

Original Research Article

Concentrations of Cadmium (Cd), Copper (Cu), Lead (Pb) and Zinc (Zn) in Soils and Vegetable Organs from Periurban Agriculture Areas of Abidjan in Cote d'Ivoire

ABSTRACT

Production quality in periurban agriculture is question mark regarding to soil potential contamination affecting yields. The level of contaminations of soils and vegetables by copper (Cu), zinc (Cu), cadmium (Cd) and lead (Pb) around Abidjan city were assessed. Survey was conducted in 2013 within cultivated areas of sweet potato and hibiscus as encountered in three locations of Abidjan district (Port-Bouët, Yopougon and Bingerville) according to the intensities of industrial and commercial activities of which, Bingerville was the control site with lowest activities. Soil (0 – 20 cm) samples associated to that of plants (leaf, stem and root) were taken randomly for laboratory analysis. Toxic levels ($> 8 \text{ mgkg}^{-1}$) of Pb were significantly ($p < 0.0001$) determined in plant organs from Port-Bouët site indifferently to crops with lower soil content of Pb (35.5 mgkg^{-1}) than that of Yopougon (39.8 mgkg^{-1}), however. Except the synergisms observed between leave concentration of Pb and soil contents of Cd, Cu and Zn, non of soil parameters were relevant for this while, the proximity of inland waters was suspected. The partitioning of Pb in plant organs pointed out phytoremediation potential of hibiscus with lowest risk of toxicity ($2.92 - 9.72 \text{ mgkg}^{-1}$) in edible leave against an average of 8.08 mgPbkg^{-1} in the tuber of sweet potato. For strengthening consistence of knowledge, studies of Pb and Zn interaction as well as Pb translocation in tuber plants were suggested in tropical ecosystems.

Key words: *Metallic Trace Elements, vegetable, lead, interaction, phytoremediation, soil and plant contamination*

1. INTRODUCTION

In the humid forest zone of West Africa, urban population is most important than that of rural zone (1): about 2/3 of the population will be urban in the foreseeable future while agriculture practice remains most important in rural zones. This trend is of challenge for food security and supplying (2). In turn, informal economies can emerge from this exodus (3) including periurban agriculture. In fact, precarious lifestyle of a part of urban population imposes upon him reconnection with agriculture around the cities for subsistence and household income (4). This agriculture is supplying about 30% of world food (5; 6). However, the concerning agricultural production is more prone to pollution risk from urbanization (7) including metallic trace element accumulations in soils and yields. Many studies reported the harmfulness of such accumulation for humans and animals (8; 9; 10; 11; 12; 13; 14) as well as for plants in certain extend (15).

Nowadays, there is increasing of urbanization coupled with periurban agriculture adoption in many african countries of which Cote d'Ivoire is included. In Abidjan areas (economic capital of Cote d'Ivoire), leafy vegetable production and local market supplying of fresh products are increasing (16). Well, this agriculture is practiced in free spaces around manufactures sometime and somewhere household refuse stocks which are auspicious to pollution (16;17;18; 19) while, yet, this pollution effect is unknown in local crops of mass-market products as vegetable.

Current study is volunteer to identify the level of pollution in soils and plants as induced by cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) as pollutants in periurban agro-ecosystems (20; 21), especially for vegetables including hibiscus and sweet patato characterized by edible leaves locally. The aims were, i) to determine the of these metal concentrations in soils and plants in relation with other soil characteristics, ii) identify vegetable species most prone to contamination risk and iii) underline toxicity risk and phytoremediation potential of studied crop according to international standard values of Pb. Roughly, the study will point out soil characteristics and vegetable species most relevant to contamination for promotion of periurban agriculture carefully to consumer health.

