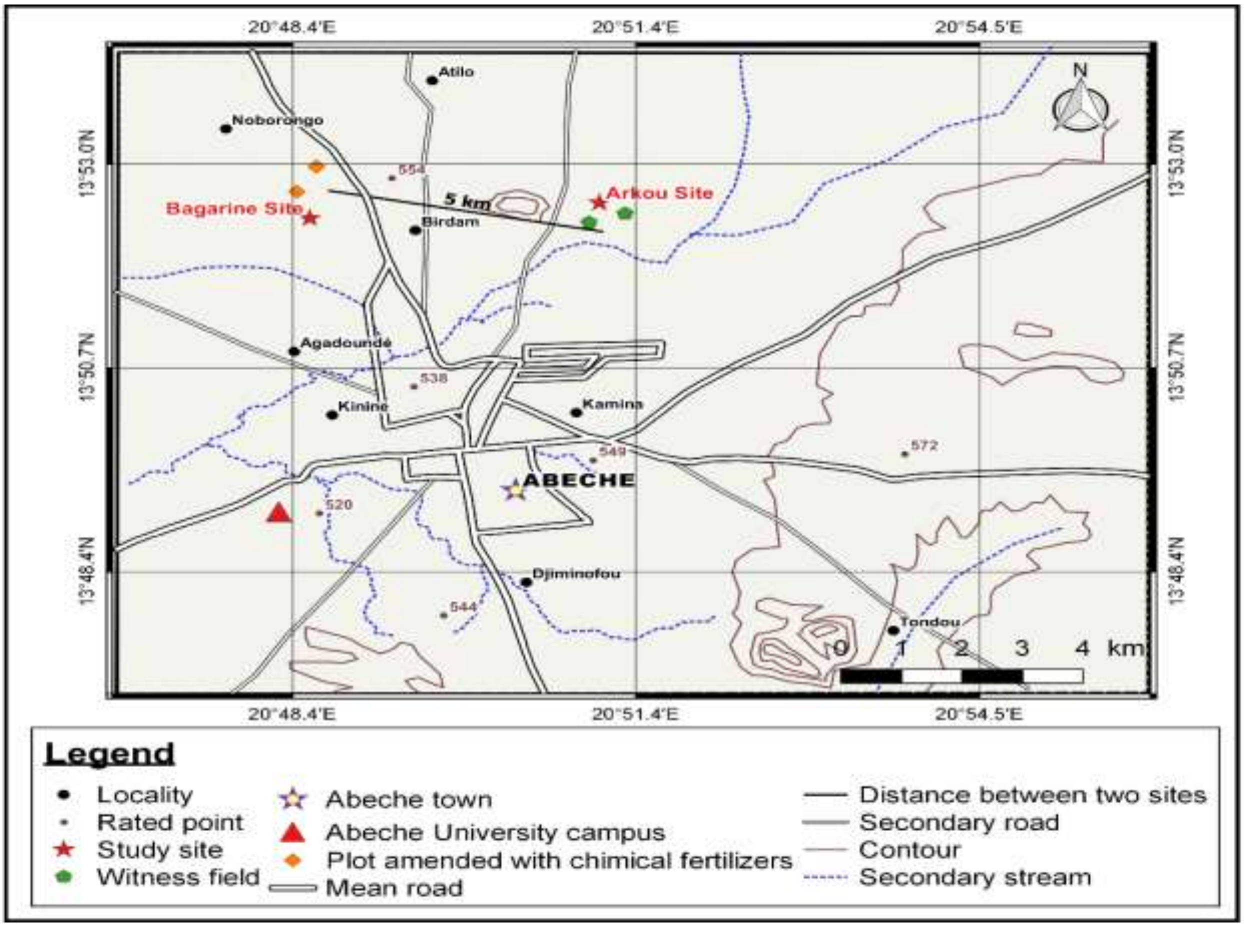

Fig. 2: Sampling map (source Hamadou, 2019)

TP1: Traditional plot of 15 years, geographical coordinates N 13°51'942; E20°48'993;
TP2: 10-year-old Traditional Plot Geographical Coordinates N 13°51'926; E20°49'081;
PE1: 05-year-old Experimental Plot with Amendment of geographical coordinates N 13°51'924; E20°49'081;
PE2: 05-year Experimental Plot Without Amendment of geographical coordinates N 13°51'924; E20°49'081.

Field Methods

To achieve our objectives, 2 traditional plots (PT1 and PT2) with at least 10 and 15 years of activities were chosen in the market gardening areas of Abéché (Arkou) and 2 experimental plots (PE1 and PE2) in the Bagarine site for a period of 5 years of activities. In total, we have 04 plots including 02 traditional plots in the Arkou site and 02 experimental plots in the Bagarine site. As for the maintenance of the control plot (EP2), no fertilizers or pesticides were used.

