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Concentrations of Cadmium, Copper, Lead and Zinc in Soils and Vegetable Organs from Periurban Agriculture Areas of Abidjan in Cote d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. Authors BK and TPG designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors GFY and NYK managed the literature searches, while authors AYK and BK were in charge of analysis, performing the study. All authors read and approved the final manuscript.

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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* locally named "Dah" 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 $mgkg^{-1}$) of Pb were significantly (p< .0001)

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determined in plant organs from Port-Bouët site indifferently to crops while, lower soil content of Pb (35.5 mgkg^{-1}) than that of Yopougon (39.8 mgkg^{-1}) was observed, 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 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 of tropical ecosystems were suggested.

Keywords: Metallic trace elements; vegetable; lead; interaction; phytoremediation; soil and plant contamination.

1. INTRODUCTION

In the humid forest zone of West Africa, the urban population is most important than that of rural zone [1] characterized by poverty and lack of job opportunities: 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 subsidence 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 crop yields. Many studies reported the harmfulness of such accumulation for humans and animals [8-14] as well as for plants in certain extend [15].

Nowadays, there is increasing of urbanization coupled with periurban agriculture adoption in many african countries including Côte d'Ivoire. In Abidjan areas (economic capital of Côte d'Ivore), 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 with household refuse stocks which are auspicious to pollution [16-19] while, yet, this pollution effect is unknown in local crops of mass-market products as vegetable, especially, as sweet potato and *Hibiscus* (*Dah*).

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 mass-market products of vegetables including *Hibiscus* and sweet potato characterized by edible leaves locally. The aims were, i) to determine these metal concentrations in soils and plants in relation with other soil characteristics, ii) identify the most prone to contamination risk among the studied vegetable species as local mass market products, 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 most relevant to contamination of studied vegetable species for promotion of periurban agriculture carefully to consumer health.

2. MATERIALS AND METHODS

2.1 Description of Studied Sites

Abidjan is the economic capital of Côte d'Ivoire (West Africa), on the shoreline of Guinea Golf within latitudes 5º00 - 5º30 N and longitudes 3º50 - 4º10 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 24ºC - 30ºC 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 anthropic activities including industrialization. The geology of the studied area belongs to the coastal sedimentary basin of Côte d'Ivoire, named "*Continental terminal*" and restricted to 2.5% of the country area [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 (5º25N - 3º94W) and Yopougon (5º35N - 4º04 W) characterized by higher industrial and commercial activities contrasting with Bingerville (5º31 N - 3º87 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 sabdaroufa* locally named "*Dah*" and sweet potato (*Ipomoea batatas*). While *Hibiscus* is matured about 2 -3 months of cropping duration sweet potato 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).

2.3 Soil and Plant Sampling

Multi-sites (Bingerville, Yopougon and Port-Bouët) survey was conducted in 2013 in the district of Abidjan (5º18 N; 4º00 W; 10 m asl): The localities of Port-Bouët and Yopougon are characterized by higher intensity of industrial and commercial activities while prevailing agricultural activity accounts for Bingerville.

In 600 m^2 of vegetables cultivated areas in each of these locations, 12 soil composite samples were randomly taken in 0 – 20 cm using hand augur (5 subsamples for about 50 m^2). Soil sampling was coupled with that of plant selecting one plant between 4 positions of soil sampling (50 m^2). About 5 g sample of matured plant organs as fresh leaf, stem and root were taken from *Hibiscus* (*Dah*) 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 (2 mm). 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, NH_4OAc (1N; pH 7.0) (extracting) and Atomic Absorption Spectrometry (apparatus) were used for soil Cation Exchange Capacity (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 HNO_3 (65%; v/v) + 1 mL de HCl (37%; v/v)] as described by [26,27]. 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 [28].