2. MATERIAL AND METHODS

2.1 Description of studied sites

Abidjan is the economic capital of Cote d'Ivoire (West Africa), on the shoreline of Guinea Golf within altitudes 5°00 - 5°30 N and longitudes 3°50 - 4°10 W. It accounts for 10 districts and the major industrial activities of the country (22). It is characterized by subequatorial climate with annual average rainfall amount fluctuating between 1637 mm and 2048 mm irregularly distributed in time and space scales as bimodal rainfall in pattern (Two rainy seasons alternating with two dry seasons). Annual averages air temperature and hygroscopic measurement are recorded between 24°C - 30°C and 75% - 88% respectively according to *Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique* (SODEXAM). Open forest characterized the southern coastal zone neighboring a rainforest toward the northern zone. They are all degraded consecutive to entropic activities including industrialization. The geology of the studied area belongs to the coastal sedimentary basin of Cote d'Ivoire, named "*Continental terminal*" restricted to 2.5% area of the country (22). The soil is sand clayed Ferralsols somewhere Acrisols developed on tertiary and quaternary sand deposits. Actual survey was conducted in vegetable cropping areas of Port-Bouët (5°25N - 3°94W) and Yopougon (5°35N - 4°04 W) characterized by higher industrial and commercial activities contrasting with Bingerville (5°31 N - 3°87 W) as control site with lower activities (Fig.1).

2.2 Plants studied

Two vegetable species characterized by edible leaf as local dietary habits (16) were concerned: Hibiscus (*Hibiscus sabdaroufa*) locally named "*Dah*" and sweet patato (*Ipomoea batatas*). While hibiscus is matured about 2 -3 months of cropping duration sweet patato does so in a longer period of 3 – 6 months depending to the cultivars and the roots are also edible as tubers. Both are characterized by shallow rhizosphere (0 – 30 cm) receiving manual daily irrigation using perched ground water of well (2 – 3 m in depth).



Fig.1. Localization of studied sites (red marks)

Table 1. Standard ranges (mgkg⁻¹) of soil content of metallic trace elements

Metals	Moderate	High	Average worldwide
Cu	20-62	65-160	20-30
Zn	100-250	250-11426	50
Cd	0.2-1.0	0.70-2.00	2.0-46.3
Pb	10-30	60-90	100-10180

2.3 Soil and plant sampling

Multi-sites (Bingerville, Yopougon and Port-Bouët) survey was conducted in 2013 in the district of Abidjan (5°18 N; 4°00 W; 10 asl): The localities of Port-Bouët and Yopougon are characterized by higher industrial and commercial activity intensities while prevailing agricultural activity accounts for Bingerville.

In 500 m² of vegetables cultivated area in each of these locations, 12 soil composite samples were randomly taken in 0 – 20 cm using hand augur. Soil sampling was coupled with that of plant selecting one plant between 4 soil samples' positions. About 5 g of matured plant organs as fresh leaf, stem and root were taken from hibiscus and sweet potato respectively. Soil and plant samples were kept in plastic package and transported in icebox for laboratory analysis.

2.4 Laboratory analysis

Soil samples were dried in room condition before being ground and sieved (2mm). Soil particle size and pH were determined using the methods of Robinson pipette (23) and glass electrode in 1/2.5 ratio of soil/solution (water or KCl) respectively. Soil electric conductivity (EC) measurement was coupled with that of soil pH. The soil contents of organic-C and total-N were determined as described by

Walkley and Black (24) and Bremner (25) respectively and a factor of 1.72 was applied to the content of organic-C to determine that of soil organic matter. Furthermore, 1N NH₄OAc (pH 7.0) (extracting) and Atomic Absorption Spectrometry (apparatus) were used for soil exchangeable capacity of cations (CEC) determination.

Soil chemical extraction of metal (Cd, Cu, Pb and Zn) was also done using a ground soil sample (0.3 g) of 150 µm in size and aqua regia [3 mL de HNO₃ (65%; v/v) + 1 mL de HCl (37%; v/v)] as described by (26; 27;28). Three measurements (Atomic Absorption Spectrometry) were done for each analysis and the average was reported and compared to the standard values (Table 1) of Alloway (29).

Plant material was washed in tap water to remove adhered soil particles and subsequently shredded, oven dried (60°C), ground (1mm) for the use of 0.5 g of sample. Plant samples were digested in 6 ml of each of H₂O₂ and HNO₃ during 3 hours at constant temperature of 95°C in a Digi PREP. Flame atomic absorption spectrometry was use for the determination of plant concentrations of Cd, Cu, Pb and Zn.

2.5 Statistical analysis

By descriptive analysis, mean value ratios of soil contents of different studied metals were determined for a given site. Analyze of variance was also done to determine the mean values of Cd, Cu, Pb and Zn concentrations in a specific plant (hibiscus and sweet patato) organs (leaf, stem and root) according to studied sites (Bingerville, Port-Bouët and Yopougon). Moreover, Pearson correlation analysis were performed between soil (0 – 20 cm) contents of Cd, Cu, Pb, Zn and their concentrations in the leave of hibiscus and sweet patato respectively. SAS (version 8) was used for statistical analysis in the confidence interval of 95% (ANOVA) to 90% (correlation).