On the two sites (Arkou and Bagarine), soil samples were taken annually after harvesting on a thickness of 0 and 20 cm. Thirteen (13) samples were taken from each plot, and after quartering, one (01) representative sample from each plot was retained for analysis. The samples were transported to the Geology Laboratory of Adam Barka University in Abéché for pre-treatment. The samples were oven-dried and stored for chemical analysis.

Laboratory Methods

Determination of the physico-chemical parameters of agricultural soils in Abeche

The determination of the physico-chemical parameters was carried out at the Laboratory of the Food Quality Control Center (LFQC) in Ndjamena.

The preparation of the samples is a stage which consisted in carrying out in turn: drying, grinding, sieving and preservation of the samples according to the standards (Afnor, 1992), NF X 31-147 and (Afnor, 1995), NF X 31-100.

The analyzes were mainly focused on determining the values of pH, MO and electrical conductivity. Soil pH was measured using the method described by Mathieu and Pieltain (2003). The measurement consisted of putting 10 g of sieved soil in contact with 25 ml of distilled water. Then the mixture was stirred with a glass rod and allowed to stand before the pH meter reading. For the determination of the OM, the method of loss on ignition by calcination in the oven was used. 10 g of previously dried soil were taken and incinerated in a Nabertherm brand oven at 550°C for 2 hours (Mwamburi, 2003).

Determination of heavy metals in soils

The determination of heavy metals was carried out at the laboratory of the Food Quality Control Center (FQCC) in N'Djamena in Chad. The analysis focused mainly on Fe, Cd, Cu, Ni, Pb and Cr and took place according to the following protocol: 2 mm sieved samples were finely ground to pass through a 0.5mm sieve. 500 mg of soil sample was digested in aqua regia. All the metals were analyzed by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) of the "perkins-elmer optima 3000XL" brand (Chen *et al*., 2001.).

Methods for estimating the intensity of contamination

In other to assess the contamination of soils in this research work, geoaccumulation index and contamination factor were calculated for each of the 25 soil samples.

Geo accumulation Index (Igeo)

The geo-accumulation index (I*geo*) was first described by (Muller, 1979) and will be use here as a second measure to identify contaminated soils.

$$I_{geo} = log_2 \frac{C_n}{1.5Bn}$$

C_n: Concentration of the examined metals in the soil; **B_n**: Geochemical background value of a given metal in average shale (Turekian and Wedepohl, 1961); The factor 1.5 is introduced to minimize the effect of possible variations in the background or control values, which may be attributed to soils lithogenic variations (Mediolla *et al*; 2008). Six classes of the geo accumulation index, values of geoaccumulation index can be defined as shown in Table 1.

Contamination factor

The contamination factor (C_f) is used to determine the contamination status (Table 2) of soil samples in study areas, in the version suggested by (Thomilson *et al.;* 1980) of formula;

$$C_f = \frac{C_{metal}}{C_{background}}$$

Where C_{metal} is the measured concentration of a specific metal and $C_{background}$ is the background value of the metal.

Statistical Analysis

The analysis of the results was carried out with XLSTAT version 2007 8.04 in which the Principal Component Analysis (PCA), and the Pearson correlation matrix were performed. The realization of the curves and graphs was done with the software Excel 2013.

Table 1: Geo accumulation Index

Igeo Values	**Contamination level**
Igeo ≤ 0	Uncontaminated
0< Igeo< 1	Uncontaminated moderately
1< Igeo< 2	Moderately contaminated
2< Igeo< 3	Moderately/strongly contaminated
3< Igeo< 4	Strongly contaminated
4< Igeo< 5	Strongly/Extremely contaminated
Igeo > 5	Extremely contaminated

Table 2: Contamination factor

C*f* value	**Contamination factor level**
$C_f < 1$	Low contamination factor indicating low contamination
$1 \leq C_f < 3$	Moderate Contamination
$3 \leq C_f < 6$	Considerable contamination
$6 \leq C_f$	Very high contamination

Results

Table 3 shows the concentration of heavy metals and physicochemical parameters of Traditional and Experimental plot of Bagarine and Arkou market garden site.

Assessment of Pollution Intensity

Geoaccumulation index

The results of geoaccumulation indices obtained on the traditional and experiment plots of Bagarine and Arkou are represented by Table 4 and 5.

Contamination factors

Tables 6 and 7 show the results of the contamination factors (Cf) of different traditional and experiments plots of Arkou and Bagarine of heavy metals analyzed.

Matrices And Correlation Circles of The Parameters And Heavy Metals Studied

Pearson correlation analysis was used to assess the correlation between studied heavy metals content and physicochemical parameters (pH and OM) in plots demonstrated in Fig. 3.

