International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 22, No. 3, p. 1-9, 2023

INNSPUB

RESEARCH PAPER | OPEN ACCESS

Effect of increasing doses of waste on the bioaccumulation of trace metal elements (TME) by *Zea mays* L in Bobo-Dioulasso (Burkina Faso)

Issaka Senou[*1,2], Hamza Ouedraogo[1], Hassan Bismarck Nacro[3], Antoine N. Some[1]

[1]*Laboratory of Natural Systems, Agro-Systems and Environmental Engineering (Sy.N.A.I.E), NAZI Boni University, Bobo-Dioulasso, Burkina Faso*

[2]*Institute of Environmental Sciences and Rural Development, University of Dédougou (UDDG), Dédougou, Burkina Faso*

[3]*Laboratory of Soil Fertility Study and Research, NAZI Boni University, Bobo-Dioulasso, Burkina Faso*

Article published on March 10, 2023

Key words: Urban waste, Heavy metals, Bioconcentration

Abstract

Corn could accumulate toxic elements. To assess the potential for corn accumulation, plots were made and organised according to a completely randomised block. Increasing doses of waste 0, 20, 40 and 60t/ha constituted the various treatments. Heavy metal trace levels of soil samples before and after harvest and biomass were determined. The results of the analyses show that the waste produced was contaminated and contributed to increase the copper and zinc content of the pre-seeded soils from 18.22 to 26.25mg/kg and from 15.16 to 63.92mg/kg of soil, respectively. In general, soil heavy metal levels are not above the contamination limit. However, at maize, the levels are higher than the contamination limit for human and animal consumption. Values range from 5.56mg/kg for cadmium, 27.75 to 30.06mg/kg for copper, 13.83 to 42.59mg/kg for lead, 18.78 to 28.41mg/kg for zinc. So, corn is an accumulating plant.

[*] **Corresponding Author:** Issaka Senou ✉ issakasenou@gmail.com

Introduction

For thousands of years, maize has played a very important role in human nutrition (Anihouvi *et al.*, 2016). Its average annual production was about 1,039 million tons in 2018 (OECD/FAO, 2018). In Africa, it is an important food in people's diets and contributes almost half of calories and protein (Macauley and Tabo, 2015). It is the first cereal consumed in Burkina Faso, (INSD, 2018). Its production requires fertile soil that Burkina Faso does not have. The high cost of chemical fertilizers, directs producers to use organic waste recognized as nutrient-rich, according to Ouattara (2014). However, this waste may contain trace elements (Ilboudo, 2014; Senou *et al.*, 2018). These toxic components are very persistent over time and penetrate food chains more or less rapidly and directly, exposing humans to slow intoxication (Khan *et al.*, 2014).

Many authors have evaluated heavy metal levels in cultivated plants such as lemongrass, cassava, lettuce (Senou *et al.*, 2014; Kalonda *et al.*, 2015; Konaté, 2018). Their results showed a bioaccumulation of toxic elements in the tissues of these consumed plants. However, very few studies have been carried out to assess the bioaccumulation potential of cereals and Zea mays in particular in the African sub-region. Recent studies have focused on the effect of heavy metals on agro-morphological parameters of maize (Hadi *et al.*, 2010; Khan *et al.*, 2014). This is the background to our study on the effect of increasing doses of waste on the bioaccumulation of trace metal elements (TRM) by Zea mays L. The main objective is to assess the absorption and bioaccumulation potential of cadmium, copper, lead and zinc by Zea mays. L. The work will consist of determining the levels of cadmium, copper, lead and zinc in the soil and in the various organs of maize.

Materials and methods

Study site

The study was conducted in Bobo-Dioulasso (11°10'43'' north; 4°18'25'' west), a town in the western part of Burkina Faso in the Hauts Bassins region. The test is being carried out in an operating unit in the Sakabi vegetable area. The geographical coordinates of this unit are 11°12'16.789" north latitude and 4°16'50.1589" west longitude. The choice of this site was justified by the use of urban waste as the main source of fertilizer by producers.

Waste identification device

The experimental set-up was a completely randomized block (CRB) whose only factor studied was the amount of waste. The test consisted of four treatments which are: T0: no waste input; T1: 20t/ha or 20kg of waste/plot; T2: 40t/ha or 40kg of waste/plot and T3: 60t/ha or 60kg of waste/plot.

These waste doses were chosen based on the results on the quantities of waste evaluated at four sites (Kodeni, Kuinima, Dogona and Colsama) by Sanou (2018). Our device consisted of a total of 24 elementary plots arranged in six blocks or repetitions. The dimensions of each elementary plot were 4m × 2.5m or 10m². Each plot was composed of 35 pockets arranged in 5 lines.