3. RESULTS

3.1 Soil characteristics

Table 2 shows the values of physicochemical properties of soil for different studied sites respectively. According to the pH values, the soil is acidic at Bingerville (pH = 5.6) and neutral (pH = 7) at Port-Bouët, contrasting with the alkalinity observed for the soil of Yopougon (pH= 8.7). Major difference is observed in soil ΔpH which is 3 – 4 times higher at Yopougon than that of the other sites. The values of soil ECC are ranging between 1.4 and 11.8 cmolk⁻¹ wherever, hence characterizing extensive low-clay activity of soils. In spite of the contrast in soil acidity, there is low values of EC at Bingerville (0.08 mScm⁻¹) and Yopougon (0.45 mScm⁻¹) where the soils are richer in fine particles (clay + silt) coupled with outstanding amount of organic matter contents. In turn, EC value is relatively higher in the soil of Port-Bouët (0.65 mScm⁻¹) ranging in acceptable level for the normal growth of most of the plants. The ratios of soil contents of Cd, Cu, Pb and Zn as measured in 0 – 20 cm are presented for each of the studied sites (Bingerville, Port-Bouët and Yopougon) in the Fig 2. Port-Bouët site is characterized by the highest proportions of Cd (44%), Cu (49%) and Zn (75%) measurements while, 36% of Pb is noticed in there next to that (49%) of Yopougon site. Lowest values of measurement proportions (< 30%) are for Bingerville as the control site with 26% and 9% accounting for Cu and Zn respectively: soil contents of Cd (0.5 mgkg⁻¹), Cu (18.5 mgkg⁻¹) and Zn (35.6 mgkg⁻¹) are low in the topsoil at Bingerville while that of Pb (21 mgkg⁻¹) is moderate according to international standard values. In turn, highest values of soil contents of Cd (0.70 – 2 mgkg⁻¹) and Pb (60 – 90 mgkg⁻¹) are noticed at Port-Bouët and Bingerville respectively. Soil content of Zn is also high in Port-Bouët while that of Cu is low (< 20 mgkg⁻¹) or moderate (20 – 62 mgkg⁻¹).

3.2 Plant analysis

Mean values of Cd, Cu, Pb and Zn concentrations in plant organs of sweet patato according to studied sites are presented in Table 3. Roughly, there I significant high grand mean concentrations of Cd (0.72 mgkg⁻¹) and Zn (57.93 mgkg⁻¹) in the root as observed for Cu (25.8 mgkg⁻¹) in leaf. In turn, highest concentration of Pb accounts for root (9.60 mgkg⁻¹) and stem (10.50 mgkg⁻¹). This trend of partitioning is confirmed for Zn in each of the studied sites while, highest concentration of Cd is significantly determined in the leaf at Port-Bouët also outstanding with highest concentration of Cu in the root contrasting with the corresponding grand mean value Of the studied three sites, lowest concentrations of Cd, Cu and Pb are observed in the leaf collected at Yopougon as observed for Cu at Port-Bouët.

Table 2: Physicochemical characteristics in topsoil (0 - 20 cm) at Port-Bouët, Bingerville and Yopougon sites

Soil characteristics	Sites		
	Bingerville	Port-Bouët	Yopougon
pH_{water}	5.6	7	8.7
pH_{KCl}	4.6	6.8	8.4
ΔpH	1	0.2	0.3
$\text{MO (gkg}^{-1}\text{)}$	19.26	21.19	13.21
$\text{C (gkg}^{-1}\text{)}$	11.2	12.32	7.68
$\text{N (gkg}^{-1}\text{)}$	1.1	1.8	0.8
$\text{ECC (cmol kg}^{-1}\text{)}$	1.47	1.53	11.8
Electric conductivity (EC) (mScm^{-1})	0.08	0.65	0.45
Sand (%)	81	84	50
Clay (%)	4	1.50	11
Silt (%)	15	14.50	39