Table 3: Concentration of heavy metals and physicochemical parameters of Traditional and Experimental plot at 15, 10, 5 years of Bagarine and Arkou market garden site.

plot 1	**Sample**	**M.O**	**pH**	**Ni**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Fe**
TP1: 15 years of activities (2006-2020)	TS1	2,43	6,43	39,03	36,68	89,35	2,89	60,24	47,31	12087,6
	TS2	2,81	6,65	42,13	39,38	87,25	2,93	61,33	49,01	12099
	TS3	1,98	6,35	40,09	45,56	67,9	3,01	57,35	45,61	13098,9
	TS4	2,07	6,43	43,72	49,44	59,71	2,56	56,03	39,99	12801,3
	TS5	1,94	6,55	42,82	48,12	99,11	3,03	67,21	48,99	12097,8
	Minimum	1,94	6,35	43,72	36,68	99,11	3,03	67,21	49,01	13098,9
	Maximum	2,81	6,65	39,03	48,12	59,71	2,56	56,03	39,99	12087,6
	Moyenne	2,24	6,48	41,56	43,83	80,66	2,88	60,43	46,18	12436,9
Plot2	**Sample**	**M.O**	**pH**	**Ni**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Fe**
TP2: 10 years of activities (2011-2020)	TS1	2,47	6,33	26,04	35,46	66,27	1,1	51,72	36,97	14730,9
	TS2	2,59	6,45	28,74	36,46	71,01	1,89	49,61	39,25	14750,8
	TS3	2,43	6,42	30,02	43,82	55,11	1,2	52,71	40,31	13991,2
	TS4	2,13	6,41	34,1	45,19	49,01	1,56	50,93	45,67	14207
	TS5	2,45	6,39	39,06	42,88	79,05	1,12	51,01	42,37	12097,8
	Minimum	2,13	6,33	39,06	35,46	55,11	1,1	49,61	45,67	14750,8
	Maximum	2,59	6,45	26,04	45,19	79,05	1,89	52,71	36,97	12097,8
	Moyenne	2,41	6,4	31,59	40,76	64,09	1,37	51,2	40,91	13955,5
Plot3	**Sample**	**M.O**	**pH**	**Ni**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Fe**
EP: 5 years of activities with amendment (2016-2020)	ES1	2,32	6,29	19,9	33,06	56,37	0,81	40,63	41,72	12330,6
	ES2	2,41	6,37	21,04	38,12	61,33	0,42	44,51	26,19	13250
	ES3	1,32	6,41	22,32	35,43	45,19	0,19	35,61	23,96	12999
	ES4	1,39	6,39	33,17	32,15	43,89	0,13	34,45	29,18	13457,3
	ES5	2,45	6,49	38,02	38,07	51,89	0,17	35,52	34,77	12895,1
	Minimum	1,32	6,29	19,9	33,06	43,89	0,13	34,45	23,96	13457,3
	Maximum	2,45	6,49	38,02	38,12	61,33	0,81	40,63	41,72	12330,6
	Moyenne	1,97	6,39	26,89	35,36	51,74	0,34	38,14	31,16	12986,4
Plot4	**Sample**	**M.O**	**pH**	**Ni**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Fe**
EP2: 5 years of activities without amendment (2016-2020)	ES1	1,51	6,47	11,33	32,01	23,09	0,1	14,06	17,49	13210,2
	ES2	1,47	6,4	19,09	34,22	25,22	0,12	14,51	21,23	12950,5
	ES3	1,31	6,33	12,91	31,97	25,04	0,11	17,21	22,16	13409,1
	ES4	1,39	6,41	17,07	36,32	26,81	0,1	15,32	21,08	13782,2
	ES5	1,91	6,39	17,02	38,07	22,89	0,12	13,96	19,02	12973,1
	Minimum	1,31	6,33	11,33	31,97	22,89	0,1	13,96	17,49	12950,5
	Maximum	1,51	6,47	19,09	38,07	26,81	0,12	17,21	22,16	13782,2
	Moyenne	1,51	6,4	15,48	34,51	24,61	0,11	15,01	20,19	13265

TP1: Traditionnal Plot 1; TP2: Traditionnal Plot 2; EP1: Experimental Plot 3; EP2 of Plot 4

Table 4: Geoaccumulation index (Igeo) of heavy metals in traditional 15-year and 10-year plots of Arkou mining

Plot 1	Sample	Igéo Ni	Igéo Zn	Igéo Cu	Igéo Cd	Igéo Cr	Igéo Pb
TP1: 15 years of activities (2006-2020)	TS1	-1,38	-1,95	0,4	2,68	-1,16	0,65
	TS2	-1,27	-1,85	0,37	2,7	-1,13	0,38
	TS3	-1,34	-1,64	0	2,74	-1,23	0,42
	TS4	-1,22	-1,52	0,17	2,5	-1,26	0,6
	TS5	-1,25	-1,56	0,55	2,75	-1	0,49
Plot 2	**Sample**	**Igéo Ni**	**Igéo Zn**	**Igéo Cu**	**Igéo Cd**	**Igéo Cr**	**Igéo Pb**
TP2: 10 years of activities (2011-2020)	TS1	-1,96	-2	-0,11	1,28	-1,38	0,3
	TS2	-1,82	-1,96	0,07	2,07	-1,44	0,38
	TS3	-1,76	-1,7	-0,29	1,41	-1,35	0,42
	TS4	-1,58	-1,65	-0,46	1,79	-1,4	0,6
	TS5	-1,38	-1,73	0,22	1,31	-1,4	0,62

Table 5: Geoaccumulation index (Igeo) of heavy metals from experimental plots of 05 years activities with, and without amendment.