Conduct of culture

The soil was prepared by manual weeding. Before the waste was brought in, it was first removed from the waste (plastic bags, pieces of metal, stones, etc.) before being homogeneously mixed with the soil according to the experimental system. The sowing was also done manually according to gaps between the sowing lines of 80cm and 30cm between the pockets. Each pouch received a seed sown at a depth of 3 to 5cm.

The cultivation was maintained through manual weeding at the daba. Intakes of mineral fumes, i.e., NPK (14-23-14) and urea 46%, were made with reference to the doses of 200kg NPK/ha and 150kg urea/ha as recommended by (Sanou, 2007). Thus, 4.8kg of NPK were used for all the plots, i.e. 200 g per elementary plot at a rate of 5.71 g per plot. The NPK was brought on the 15th day after sowing. As for urea, 3.6kg were brought for all plots, applied on the 25th and 35th day after sowing. At the 25th JAS, 2.4kg were brought for all plots, i.e. 100 g per plot at a rate of 2.86 g per plot. At the 35th JAS, 1.2kg were brought, i.e. 50 g per plot at a rate of 1.43 g of urea per plot. Irrigation was carried out manually with watering cans every three days and as required.

Sampling

Soil samples were taken diagonally from all 24 plots at 15cm depth, before sowing and at harvest. The waste was also collected. The samples of the plants were taken at the physiological maturity of the grains at 85 days after sowing. Three whole plants were uprooted individually per plot.

Laboratory analysis

The analysis was carried out at the BU.MI.GEB geochemistry laboratory and consisted of the determination of heavy metal contents (Cd, Cu, Pb and Zn) of substrates and plants through the flame atomic absorption spectrometer (Perkin Helmer Analyst 100). The operation was carried out according to the regal water attack protocol defined by French standard NF X 31-415 and ISO standard II 466 respectively for the analyzes of substrate and plant samples.

Statistical analysis

The data was processed using XLSTAT software. The Shapiro Wilk test determined the normality of the data. An analysis of variance (ANOVA) at the threshold of 5% was carried out with the software R.

Two indicators have been calculated

Bioconcentration Factor (BCF) (Ghosh and Singh, 2005): It is used to assess the accumulation potential of maize. When the BCF is less than 1, the plant is classified in the category of ordinary plants (non-accumulating plants), but when it is greater than 1, it is accumulative and greater than 10, it is classified as hyperaccumulative.

$$\text{Bioconcentration Factor (BCF)} = \frac{[\text{ETM}]veg}{[\text{ETM}]soil}$$

The Pollution Index (PI) (Baize, 1994) : It determines the level of soil contamination with cadmium, copper, lead and zinc. When the value is greater than 1, the soi lis contaminated according to AFNO U44-41.

$$\text{Pollution Index (PI)} = \frac{\frac{[\text{Cd}]}{2} + \frac{[\text{Cu}]}{100} + \frac{[\text{Pb}]}{100} + \frac{[\text{Zn}]}{300}}{4}$$

Results

Heavy metal content in municipal waste and soil

The results of the urban waste analysis showed contamination with cadmium (1,089mg/kg), copper (27,258mg/kg), lead (93,39mg/kg) and zinc (206,481mg/kg). These levels are lower than the French and German standards for all heavy metals studied except cadmium where the level is slightly above the German standards. However, these levels are relatively high, which shows that these wastes can be potential contaminants for soils.

The atomic absorption spectrometer detected Cd in soils before sowing. In soils after harvesting, they varied significantly between 0.04mg/kg for the T0 treatment and 0.61mg/kg of soil for the T3 treatment.

Cu levels in soils before sowing increased after the addition of waste compared with the T0 control. They evolved in the same direction as the quantities of waste and varied between 18.22 and 26.25mg/kg. Post-harvest soils ranged from 13.35 to 14.04mg/kg. Analysis of variance (ANOVA) at the 5% cut-off showed a significant difference in Cu levels between treatments for pre-sowing soils, while Cu levels in post-harvest soils did not vary statistically between treatments.

The Pb content in the soils before sowing is zero except for the T2 treatment where it recorded a concentration of 0.72mg/kg of soil. In post-harvest soils, Pb levels were high relative to the control and ranged from 12 to 32.39mg/kg soil. They have evolved in line with the amount of waste. ANOVA at the 5% threshold showed a significant difference in Pb levels for both pre-sowing and post-harvest soils.