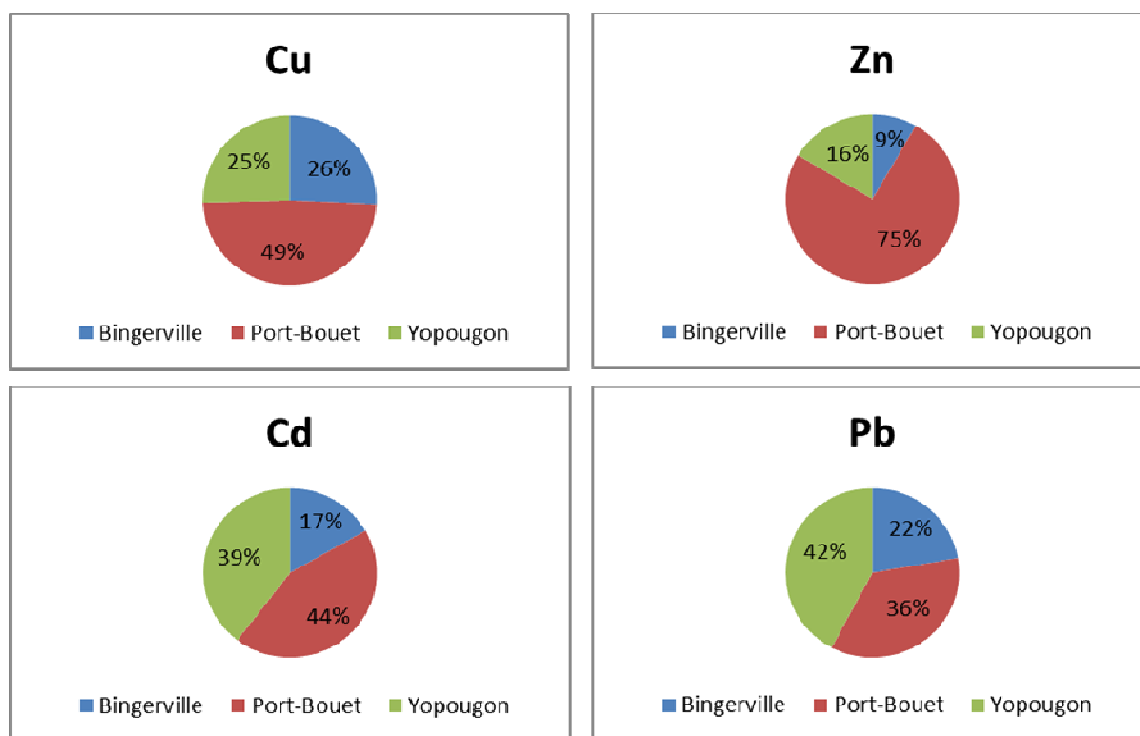


Fig.2. Proportion of metals (%) content in topsoil (0 – 20 cm) as determined in vegetable growing areas at Bingerville, Port-Bouët and Yopougon.

152 **Table 3:** Concentrations of Zn, Cu, Cd and Pb in leaf, stem and root of sweet patato at Bingerville, Port-Bouet and Yopougon sites

	Concentration of Zn (mgkg ⁻¹)				Concentration of Cu (mgkg ⁻¹)			
	Bingerville	Port-Bouet	Yopougon	Moyenne	Bingerville	Port-Bouet	Yopougon	Moyenne
Leaf	52.63 bA	40.74 cC	42.33 cB	45.24c	25.80 aA	21.73 bB	12.60 aC	20.03a
Stem	52.19 bA	41.21 bB	50.91 bC	48.11b	20.58 cB	21.67 bA	7.84 bC	16.68c
Root	57.93 aA	43.74 aC	53.01 aB	51.56a	21.31 bB	24.08 aA	6.7 cC	17.36b
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<0.001
	Concentration of Cd (mgkg ⁻¹)				Concentration of Pb (mgkg ⁻¹)			
	Bingerville	Port-Bouet	Yopougon	Moyenne	Bingerville	Port-Bouet	Yopougon	Moyenne
Leaf	0.52 cB	0.81 aA	0.57 bC	0.63b	6.17 cB	9.72 bA	2.92 bC	6.27b
Stem	0.64 bB	0.72 bA	0.41 cC	0.59b	6.41 bB	10.50 aA	5.01 aC	7.31a
Root	0.72 aB	0.65 cC	0.94 aA	0.77a	7.80 aB	9.60 bA	5.81 aC	7.73a
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<0.001