Plot 3	Sample	Igéo Ni	Igéo Zn	Igéo Cu	Igéo Cd	Igéo Cr	Igéo Pb
PE3: 05 years of activities with amendment (2016-2020)	ES1	-2,35	-2,1	-0,25	0,84	-1,73	0,06
	ES2	-2,27	-1,9	-0,13	-0,09	-1,6	-0,19
	ES3	-2,19	-2	-0,57	-1,24	-1,92	-0,32
	ES4	-1,45	-2,14	-0,62	-1,79	-1,97	-0,03
	ES5	-1,42	-1,9	-0,37	-1,4	-1,92	0,26
Plot 4	**Sample**	**Igéo Ni**	**Igéo Zn**	**Igéo Cu**	**Igéo Cd**	**Igéo Cr**	**Igéo Pb**
PE4: 05 years of activities without amendment (2016-2020)	ES1	-3,17	-2,15	-1,54	-2,16	-3,26	-0,77
	ES2	-2,41	-2,05	-1,42	-1,9	-3,21	-0,49
	ES3	-2,98	-2,15	-1,43	-2,03	-2,97	-0,43
	ES4	-2,57	-1,97	-1,33	-2,16	-3,13	-0,5
	ES5	-2,58	-1,9	-1,56	-1,9	-3,27	-0,65

Table 6: Contamination factor for heavy metals in experimental plots from 05 years of activities with, and without amendment in Bagarine.

Plot 1	Sample	C_f Ni	C_f Zn	C_f Cu	C_f Cd	C_f Cr	C_f Pb
TP1: 15 years of activities (2006-2020)	TS1	0,57	0,39	1,99	9,63	0,67	2,37
	TS2	0,62	0,41	1,94	9,77	0,68	2,45
	TS3	0,59	0,48	1,51	10,03	0,64	2,28
	TS4	0,64	0,52	1,33	8,53	0,62	2
	TS5	0,63	0,51	2,2	10,1	0,75	2,45
Plot 2	**Sample**	**C_f Ni**	**C_f Zn**	**C_f Cu**	**C_f Cd**	**C_f Cr**	**C_f Pb**
TP2: 10 years of activities (2011-2020)	TS1	0,38	0,37	1,47	3,67	0,57	1,85
	TS2	0,42	0,38	1,58	6,3	0,55	1,96
	TS3	0,44	0,46	1,22	4	0,59	2,02
	TS4	0,5	0,48	1,09	5,2	0,57	2,28
	TS5	0,57	0,45	1,76	3,73	0,57	2,12

Table 7: Contamination factor of heavy metals in experimental plots from 05 years activities with, and without amendment to Bagarine.

Plot 3	**Sample**	***C_f* Ni**	***C_f* Zn**	***C_f* Cu**	***C_f* Cd**	***C_f* Cr**	***C_f* Pb**
	ES1	0,29	0,35	1,25	2,7	0,45	2,09
PE3: 05 years of activities	ES2	0,31	0,4	1,36	1,4	0,49	1,31
with amendment	ES3	0,33	0,37	1	0,63	0,4	1,2
(2016-2020)	ES4	0,49	0,34	0,98	0,43	0,38	1,46
	ES5	0,56	0,4	1,15	0,57	0,39	1,74
Plot 4	**Sample**	***C_f* Ni**	***C_f* Zn**	***C_f* Cu**	***C_f* Cd**	***C_f* Cr**	***C_f* Pb**
	ES1	0,17	0,34	0,51	1,71	0,16	0,87
PE4: 05 years of activities	ES2	0,28	0,36	0,56	1,87	0,16	1,06
without amendment	ES3	0,19	0,34	0,56	1,85	0,19	1,11
(2016-2020)	ES4	0,25	0,38	0,6	1,99	0,17	1,05
	ES5	0,25	0,4	0,51	1,7	0,16	0,95