The Zn contents of soils before sowing are between 15.16 and 63.92mg/kg of soil and between 4.74 and 16.01mg/kg for soils after harvest. Both pre-sowing soils and post-harvest soils recorded their minimum contents in the T1 treatment and their maximum contents in the T2 treatment. Analysis of variance at the 5% threshold showed a significant effect of urban waste on heavy metal contents of pre-sowing and post-harvest soils. Unlike Cd and Pb, which increased in soil after harvest, Cu and Zn levels decreased.

Urban and soil pollution index

Pollution indices for soils before sowing and after harvesting are less than 1 in all treatments. This indicates that the soil is not contaminated beyond the limit established by AFNOR U44-41. However, a general study of these values reveals that soils after harvesting are more contaminated than soils before sowing. Also, these indexes tend to increase with the amount of waste brought in.

Potential for heavy metals to bioaccumulate in different organs of maize

Root analysis showed zero Cd levels in all treatments except T3 which recorded 1.13mg/kg DM. For Cu, the contents varied between 6.07 and 36.07mg/kg of DM, respectively, for treatments T3 and T1. Pb, like Cd, recorded zero levels in all treatments except T3 which had a concentration of 103mg/kg DM. For Zn, the contents varied between 42.97 and 66.57mg/kg of DM for treatments T0 and T2 respectively. The ANOVA test at the 5% threshold showed that urban waste significantly influenced the levels of ETM in the roots.

Table 1. Heavy metal contents in urban waste.

	Heavy metal content (mg/kg of waste)			
	Cd	Cu	Pb	Zn
Waste	1.089	27.258	93.39	206.481
AFNOR U44-41 Standards	2	100	110	300
French standards	3	300	180	600
German standards	1	75	100	300

Table 2. Pollution index for heavy metals in soil.

	T0	T1	T2	T3
SAS	0.04	0.05	0.08	0.06
SAR	0.05	0.07	0.12	0.14

SAS: pre-sowing soils SAR : post-harvest soils T0 : no waste input T1 : 20kg waste input T2 : 40kg waste input T3 : 60kg waste input.

Table 3. Heavy metal contents (mg/kg DM) in roots, stems, leaves and grains of maize.

Organs	Treatments	Heavy Metal Contents			
		Cd	Cu	Pb	Zn
Roots	T0	0.00a ± 0.00	29.13ab ± 16.67*	0.00a ± 0.00	42.97a ± 4.37*
	T1	0.00a ± 0.00	36.07b ± 17.87**	0.00a ± 0.00	45.87a ± 0.45*
	T2	0.00a ± 0.00	20.97ab ± 21.68*	0.00a ± 0.00	66.57b ± 3.44*
	T3	1.13b ± 0.21**	6.07a ± 5.03*	103.0b ± 49.70**	63.27b ± 4.97*
Probabilité (5%)		0.039	0.028	0.003	0.011
Stems	T0	0.00a ± 0.00	18.03 ± 6.55*	29.0b ± 8.53*	22.03b ± 6.91*
	T1	0.00a ± 0.00	17.40 ± 5.33*	0.00a ± 0.00	10.63a ± 3.50*
	T2	0.00a ± 0.00	20.67 ± 7.86*	0.00a ± 0.00	18.43ab ± 6.65*
	T3	14.1b ± 9.22**	19.37 ± 6.46*	0.00a ± 0.00	14.6ab ± 3.64*
Probability (5%)		0.0001	0.694	0.003	0.018
Leaves	T0	0.00a ± 0.00	25.33a ± 2.15*	49.33b ± 1.03**	36.9b ± 3.57*
	T1	0.04a ± 0.02	25.07a ± 4.38*	65.67c ± 25.87**	27.87a ± 7.28*
	T2	0.00a ± 0.00	31.3b ± 4.23**	0.00a ± 0.00	37.03b ± 4.46*
	T3	0.51b ± 0.45*	36.47c ± 5.07**	0.00a ± 0.00	32.37ab ± 3.21*
Probability (5%)		0.042	0.036	0.0016	0.022
Corn	T0	0.00 ± 0.00	52.63c ± 4.88**	0.00a ± 0.00	19b ± 5.83*
	T1	0.00 ± 0.00	42.67b ± 0.93**	5.00a ± 0.89*	11.1a ± 1.97*
	T2	0.00 ± 0.00	36.80a ± 2.44**	51.33b ± 4.93**	20.53b ± 4.22*
	T3	0.00 ± 0.00	37.51a ± 5.82**	137.33c ± 21.21**	19.5b ± 3.53*
Probability (5%)		–	0.013	0.0001	0.009
All organs	T0	0.00a ± 0.00	30.06 ± 9.03**	27.17b ± 15.79*	28.17b ± 7.01*
	T1	0.01a ± 0.02*	27.75 ± 5.57*	22.47ab ± 8.77*	18.78a ± 5.63*
	T2	0.00a ± 0.00	28.39 ± 5.52*	13.83a ± 2.36*	28.41b ± 7.95*
	T3	5.56b ± 3.46**	28.05 ± 1.44*	42.59c ± 5.14**	25.06ab ± 1.12*
Probability (5%)		0.008	0.376	0.005	0.020
Seuil de toxicité pour l'homme (CODEX STAN 193-1995; OMS, 2004)		0.1	9	0.2	15
Seuil de toxicité pour le bétail (Meschy F.. 2007; Commission européenne, 2013)		1	30	30	250