Table 1. Standard ranges ($mgkg^{-1}$) of soil content of metallic trace elements (Alloway [28])

Metals	Moderate	High	Average worldwide
Cu	20-62	65-160	20-30
Zn	100-250	250-426	50
Cd	0.2-1.0	0.70-2.00	2.0-46.3
Pb	10-30	60-90	100-10180

Plant material was washed in tap water to remove adhered soil particles and subsequently shredded, oven dried (60ºC), ground (1 mm) for the use of 0.5 g of sample. Plant samples (leaf, stem and root) were separately digested in 6 ml of each of H_2O_2 and HNO_3 during 3 hours at constant temperature of 95ºC in a Digi PREP and repeated for *Hibiscus* and sweet potato respectively. 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 values of different studied metal contents in soil and their ratios 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 potato) 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 *Dah* (*Hibiscus*) and sweet potato respectively. SAS (version 8) was used for

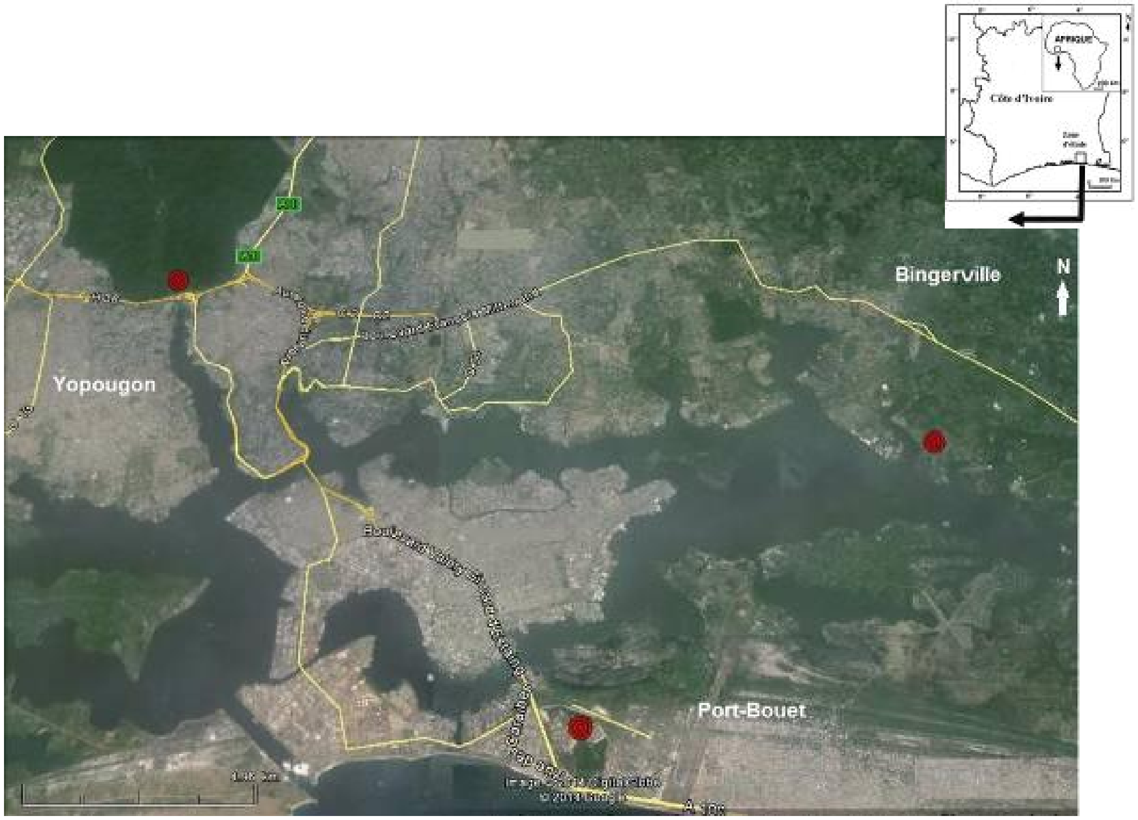

Fig. 1. Localization of studied sites (red marks)

statistical analysis in the confidence intervals ranging from 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 ∆pH which is 3 – 4 times higher at Yopougon than that of the other sites. The values of soil CEC are ranging between 1.4 and 11.8 $cmolkg^{-1}$ 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 amounts 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 mg kg^{-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 (Fig. 3) according to international standard values (Table 1). 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 Yopougon respectively. Soil content of Zn is also high in Port-Bouët while that of Cu is low (< 20 $mgkg^{-1}$) or moderate (20 – 62 $mgkg^{-1}$).