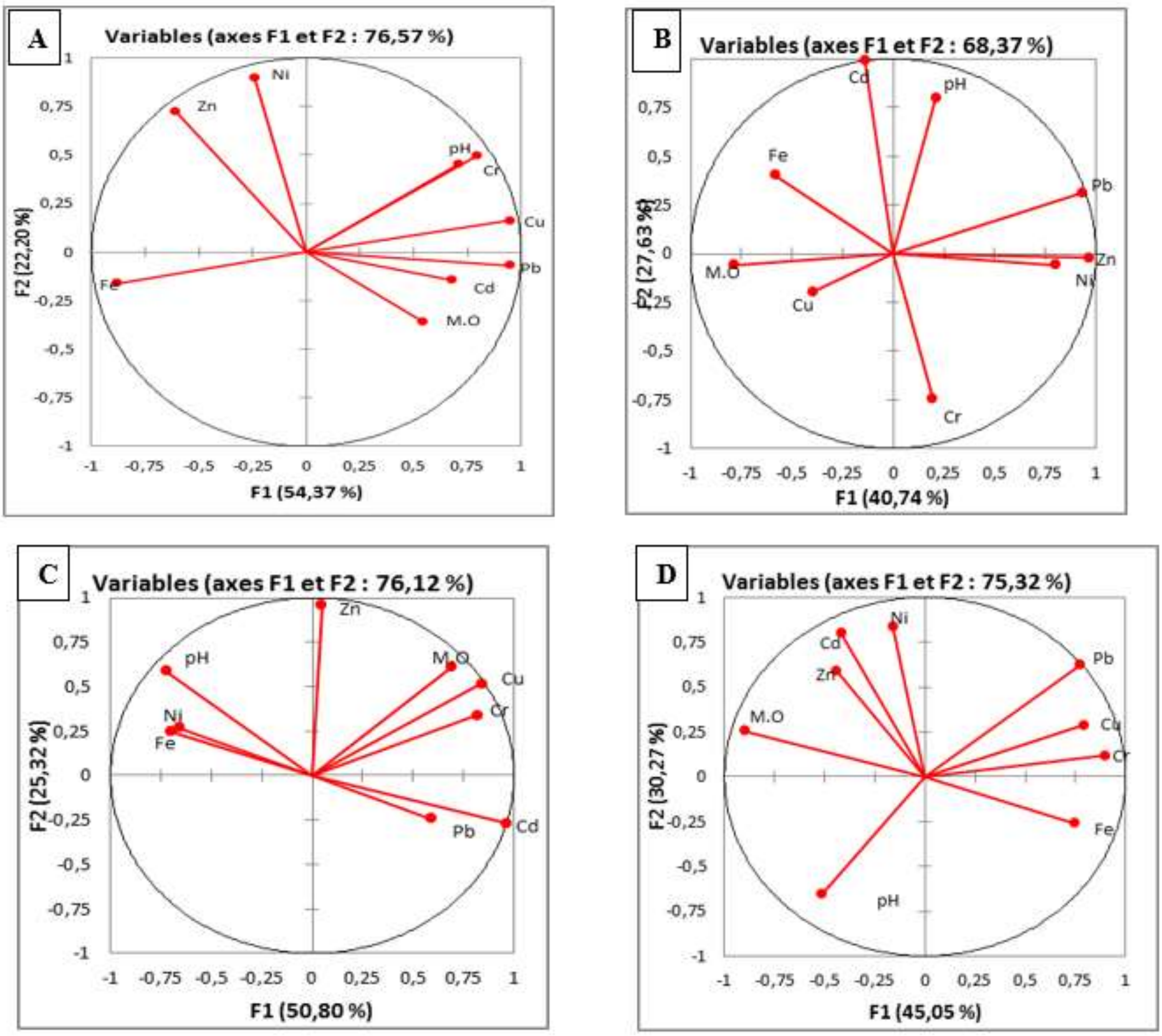

Fig. 3: circle of correlation between heavy metals and the physicochemical parameters (OM and pH) of the plot: A) 15 years of activity with amendment, B) 10 years of activity with amendment, C) 05 years with amendment and D) 05 years of activities without amendment.

Discussion

The Physicochemical Parameters of The Bagarine And Arkou Sites

The study of physicochemical parameters is mainly focused on the determination of pH values and organic matter. pH and OM are considered to be the main parameters controlling the bioavailability of heavy metals in the soil (Brallier *et al*., 1996) and (Kao *et al*., 2007). The results in Table 1 show that the organic matter content varies from one sampling point to another. The values presented that, the traditional plots of 15 years and 10 years of exploitation have a high OM load compared to the other plots (of experiments of 05 years). They vary from 1.94% to 2.81% with an average of 2.24% in the traditional plot of 15 years of exploitation and from 2.13% to 2.59%, with an average of 2.41% in the traditional plots of 10 years of exploitations of Arkou. On the other hand, in the experimental sites of 05 years of Bagarine activities, it varies from 1.32% to 2.45% with an average of 1.97% in the experimental plot of 05 years with amendment. Moreover, they are 1.31% to 1.51% with 1.51% on average. The MO levels at our sites are below standards. They are also lower than the content results obtained by Ballot *et al*. (2016) who worked on the physico-chemical characterization of soils with a view to improving cassava productivity in the Damara region in the center-south of the Central African Republic. However, Kouassi *et al*. (2008) obtained similar results on market garden soils in Abidjan. In Nigeria, similar results were also obtained by Oyedelé *et al*. (2008) and Oluyemu *et al*. (2008).