*: Values within the range of critical concentrations for human consumption

**: Values within the range of critical concentrations for animal consumption.

T0 : no waste input ; T1 : 20kg waste input ; T2 : 40kg waste input ; T3 : 60kg waste input.

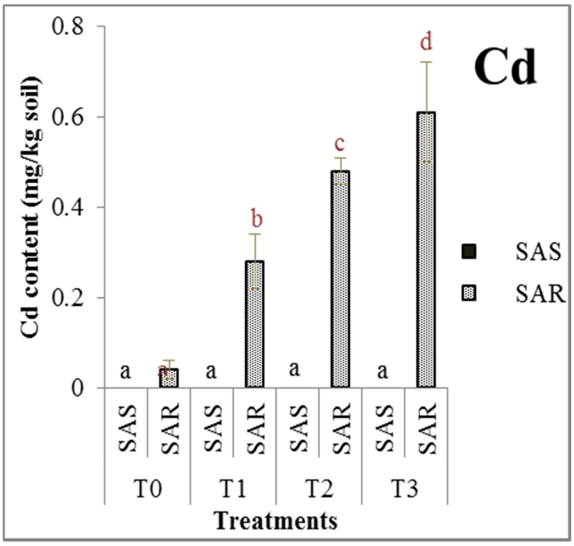

Fig. 1. Soil Cd content (mg/kg soil).

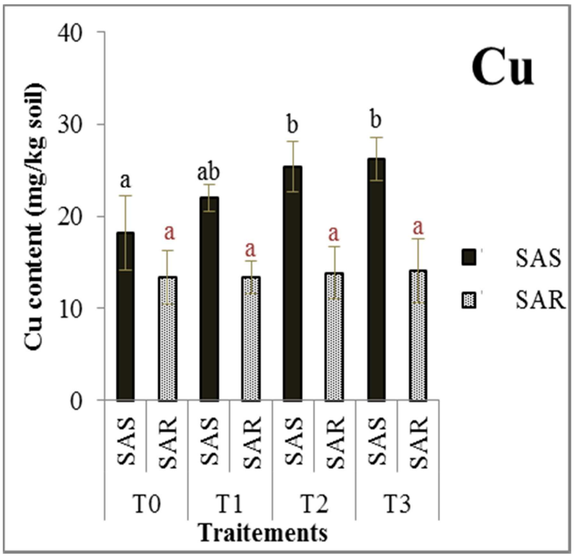

Fig. 2. Soil Cu content (mg/kg soil).

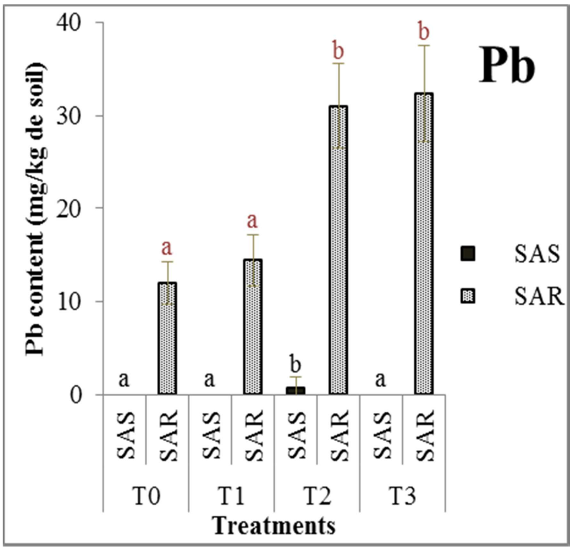

Fig. 3. Soil Pb content (mg/kg soil).