153 a, b and c are indicating mean values with significant difference in column for α=0.05; A, B and C are indicating mean values with significant difference in line
 154 for α=0.05

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161 **Table 4:** Concentrations of Zn, Cu, Cd and Pb in leaf, steam and root of hibiscus at Bingerville, Port-Bouet and Yopougon sites

Concentration of Zn (mgkg ⁻¹)					Concentration of Cu (mgkg ⁻¹)			
	Bingerville	Port-Bouët	Yopougon	Average	Bingerville	Port-Bouët	Yopougon	Average
Leaf	50.39bA	42.31bB	41.72bC	44.81b	22.44bA	18.70 bB	12.93aC	18.02a
Stem	50.52bA	47.3aC	52.52aB	50.13a	20.60bA	19.62bB	9.3bC	16.51b
Root	58.32aA	42.46bC	51.06aB	50.62a	23.40aA	22.71aB	7.23bC	17.78a
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001
Concentration of Cd (mgkg ⁻¹)					Concentration of Pb (mgkg ⁻¹)			
	Bingerville	Port-Bouët	Yopougon	Average	Bingerville	Port-Bouët	Yopougon	Average
Leaf	0.46cC	0.64aA	0.48bB	0.48b	6.91bB	8.81bA	3.10cC	6.28c
Stem	0.53bB	0.60aA	0.47bC	0.47b	6.17bB	9.42aA	5.52bC	7.04b
Root	0.61aC	0.66aB	0.77aA	0.77a	8.42aB	9.71aA	6.12aC	8.08a
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001

162 a, b and c are indicating mean values with significant difference in column for $\alpha=0.05$; A, B and C are indicating mean values with significant difference in line
 163 for $\alpha=0.05$

Similar results are noticed for the grand mean concentrations of Cd, Cu, Pb and Zn in the different organs of hibiscus (Table 4): Highest concentrations are determined in the root. However, highest significant concentration of Zn is similarly observed in the stem as previously observed for Pb concentration in both root and stem of sweet potato. Nevertheless, there is variance of these results at Port-Bouët and Yopougon sites characterized by highest concentrations of Zn (47.3 mgkg^{-1}) and Cu (12.93 mgkg^{-1}) in stem and leaf respectively. Furthermore, highest concentrations of Zn (50.39 mgkg^{-1}) and Cu (22.4 mgkg^{-1}) are determined in the leaf collected at Bingerville while, highest concentrations of Cd (0.64 mgkg^{-1}) and Pb (8.81 mgkg^{-1}) account for the leaf sampled at Port-Bouët. The concentrations of studied metals (Cd, Cu, Pb and Zn) are low or moderate in the leaf of hibiscus at Yopougon area.

3.3 Soil and plant relationship

Table 5 shows Pearson correlation coefficients (R) as observed between soil contents of Cd, Cu, Pb and Zn and their corresponding concentrations in the leave of studied plants (sweet potato and hibiscus) indifferently to sites. Significant correlation ($R = 0.75$) is limited soil contents of Cu and Zn among soil chemical parameters. But, there is significant and positive correlation between soil content of Cu and the concentrations of Pb in the leave of sweet potato and hibiscus in similar range of 0.61 – 0.63 respectively. However, there are different relations between soil content of Cu and leaf concentration in Cd according to crops: In fact, significant and positive R (0.75) value is observed for sweet potato while no significant correlation accounts for hibiscus. Significant and positive correlations are observed for the concentrations of Pb (0.76) and Cd (0.91) in the leave of sweet potato regarding to soil content of Zn while, only occurring as it for Pb (0.71) in the leaf of hibiscus as the most pollutant influenced by studied soil chemical elements. Moreover, there is no significant correlation for soil contents of Cd and Pb regarding to studied metal concentrations in both soil and plant leave indifferently to sites.