As for the pH, the values vary from 6.35 to 6.48 in the traditional plot 1 (TP1) of 15 years of activity and from 6.33 to 6.40 in the traditional plot 2 (TP2) of 10 years of activity. farms at the Arkou site. As for the experimental plot (EP) of 05 years of exploitations of Bagarine, pH values range from 6.29 to 6.39. The overall pH results show that the soils in our study area are weakly acidic. These results of pH values are similar to those obtained on soils with clay textures of vegetable crops in Dschang (Cameroon) (Temgoua *et al*., 2015). The variation in pH is a parameter that easily modifies the behavior of metals (Martinelli, 1999).

The Concentrations of Heavy Metals In The Agricultural Soil of Bagarine And Arkou

To assess soil contamination levels, Cd, Ni, Pb, Cr, Zn and Fe were analyzed and the results are given in Table 3.

The average Cu concentration in the traditional plots of 15 years and 10 years of activities is 80.66 kg/mg and 64.09 kg/mg respectively. These levels are higher than the average concentrations obtained (42.35 mg/kg) and (28.78 mg/kg) by Imane *et al*., 2009 in the rice fields of the Gharb plain in Morocco. These values are higher than of the 05-year-old experimental plot without amendment with 24.64 kg/mg on average. The concentrations recorded on the traditional plots of 15 and 10 years are higher than those obtained on the soils of market gardening (8mg/Kg) of the city of Dschang in Cameroon (Temgoua *et al*., 2015); and they are higher than the Canadian standard (63mg/Kg) (CCME, 2002). It appears from these results that the soils of the traditional plots generally have high concentrations of heavy metals compared to those of 05-year-old experimental plots. Low levels are recorded in the experimental plot without amendment (24.61 mg/kg on average). This difference in concentrations could be linked to the duration of exploitation of the plots. These Cu contents on the soils can be explained by the fact of a significant and repeated contribution of chemical inputs to the soils for its fertilization (Naveedullah *et al*., 2013) over the years and would be of anthropogenic origin.

The average Cd concentration obtained on the traditional plots of 10 years and 15 years (average) are higher than those recorded on the experimental soils of 05 years and the reference concentration of Average shale (0.30mg/kg) (Turekian and Wedepol, 1961). The average Cd concentrations are (2.88 mg/kg) and (1.37 mg/kg) respectively in the traditional plots of onions of 15 years and 10 years of exploitation. In addition, the average Cd concentrations of experimental plots of 05 years of activity are respectively 0.34 mg/kg and 0.11 mg/kg with amendment and without amendment. The values of traditional plots are higher than the concentrations of experimental plots of 05 years of activity (with amendment; and without amendment). These concentrations are higher than the mean concentration (0.14 mg/kg) obtained by (Wu *et al*., 2010) in agricultural soils in Yixing province (China) and the mean concentration estimated in normal soil (Kao *et al*., 2017). The presence of Cd in agricultural soils after cultivation could be due to the repeated use of phosphate fertilizers such as NPK and urea which mainly bring cadmium to the soils (Michel *et al*., 1985). High doses of phosphorus fertilizer enriched the soil with cadmium (Kozlowski, 2003).

For Cr, the results obtained on the traditional plots of Arkou are: 60.43 mg/kg and 51.20 mg/kg respectively in the traditional plots of 15 years and 10 years of exploitation. The minimum values are 38.14 mg/kg in the 5-year-old farm plot with amendment and 15.01 mg/kg in the 5-year-old experimental plot without amendment. We notice that the concentration of the plots of Arkou is higher than the concentration of the control plots of Bagarine. However, these contents hardly exceed the reference. These concentrations are also similar to the average levels (34.2 mg/kg; 49.66 mg/kg) obtained by Syed *et al*., 2012 on cultivated soils located near the Dhaka export zone in Bangladesh. The traditional plots of 15 and 10 years, as well as those of experiments of 05 years of activities with amendment or without amendment present low concentrations compared to the reference values which is 74.90 mg/kg.

The Pb concentrations in the plots of Arkou are 46.38 mg/kg and 42.17 mg/kg on average, respectively in the traditional plot of 15 years and 10 years of Arkou farms. Hawever, the minimum concentrations of Pb are recorded in the experimental plot of 05 without amendment of Bagarine with 20.19 mg/kg, and in the experimental plot of 05 with amendment of Bagarine with 31.16 mg/Kg. These average soil lead contents are higher than the Average shale reference (20 mg/kg) estimated by Turekian and Wedepohl (1961) and UCC (17 mg/Kg) Wedepohl *et al*., (1961). However, they are below the Canadian standard for the quality of agricultural soils set at 70 mg/kg (CCME 2002) and below the limit content (60 mg/kg) set by Baize (1997). The work of Syed *et al*., 2012 on the contamination of soils under cultivation located near the Dhaka export zone in Bangladesh, showed average concentrations (27.6 mg/kg) different from these. These values are well below the limit value (100 mg/kg) set by the WHO in (Godin *et al*., 1985). The increase in lead content in cultivated soils could be explained by the use of chemical inputs (fertilizers and pesticides) (Baize, 2009).