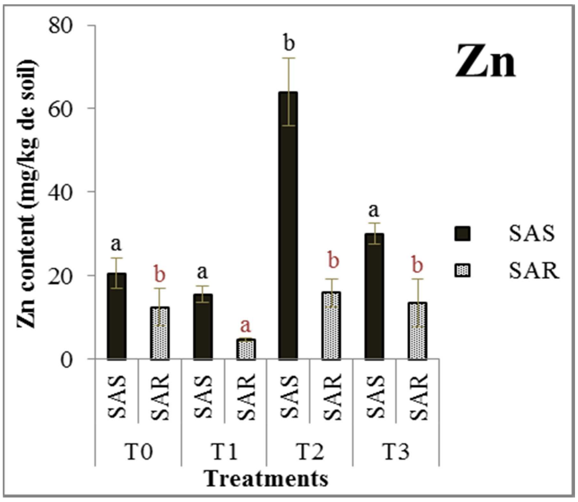

Fig. 4. Soil Zn content (mg/kg soil).

SAS: pre-sowing soils; SAR: post-harvest soils; T0: no waste input; T1: 20kg waste input; T2: 40kg waste input; T3: 60kg waste input.

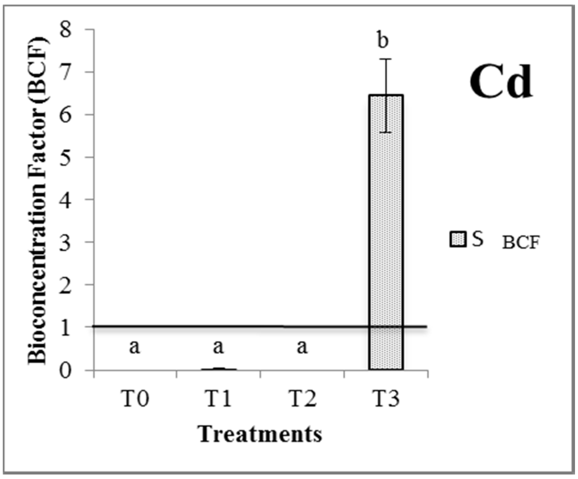

Fig. 5. Bioconcentration factors for Cd in different tre atments.

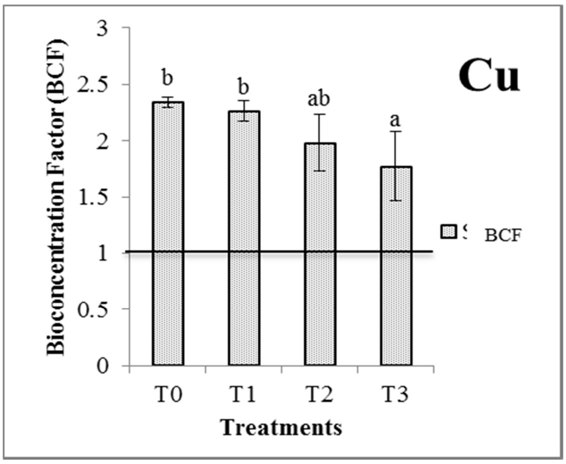

Fig. 6. Bioconcentration factors for Cu in different tr eatments.

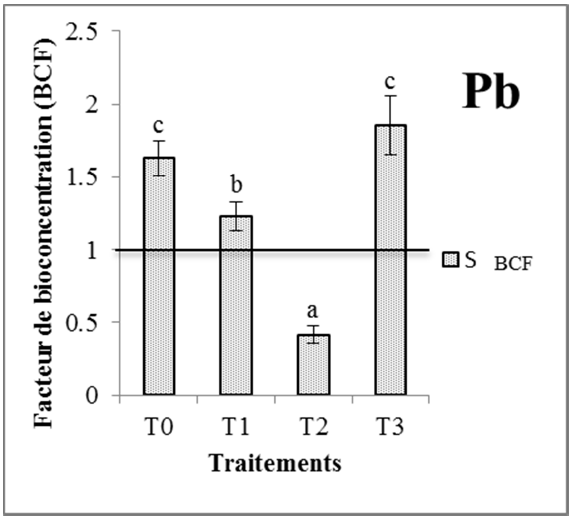

Fig. 7. Bioconcentration factors for Pb in different tre atments.