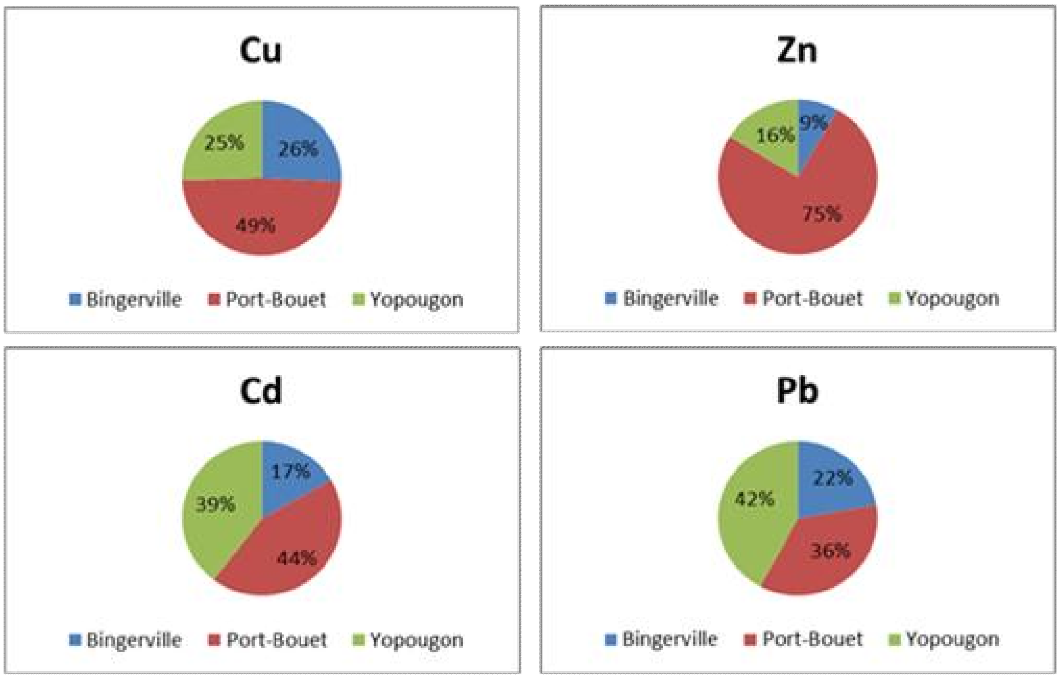

Fig. 2. Proportion (%) of metal contents in topsoil (0 – 20 cm) as determined in vegetable growing areas at Bingerville, Port-Bouët and Yopougon

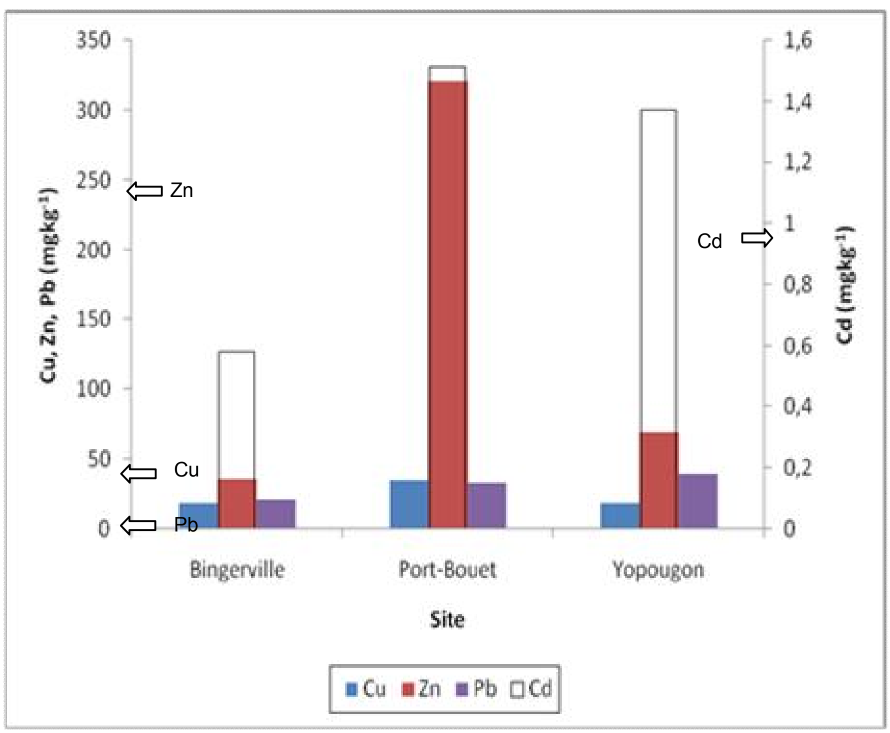

Fig. 3. Mean values of soil contents of Cu, Zn, Pb and Cd in topsoil (0 – 20 cm) according the three sites studied (Moderate levels are pointed respectively)