Table 5 : Pearson correlation coefficients (R) between soil contents of Cd, Cu, Pb and Zn and corresponding concentrations in leaf, stem and root indifferently to studied plants

Coefficient of correlation (R) for sweet potato				
	Cu (soil)	Zn (soil)	Pb (soil)	Cd (soil)
Cu (soil)	1.00			
Zn (soil)	0.75***	1.00		
Pb (soil)	-0.01	0.01	1.00	
Cd (soil)	0.07	0.05	0.27	1.00
Cu (leaf)	0.16	0.19	-0.47	-0.09
Zn (leaf)	-0.41	-0.50	-0.35	-0.19
Pb (leaf)	0.63***	0.76***	-0.17	0.06
Cd (leaf)	0.77***	0.91***	0.15	0.16
Coefficient of correlation (R) for hibiscus				

Cu (soil)	1.00			
Zn (soil)	0.75***	1.00		
Pb (soil)	-0.01	0.01	1.00	
Cd (soil)	0.07	0.05	0.27	1.00
Cu (leaf)	0.07	0.09	-0.48	-0.03
Zn (leaf)	-0.36	-0.41	-0.39	-0.25
Pb (leaf)	0.61***	0.71***	-0.29	-0.11
Cd (leaf)	0.48	0.58	0.10	-0.06

*** significant for $P < .001$; () : origin

4. DISCUSSION

4.1: Soil potential as source of pollutant

All the studied soils are derived from sedimentary material named locally “continental terminal” (30) and their difference could account for difference in serials of this sedimentation: Yopougon site in Northern of lagoon fault line was differing to the other sites by ferruginous sand stone as bed rock and the most fine particle size (clay + silt) of soil. However, difference in serial sedimentations should not be able to induce significant difference in soil content of metallic trace elements regarding to the extending homogeneous geologic and climatic conditions as basic characteristic of their native sources (31). In contrast, soil contents of Cd and Pb were higher for Yopougon and Port-Bouët site compared to that of Bingerville and was looking like to be contaminated according to the standard values of Alloway (29). Hence, there was clearness of soil pollution as entropic consequence (e.g. agriculture and industry). High contribution of surface water dynamic as runoff and deep infiltration of lagoon water affecting ground water quality as early reported by Coulibaly *et al.* (32) and Soro *et al.* (33) in the studied area could be relevant for the pollution process since, this ground water was daily used for crop irrigation.

Thus, soil polluted potential as observed by Cd and Pb was likely relative to the distance from the local lagoon (*Lagune Ebrié*), as a driving fact early stigmatized as it by Koné *et al.* (34) in the pollution hazard of costal environment of Cote d'Ivoire; Bingerville site was most distant from the lagoon and less impacted than the other two sites.

Yet, of differences in studied soil acidities and soil contents of organic matter as well as the proportion of fine particle size in the soil, non accounted for obviousness in effective crop pollution by Cd, Cu, Pb and Zn contrasting with the arguments of Schwartz *et al.* (35) relating to highest mobility of these metals into plant from a soil with moderate acidity (pH ~6.5) and high content of organic matter. This contrast was further illustrated by the case of lowest soil content of Zn (35.6 mgkg^{-1} = 9% of measurements) at Bingerville characterized by highest concentrations ($> 50 \text{ mgkg}^{-1}$) of Zn indifferently to plant organs (root, stem and leaf) and crops (sweet potato and hibiscus). Moreover, highest concentrations of Pb in plant organs were observed at Port-Bouët with 36% of measurements (33.6 mgkg^{-1} in soil) against 42% (39.8 mgkg^{-1} in soil) at Yopougon. The consideration of metal speciation which is moreover widely variable (36) and their interactions (37) could have contributed to this: Bio-

availability of organic – Pb^{2+} and Pb^+ are depending to ecological conditions and some forms (polysaccharide) of Cd are not extractable. As consequence, soil total contents of these metals have limited accuracy in presuming soil potential of plant contamination. In turn, it is reported synergistic relation between Cd and Pb (not significant in current study) beside the effects of Cu/Cd and Cd/Zn ratios controlling the availability of soil Cd for plant uptake (38). Consequently, synergism can occurred between Cu and Pb as documented in Table 5 of current study. In contrast, antagonism was suspected between Cd and Zn (39) while highest concentrations of Cd and Pb were determined in the leave and stem collected at Port-Bouët in spite of noticeable amounts of Cu (35 mgkg^{-1}) and Zn (320.7 mgkg^{-1}) in the soil. With that in mind, positive correlations were observed between soil content of Zn and the concentrations of Cd and Pb in the leaf and steam of sweet patato while the concentration of Cd was not concerned as much for hibiscus. Hence, there is insight of minimizing atmospheric deposit of Pb effect in the studied environment while this process was accounting for 95% of Pb-source in plant pollution elsewhere (40) and ecological variance of Pb-Zn interaction is pointed out as topic of future study.