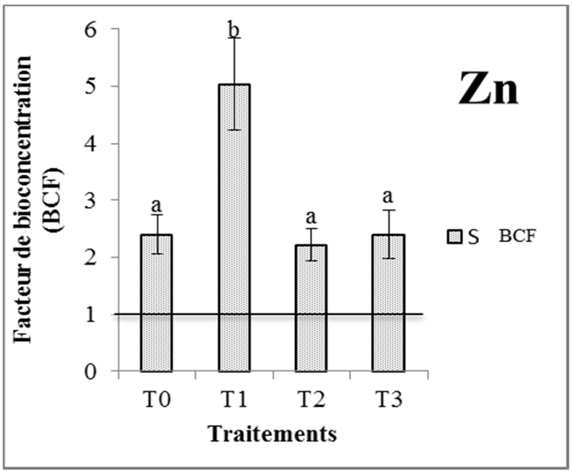

Fig. 8. Bioconcentration factors for Zn in different tr eatments.

The bioconcentration factors (BCFs) are expressed as the means for each sample.

T0: no waste input; T1: 20kg waste input; T2: 40kg waste input; T3: input of 60kg of waste.

The Cd contents of the stems were zero in all treatments except in the T3 treatment where it was 14.1mg/kg of DM. However, the Cu contents varied between 17.40 and 20.67mg/kg of DM, respectively, for the treatments T1 and T2. At Pb level, the levels were zero in all treatments except for T0 which recorded a value of 29.0mg/kg DM. As for Zn, the contents varied between 10.63 and 22.03mg/kg of stem DM, respectively, for treatments T1 and T0. Heavy metal contents of stems showed a significant change at the 5% threshold with the exception of Cu where the analysis of variance did not show a significant difference between treatments.

The Cd contents of the leaves are zero in all the treatments except in the T3 treatment where it is 0.51mg/kg of DM. At the Cu level, they varied between 25.07 and 36.47mg/kg of DM, respectively, for treatments T1 and T3. These contents tend to increase with the amount of waste. For Pb they oscillated between 0.0mg/kg of DM for the T0 treatment and 65.67mg/kg of DM for the T1 treatment. For Zn, the contents varied between 27.87 and 37.03mg/kg DM, respectively, for treatments T1 and T2. Overall, the analysis of variance at the 5% threshold showed that urban waste doses influenced leaf heavy metal contents.

The atomic absorption spectrometer did not detect Cd in maize grains. At the Cu level, the contents are between 36.80 and 52.63mg/kg of DM, respectively, for the treatments T0 and T2. These contents tend to decrease as the amount of waste increases. The Pb contents, unlike that of Cu, increased with the amount of waste, they varied between 0 and 137.33mg/kg of DM respectively for the treatments T0 and T3. At the Zn level, they varied between 11.1 and 20.53mg/kg of DM, respectively, for treatments T1 and T2. Apart from Cd, all the other metals experienced a significant variation ($p<0.05$) in their contents between the different treatments.

Bioconcentration factors (BCFs)

At Cd, BCFs were nil in all treatments except T3 whic h recorded a value of 6.44. For Cu, BCFs ranged from 1.77 to 2.34 for treatments T3 and T0, respectively. At the Pb level, BCFs varied between 0.41 and 1.86 for tr eatments T2 and T3, respectively. As for Zn, the BCFs variedbetween 2.23 and 5.03 respectively for the treat ments T2 and T1. Analysis of variance at the 5% cut-off showed a significant difference in BCF between treatments for all metals. For eachheavy metal, BCFs were greater than 1 in all treatments except Cd which recorded BCFs less than 1 in treatments T0, T1 and T2 and Pb which recorded BCF less than 1 in treatment T2. As a result, maize was classified as accumulating plants of Cd, Cu, Pb and Zn.

Discussion

Heavy metal content in municipal waste

The analysis of heavy metals in waste revealed fairly high levels of Cd, Cu, Pb and Zn. However, they are below the standards (Table I). These results could be explained, on the one hand, by the embryonic state of our industries, which pollute less than developed countries, and, on the other hand, by the absence of mining sites near Bobo-Dioulasso. The heavy metal contents measured in the waste are comparable to those obtained by Yé (2007) which had characterized urban waste from the town of Bobo-Dioulasso. But they are low compared to those obtained by Ilboudo (2014) in the same city. These differences in our results may be due to the nature of the waste. However, there is a risk of accumulation of these trace metal elements due to the regular spreading of waste in the fields. This is because heavy metals can gradually accumulate in the soil to toxic levels even if the levels of heavy metals in the waste supplied are low.

Effects of different doses of urban waste on soil contamination

Analysis of heavy metals from soils before sowing of T0 treatments revealed relatively high Cu and Zn contents and zero Cd and Pb contents. The Cu and Zn present in these soils could originate from some of the parent rock. Indeed, according to Baize (2000), heavy metals exist naturally in soils because they are present in the mother rock, which releases them as a result of the erosion and alteration phenomena to which it is subjected. On the other hand, they could come from organic amendments made a few years earlier. Our results are in agreement with those of Dauguet *et al.* (2010) which showed in France quite high Cu and Zn contents and very low Cd and Pb contents on soils polluted by waste.