For Ni, the average contents are 41, 56 mg/kg, 31.59 mg/kg, 26.89 mg/kg and 15.48 mg/kg respectively in the traditional plots of 15 years, 10 years and experiments with amendment; and without amendment. These concentrations are lower than the reference (68 mg/g) of Average shale. But they are also lower than the permissible limit concentrations for the accumulation of heavy metals in agricultural soils of France, Ukraine, Germany, USA (Al Jal'oud 1997). These values are also below the average value (50 mg/kg) estimated for normal soil (Kao *et al*., 2007). The Ni levels do not constitute a polluting element in all of our traditional plots and experiments because all the levels are below the standards.

Similarly, the average Zn concentration is 43.83 mg/kg in the traditional 15-year plot and 40.76 mg/kg in the traditional 10-year plot. In addition, the concentrations are 35.36 mg/kg and 34.51 mg/kg respectively in the experimental soil from 05 years of activity with amendment and the experimental soil from 05 years of activity without amendment. The average Zn concentrations (43.83 mg/kg and 40.76 mg/kg) in the soils of traditional plots of 15 and 10 years are higher than the average concentrations recorded in the experimental soils of 05 years of activity (35.36 mg/kg) and (34.51 mg/kg). These concentrations are lower than the permissible limit concentrations for the accumulation of heavy metals in agricultural soils in Canada, France, Ukraine, Germany (Al Jal'oud 1997) and are also similar to those (25.36 mg/kg and 48. 26mg/kg) obtained by Bouchouata *et al*., 2012 in agricultural soils of the Sebou basin in Morocco.

The average Fe concentrations of our different traditional plots and experiments are (12436.9 mg/kg), (13955.5 mg/kg), (12986.4 mg/kg), (13265.02 mg/kg) respectively in the traditional plots of 15 years and 10 years as well as in the experimental plots of 05 years with amendment and 05 years without amendment. However, all of the average Fe concentrations remain below the reference (46700 mg/kg) for Average shale. These levels are above the average levels (5923.4 mg/kg and 10007.9 mg/kg) obtained in the surface horizons of the market garden soils of Marcory and Cocody in Ivory Coast (Kouakou *et al*., 2012). This low concentration of Fe in cultivated soils can be explained by the phytoextraction of cultivated plants and also a possible migration of Fe towards the underlying horizons.

Assessment of Pollution Intensity

To estimate the contamination levels, two methods were used, namely the geoaccumulation index (Igeo) and contamination factors.

The results of the tables: present the results of the geoaccumulation indexes (Igéo) of different traditional plots of 15 years and 10 years of activity with Arkou amendment. In the 15-year plot, Ni (-1.38 to -1.22), Zn (-1.95 to 1.52), Cr (-1.26 to -1.00) show no contamination. On the other hand, Cu (0 to 0.55) and Pb (0.49 to 0.65) show slight contamination. On the other hand, Cd (2.50 to 2.75) shows moderate to moderate to high contamination.

Furthermore, in the 10-year-old plot with Arkou amendment, Cr (-1.35 to 1.44), Pb (-2.88 to -3.25), Ni (-1, 96 to -1.38) and Zn (2.00 to -1.65) show no contamination. Cu (-0.11 to 0.22), present without to slight contamination and as for Cd (1.28 to 2.07) presents moderate contamination to moderate to heavy contamination.

For the 5-year-old experimental plot with amendment, the geoaccumulation index values show no contamination for Ni (-2.35 to -1.42); Zn (-2.90 to -2.14); Cu (-0.37 to -0.13); Cr (-1.97 to -1.60). However, Cd (-0.09 to 0.87) and Pb (-0.03 to 0.26) vary from no contamination to moderate contamination.

Finally, in the 05-year experimental plot without amendment, the Ni geoaccumulation index (-3.17 to -2.41); Zn (-2.15- to 1.90); Cu (-1.56 to -1.33); Cr (-3.26 to -3.21); Cd (-2.16 to -1.90) shows no contamination. On the other hand, for Pb (-0.43 to 0.75), contamination varies from zero contamination to moderate contamination. It has been noted that the duration of activities, the use of fertilizers and pesticides for agriculture have contributed to a continuous accumulation of heavy metals in the soil (Nouri *et al*., 2008).