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±0.50	7±0.75	8.7±0.55
pH_{KCl}	4.6±0.76	6.8±0.98	8.4±0.53
∆pH	1±0.05	0.2±0.02	0.3±0.04
MO (gkg^{-1})	19.26±1.35	21.19±1.42	13.21±2.34
C (gkg^{-1})	11.2±1.05	12.32±1.56	7.68±2.25
N (gkg^{-1})	1.1±0.23	1.8±0.36	0.8±0.16
CEC (cmol kg^{-1})	1.47±0.88	1.53±0.56	11.8±0.35
Electric conductivity (EC) ($mScm^{-1}$)	0.08±0.01	0.65±0.06	0.45±0.03
Sand (%)	81±9.32	84±7.75	50±6.26
Clay (%)	4±1.45	1.50±0.53	11±2.02
Silt (%)	15±1.56	14.50±1.32	39±1.75

± is referring to standard deviation

3.2 Plant Analysis

Mean values of Cd, Cu, Pb and Zn concentrations in plant organs of sweet potato according to studied sites are presented in Table 3. Roughly, there is 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 for the three sites. Lowest concentrations of Cd, Cu and Pb are observed in the leaf collected at Yopougon as observed for Cu at Port-Bouët.

Similar results are noticed for the grand mean of Cd, Cu, Pb and Zn concentrations 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 steam 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 the stem and leaf respectively. Furthermore, highest concentrations of Zn (50.39 $mgkg^{-1}$) and Cu (22.4 $mgkg^{-1}$) are determined in the leave collected at Bingerville while, highest concentrations of Cd (0.64 $mgkg^{-1}$) and Pb (8.81 $mgkg^{-1}$) account for the leave sampled at Port-Bouët. The concentrations of studied metals (Cd, Cu, Pb and Zn) are low or moderate in the leaf of *Dah* (*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 the sites. Significant correlation (R = 0.75) is limited soil contents of Cu and Zn among soil chemical parameters. But, there is significant and positive correlations between soil content of Cu and the concentrations of Pb in the leave of sweet potato and *Dah* (*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 similarly 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 the sites.

Table 3. Concentrations of Zn, Cu, Cd and Pb in leaf, stem and root of sweet potato at Bingerville, Port-Bouët and Yopougon sites

	Concentration of Zn ($mgkg^{-1}$)			Concentration of Cu ($mgkg^{-1}$)		
	Bingerville	**Port-Bouët**	**Yopougon**	**Bingerville**	**Port-Bouët**	**Yopougon**
Leaf	52.63 bA±2.75	40.74 cC±4.92	42.33 cB±2.83	25.80±2.73aA	21.73 bB±2.42	12.60 aC±0.45
Stem	52.19 bA±1.63	41.21 bB±7.13	50.91 bC±4.22	20.58±1.54cB	21.67 bA±1.60	7.84 bC±1.14
Root	57.93 aA±6.60	43.74 aC±7.15	53.01 aB±3.26	21.31±1.47bB	24.08 aA±1.44	6.7 cC±0.80
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001
	Concentration of Cd ($mgkg^{-1}$)			**Concentration of Pb ($mgkg^{-1}$)**		
Leaf	0.52 cB±0.10	0.81 aA±0.11	0.57 bC±0.13	6.17 cB±0.55	9.72 bA±2	2.92 bC±0.79
Stem	0.64 bB±0.10	0.72 bA±0.11	0.41 cC±0.05	6.41 bB±0.45	10.50 aA±2.60	5.01 aC±1.31
Root	0.72 aB±0.09	0.65 cC±0.07	0.94 aA±0.13	7.80 aB±1.20	9.60 bA±2.37	5.81 aC±1.18
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001

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 for α=0.05 (± is referring to standard deviation)

Table 4. Concentrations of Zn, Cu, Cd and Pb in leaf, steam and root of *Dah* (*Hibiscus*) at Bingerville, Port-Bouët and Yopougon sites