In addition, the addition of the waste resulted in the presence of heavy metals in the soil, except for Cd and Pb, where they did not vary significantly. These results could be explained by the fact that the waste contained low levels of Cd and Pb to contaminate the soil to a level detectable by the Atomic Absorption Spectrometer (AAS). As for the Cu content, it increased with the amount of waste. The extra Cu could come from the urban waste brought in. These findings are consistent with the results of Senou *et al.* (2012) which showed an increase in the content of Cu following the doses of waste provided. At Zn levels, concentrations did not vary in the same direction as the waste doses. The Zn case may be answered by the heterogeneity of the distribution of Zn in soil, which supports Yé (2007) who found in his research that the heavy metal content of the soil was not necessarily a function of the amount of waste delivered. After harvesting, soil Cd and Pb levels increased while those of Cu and Zn decreased, and additional Cd and Pb could come from irrigation water, which would contain significant amounts of these metals. According to a study conducted by Youssao *et al.* (2011) In Benin, surface run-off water is charged with dissolved trace metals that can contaminate soils as they pass through or when used for irrigation.

The decrease in the concentration of Cu and Zn could be explained on the one hand by the leaching of metals towards the deep horizons. Indeed, according to Adriano (2001) (cited by Huynh, 2009), Cu and Zn are the most soluble and mobile among the four metals studied. This is consistent with Ilboudo (2014), which showed an increase in the availability of metals in the deep horizons of soil amended with solid urban waste. On the other hand, this decrease could be explained by the phytoextraction of heavy metals by maize. Soil metal levels are in line with international standards. This could be justified by the fact that the concentrations of heavy metals contained in the waste used are not beyond the limit set by the French and German standards. Our results are consistent with those of Ilboudo (2014), which analyzed the effect of different types of waste on the availability of heavy metals in soil and found that all soils were low in heavy metals compared to standards (AFNOR NF U44-041, 1985) (Table 1). However, our results are not in agreement with those of Lock and De Zeeuw (2001), which showed that

Conclusion and recommendations

The primary objective of this study is to evaluate the absorption and bioaccumulation potential of heavy metals in maize (Zea mays).

The results showed that the input of urban waste significantly increased the Cu and Zn content of the soils before sowing, unlike Cd and Pb, whose contents did not vary significantly compared to the T0 control. At post-harvest soil level, the levels decreased for Cu and Zn while they increased for Cd and Pb. However, these levels are below the contamination limit. In plant tissues, in addition to Cd, which is absent in the grains, all the organs of maize have accumulated heavy metals. For each organ, heavy metal contents varied with waste doses except for Cd and Cu where contents remained for grains and stems, respectively. Comparison of these levels with the standards shows contamination of the grains with Cu, Pb and Zn beyond the contamination threshold for human consumption. Animals are exposed to contamination risks only for Cu and Pb. Of these concentrations, the calculated bioconcentration factors (BCFs) show a significant uptake of these heavy metals (BCF>1) by maize, which makes it possible to classify it among the accumulating plants.

This study allowed us to know the potential for bioaccumulation of Cd, Cu, Pb and Zn by maize grown on soil amended with urban waste. The results obtained could positively influence decision-making when the State or NGOs intervene in sites directly using urban waste and help find appropriate solutions towards sustainable agriculture.

References

Atidegla SC, Agbossou EK, Huat J, et Glele Kakai R. 2011. Contamination métallique des légumes des périmètres maraîchers urbains et périurbains : Cas de la commune de Grand-Popo au Bénin. International Journal of Biological and Chemical Sciences **5(6),** 2351-2361.

Baize D. 1997. Teneurs totales en éléments traces métalliques dans les sols . Paris, France. INRA Editions, 408 p.

Dauguet S, Denaix L, Nguyen C, Coudure R, et Barrier-Guillot B. 2010. Apports organiques, ETM: Cerner les transferts du sol aux plantes. Perspectives Agricoles - N°373 70-75.

Hadi F, Bano A, Fuller MP. 2010. The improved phytoextraction of lead (Pb) and the growth of maize (*Zea mays* L.): the role of plant growth regulators (GA 3 and IAA) and EDTA alone and in combinations. Chemosphere **80(1),** 457-462.