In the light of this analysis, plant pollution by Pb is most likely in the study periurban agro-ecosystem of Abidjan characterized by higher concentration ($> 8 \text{ mgkg}^{-1}$) than the standard values defined by Godin (41). The conditions observed at Port-Bouët (neutral pH, sandy, high contents of organic matter and Zn coupled with moderate content of Cu and high EC) could be concerned with bio-availability of Pb, inducing plant contamination around the lagoon.

4.2: Phytoremediation of lead polluted soil

In spite of noticeable soil content of Pb (21 mgkg^{-1}) at Bingerville, lowest synergism with the other metals (Cd, Cu and Zn) observed in low range of soil content respectively can be suspected as condition of riskless for plant pollution in Pb. Similarly, the low soil contents of Cu (18.2 mgkg^{-1}) and Zn (69.6 mgkg^{-1}) at Yopougon could have inhibited bio-availability of Pb (39.8 mgkg^{-1}) which was characterized by high soil content however. Coupling these contrasts with plant contamination as observed at Port-Bouët allows the proscription of Zn and Cu fertilizer applications in agro-ecosystem prone to Pb pollution as periurban agriculture. This finding reinforces the knowledge of fertilizer practice as previously concerning Ca, P and S with potential to reduce bio-availability of Pb (42; 39). However, there is no improving of soil health and quality by these practices beside its high cost, and the soil still remained threatening for microbial activity which is required in sustaining agricultural ecosystem services (43; 44). Therefore, polluted soil phytoremediation is a required efficient strategy in restoring soil health: soil metal bioextraction (bioharvesting) is estimated by high accumulation in growing plant (44), depleting soil content of concerning pollutant metal.

Lead (Pb) concentrations in vegetal organs of sweet patato were roughly lower in leaf than the stem and root. But at Port-Bouët site where Pb concentration was over the critical toxicity level ($> 8 \text{ mgkg}^{-1}$), highest concentration (10.5 mgkg^{-1}) accounted for the stem contrasting with the argument of low translocation of Pb in plants. Thereby, an average yield of 10 kg ha^{-1} will export about $105 \text{ mg Pb ha}^{-1}$ from soil according to soil particle size density in Africa (45). This is a noticeable removal amount of Pb as compared with the normal level of $100 \text{ mg Pb kg}^{-1}$ in soil (41). This aptitude can be considered as a potential of soil remediation so far, only the root and leave of sweet patato are edible.

This property is better with hibiscus characterized by non edible root and steam accounting for about 20 mg Pb kg^{-1} concentration as twice level determined for the steam of sweet patato. Moreover, the concentration of Pb in edible leaf of hibiscus did not exceed the critical

level of 8 mg Pb kg⁻¹ at Port-Bouët as the most polluted site and a low grand mean value of 6.3 mg kg⁻¹ observed in there was riskless for human consumption. Hence, hibiscus can be recommended in periurban agriculture in area prone to industrial and commercial pollution as Abidjan city for consumption and Pb-polluted soil remediation as compared with sweet potato. This tuber crop (sweet potato) has highest concentration of Pb in both root and steam at Port-Bouët and tuber consumption will be risky for human health meanwhile, tuber crops are supposed to have low potential of Pb accumulation comparing to leafy vegetables (46). Genotypes and ecological differences could have contributed to this contrast that should be explored with variance of scenarios in tropical ecosystems by further study.

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283 5. CONCLUSION

Practice of periurban agriculture is of effective risk of Pb toxicity around Abidjan district, especially for tuber crop as sweet potato, and the proximity of surface water is likely more contributing to this compared with soil properties in extended similar geologic and climatic conditions. However, moderate soil contents of Cu and Zn are required at least for high Pb accumulation in plant tissues independently to soil total content of metal which effective effects are attributed to the speciations. Cropping of vegetable as hibiscus with edible leaf, was recommended for remediation of Pb-polluted soil because high accumulation of Pb in both root and steam.

However, pending matters are underlined by the study in relation with genotype and ecological effects in plant nutrition of Pb, especially, the interaction with Zn and the of Pb accumulation in tuber crop are concerned.

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