	Concentration of Zn ($mgkg^{-1}$)			Concentration of Cu ($mgkg^{-1}$)		
	Bingerville	**Port-Bouët**	**Yopougon**	**Bingerville**	**Port-Bouët**	**Yopougon**
Leaf	50.39bA±2.52	42.31bB±2.29	41.72bC±3.12	22.44bA±2.68	18.70 bB±2.26	12.93aC±0.34
Stem	50.52bA±1.84	47.3aC±1.31	52.52aB±2.80	20.60bA±1.25	19.62bB±1.38	9.3bC±0.73
Root	58.32aA±7.28	42.46bC±7.02	51.06aB±2.67	23.40aA±1	22.71aB±1.72	7.23bC±0.07
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001
	Concentration of Cd ($mgkg^{-1}$)			**Concentration of Pb ($mgkg^{-1}$)**		
Leaf	0.46cC±0.14	0.64aA±0.09	0.48bB±0.16	6.91bB±0.16	8.81bA±0.61	3.10cC±1
Stem	0.53bB±0.11	0.60aA±0.10	0.47bC±0.05	6.17bB±0.60	9.42aA±2.33	5.52bC±1.05
Root	0.61aC±0.09	0.66aB±0.09	0.77aA±0.14	8.42aB±0.51	9.71aA±2.06	6.12aC±1.18
P>F	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001

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 for α=0.05 (± is referring to standard deviation)

4. DISCUSSION

4.1 Soil Potential as Source of Pollutant

All the studied soils are derived from sedimentary material named locally "*continental terminal*" [29,30] and their difference could accounted in serial variances of this sedimentation: Yopougon site in Northern of lagoon fault line was differing to the other sites by ferruginous sand stone as bed rock with 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 characteristics of their native sources [31]. In contrast with this homogeneity, soil contents of Cd and Pb were higher for Yopougon and Port-Bouët sites compared to that of Bingerville and were likely contaminated according to the standard values of Alloway [28]. Hence, there was clearness of soil pollution as anthropic consequence (e.g. agriculture and industry) against the native homogeneity. 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 for Cd and Pb was likely relative to the distance from the local lagoon (*Lagune Ebrié*), as a driving fact early stigmatized as by Koné et al. [34] in the pollution hazard of costal environment of Côte 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 sizes 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 from a soil into plant 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 $mgkg^{-1}$) of Zn indifferently to plant organs (root, steam 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^{+} is 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 potato while the concentration of Cd was not concerned as much for *Hibiscus*. Hence, there is insight of minimizing atmospheric (including traffic) 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 further challenge of new coming study.

In the light of this analysis, plant pollution by Pb is most likely concerned in the periurban agro-ecosystem of Abidjan characterized by higher concentration [>8 $mgkg^{-1}$) in plant tissues 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 affected by wastewater as observed by Hassan et al. [42] elsewhere.

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 observed 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 highest soil content of Pb 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 in periurban agriculture. This finding reinforces the knowledge of fertilizer practice as previously limited to Ca, P and S potentially reducing the bio-availability of Pb [43,39]. However, there is no improving of soil health and quality by these practices beside its high cost while, the soil still remained harmfulness for microbial activity which is required in sustaining agricultural ecosystem services [44,45]. 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 [45], depleting soil content of concerning pollutant metal.

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 sites

	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 *Dah* (*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*

Lead (Pb) concentrations in vegetal organs of sweet potato 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 $mgkg^{-1}$), 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 $kgha^{-1}$ will export about 105 mg Pb ha^{-1} from soil according to soil particle size density in Africa [46]. This amount of Pb is a noticeable removal as compared with the normal level of 100 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 potato are edible.

This property is better with *Hibiscus* (*Dah*) characterized by non edible root and steam accounting for about 20 $mgkg^{-1}$ for Pb concentration corresponding to twice level determined for the steam of sweet potato. 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 in some extend when 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 [47] meanwhile, tuber crops are supposed to have low potential of Pb accumulation comparing with 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.

5. CONCLUSION

The consumption of periurban agriculture production 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 may have effective effects relevant to the speciations with variance in transport mechanisms depending also to co-transport species. Cropping of vegetable as *Hibiscus* (*Dah*) with edible leaf, was recommended for remediation of Pb-polluted soil because of 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 that of Pb accumulation in tuber crop are concerned.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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