Ilboudo TJL. 2014. Effet de différents types de déchets urbains solides de la ville de Bobo-Dioulasso sur la disponibilité et la distribution verticale de métaux lourds dans le sol. Mémoire de Diplôme d'Etudes Approfondies en Science du sol. 51 p.

INERIS. 2006. Eléments traces métalliques : Rapport d'étude INERIS-DRC-06-66246/DESP-R01a. 119 p.

Kalonda DM, Tshikongo AK, koto FKK, Busambwa CK, Bwalya YK, Cansa HM, Tambwe JLK, Kalala ZL, et Otshudi AL. 2015. Profil des métaux lourds contenus dans les plantes vivrières consommées couramment dans quelques zones minières de la province du Katanga. Journal of Applied Biosciences **96(1),** 9049-9054.

Khan MS, Khan SA, Sajad MA, Ali F, Ali H, Khan WM, Ali S, et Hussain F. 2014. Phytoremediation of cadmium from effected soil using maize plant (*Zea mays* L.). Journal of Biologie and Environmental Sciences **2(1),** 1-8.

Khatori M, et Benhoussa A. 2017. ICP analysis of heavy metals in corn and soil irrigated by Berrechide waste water (Morocco). Journal of Materials and Environmental Sciences **8(5),** 1853-1859.

Konaté H. 2018. Evaluation du niveau de transfert de métaux lourds (Cd, Cu, Pb et Zn) dans la laitue co-cultivée avec *Cymbopogon citratus* (DC). Mémoire d'ingénieur du Centre de formation agricole de Matourkou, Bobo-Dioulasso, Burkina Faso 64 p.

Lock K, De Zeeuw H. 2001. Health risks associated with urban agriculture. Centre de Recherche sur l'Agriculture Urbaine et les Forêts (RUAF)/ Netherlands 6 p.

Macauley H, et Tabo R. 2015. Les cultures céréalières : riz , maïs , millet , sorgho et blé. In Nourrir l'Afrique: Un plan d'action pour la transformation de l'agriculture africaine. Dakar, p 37.

OCDE/FAO. 2018. Perspectives agricoles de l'OCDE et de la FAO 2018-2027. Céréales. pp 125-144.

Ouattara S. 2014. Diagnostic des pratiques de valorisation agronomique de substrats organiques dans la zone urbaine et périurbaine de la ville de Bobo-Dioulasso. Mémoire de fin de cycle d'ingénieur du développement rural, option Agronomie. Université Polytechnique de Bobo-Dioulasso, Institut du Développement Rural, Bobo-Dioulasso, Burkina Faso, 81 p.

Sanou J. 2007. Nouvelles variétés de maïs vulgarisées au Burkina. Doc. CNRST/INERA-Burkina Faso.

Senou I, Gnankambary Z, Somé AN, et Sedogo MP. 2012. Phytoextraction de métaux lourds (Cd, Cu, Pb et Zn) par *Oxytenanthera abyssinica* en sols ferrugineux tropicaux et en sols vertiques dans la zone sud soudanienne du Burkina Faso. Journal de la Société Ouest-Africaine de Chimie **34(1),** 26-34.

Senou I, Gnankambary Z, Some AN, et Sedogo PM. 2014. Projection de trois especes de plantes locales pour la phytoextraction de métaux lourds à partir de deux types de sols au Burkina faso. Agronomie Africaine **26(2),** 155-166.

Senou I, Gnankambary Z, Some NA, Nacro HB. 2018. Responses of five local plant species to metal exposure under controlled conditions. International Journal of Development Research **8(1),** 18507-18514.

Senou I. 2014. Phytoextraction du cadmium, du cuivre, du plomb et du zinc par cinq espèces végétales (*Vetiveria nigritana* (Benth.), *Oxytenanthera abyssinica* (A. Rich.) Munro, *Barleria repens* (Ness), *Cymbopogon citratus* (DC.) Stapf et *Lantana camara*(Linn.)) cultivées sur des sols ferrugineux tropicaux et vertiques. Thèse de doctorat, Universite Polytechnique de Bobo-Dioulasso (UPB).170 p.

Sezgin N, Ozcan HK. Demir G. Nemlioglu S, Bayat C. 2004. Determination of heavy metal concentrations in street dusts in Istanbul E-5 highway. Environment International **29(1),** 979-985.

Yé L. 2007. Caractérisation des déchets urbains solides utilisables en agriculture urbaine et périurbaine : cas de Bobo Dioulasso. Mémoire de Diplôme d'Etudes Approfondies en Gestion Intégrée des Ressources Naturelles. Université Polytechnique de Bobo Dioulasso (Burkina Faso). 44 p.