The Tables 6 and 7 present the results of the contamination factors of different traditional plots and experiments of Bagarine and Arkou of these six heavy metals analyzed. In the plots of 15 years of activity, Cu (0.57 to 0.64), Cr (0.62

to 0.67), Ni (0.57 to 0.64) and Zn (0.39 at -0.51) show low contamination. On the other hand, Cd (0.07 to 1.63) shows low to moderate contamination. On the other hand, Pb (2.00 to 2.45) presents a moderate contamination.

For the traditional plot of 10 years of exploitation, Cr (0.55 to 0.59), Ni (0.38 to 0.57) and Zn (0.37 to 0.48) show low contamination. As for Cu (1.09 to 1.76) and Pb (1.85 to 2.28) the contamination is moderate. On the other hand, Cd (3.67 to 6.30) presents a high contamination. The amounts of chemicals applied annually to agricultural soils as fertilizers and pesticides can result in the increase of heavy metals and particularly Cd and Pb in the environment (Zahra *et al*., 2010).

Moreover, in the 5-year-old experimental plot with Bagarine amendment, Ni (0.29 to 0.56), Zn (0.35 to 0.40) and Cr (0.38 to 0.49) have low contamination. Cu (0.98 to 1.36) and Cd (0.43 to 2.70) range from low contamination to moderate contamination.

Finally, in the 05-year-old experimental plot without amendment, the Ni contamination factor (0.17 to 0.28); Zn (0.34 to -0.40); Cu (0.51 to 0.60) and Cr (0.16 to 0.19) show low contamination. On the other hand, Cd (1.70 to 1.99) and Pb (0.87 to 1.11) contaminations vary from low contamination to moderate contamination. Soil contamination by Cd and Pb in the plot without amendment could be of atmospheric origin from the dumping and incineration of household and industrial waste such as plastics, plant and animal debris and automobile traffic can be the main sources of heavy metals (Rouamba *et al*., 2021).

Statistical Analysis

The Pearson correlation matrices made it possible to establish the correlations between the heavy metals studied and the physic-chemical parameters (pH and OM) ($P < 0.05$).

Fig. 3A presents the Pearson correlation matrix between heavy metals and the physico-chemical parameters of traditional plots of 15 years of activity. We observe a positive and very significant correlation between Cu/Cr; positive and significant correlations between Ni/Zn, Cu/Pb, Cd/Pb and Cr/Pb. Moreover, they are positive and moderately significant between Cu/Cd, Cu/pH, Cd/Cr, Cr/pH and MO/pH, and positive and moderately significant between Zn/MO, Zn/Fe and Pb/pH.

Fig. 3B: presents the Pearson correlation matrix between heavy metals and the physico-chemical parameters (MO and pH) of a traditional plot of 10 years of activity. Positive and significant correlations are only observed between Ni/Zn, Ni/Pb, Zn/Pb and Cu/pH.

As for Fig. 3C: it presents the Pearson correlation matrix between heavy metals and the physico-chemical parameters (MO and pH) of the experimental plot of 05 years of activities with amendment. Indeed, the correlation is positive and very significant between Cu/MO. We observe positive and significant correlations between Ni/pH and Cu/MO. Correlations are moderately positive and significant between Cu/Cd, Cd/Cr, Cd/Pb and Cr/MO. They are moderately positive and significant between Zn/Cu, Zn/MO, Zn/pH and Pb/MO.

Finally, Fig. 3D: presents the Pearson correlation matrix between heavy metals and the physico-chemical parameters (MO and pH) of the experimental plot of 05 years of activities without amendment. The correlations are positive and significant between Ni/Zn, Zn/MO, Cu/Pb and Cr/Pb. Moderately positive and significant correlations are observed between Ni/Cd, Cu/Cr, Cd/MO and Cr/Fe. Fig. 3 shows the circles of correlations observed in the traditional and experimental plots of Arkou and Bagarine.

Conclusion

In order to assess the level of metal pollution in the soils of onion crops in Abéché following the use of agricultural inputs, a study was carried out in the sites of Arkou and Bagarine. The results of the physicochemical parameters obtained show that the pH of the study area is acidic. The organic matter content of the plots is below standards. The determination of heavy metal concentrations revealed relatively low contents for Ni, Zn, Cu, Cr and Fe; and are generally lower than the reference values. Calculations of the geoaccumulation (Igeo) and contamination factor (Cf) indices revealed pollution indices in the traditional plots of Arkou. In these plots, Cd shows moderate to high contamination. Otherwise, Pb presents a slight contamination. These two metals require special environmental monitoring. The correlations ($P < 0.05$) observed in our study area are positive and significant. It can therefore be deduced that the soils studied present low to moderate pollution due to the use of chemical inputs. These high levels of Cd and Pb can be a source of contamination for plants grown on these soils. In the short or medium term, we must fear the "time bomb" effect. After a long period of accumulation in soils, metals can be suddenly released.

Author's Contribution

All authors contributed equally all stages of research work and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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