

Contamination of Vegetables Grown on Urban Waste Landfill and Health Risks : Case of Akouedo (Abidjan, Cote D'ivoire)

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ABSTRACT

The contamination of vegetables grown on the Akouedo landfill was studied and the health risks associated with their consumption was assessed. The concentrations of Cu, Zn, Ni, Pb and Cd in soil and vegetables were determined on the Abandoned and Operating sites. The concentrations of the bioavailability heavy metals in the soils showed that Zn and Pb have the highest levels at both sites. These concentrations are in the range of 426 mg / kg (Operating Site) and 432 mg / kg (Abandoned site) for Zn and 62.7 mg / kg (Abandoned site) and 66.4 mg / kg (Operating Site) for Pb. The heavy metals concentration in the fruits and leaves of the vegetables were higher for Zn (1.91-13.50 mg/kg dw) and Cu (0.50-8.50 mg/kg dw). However, the concentrations of Zn and Cu obtained in the different vegetables were very low compared to the sanitary standard. The Pb concentration recorded in the tomato fruits harvested on the abandoned site (0.36 mg / kg Pb dw) and those of okra taken from abandoned site (0.57 mg / kg Pb dw) and operating site (0.35 mg / kg Pb dw) were higher than the sanitary standard (0.3 mg / kg Pb dw). The consumption of those vegetables fruits contaminated with Pb could cause anemia and disorders of the nervous system. Moreover, the Bioconcentration Factor (BCF) values were higher for Cu on the abandoned site for okra (0.343) and operating site for eggplant (0.447). Generally, Pb presented the lowest BCF value for all vegetables on the two sites.

KEY WORDS: Heavy metals, Akouedo landfill, vegetables contamination, health risks.

INTRODUCTION

Soils have become increasingly polluted by heavy metals with increasing urbanization and industrialization and this threatens ecosystems, surface and ground waters, food safety, and human health [1-2-3-4]. Heavy metals concentrations in soils are influenced by anthropogenic activities such as agricultural practices, industrial activities and waste disposal methods [5-6]. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and nonbiodegradability which is responsible for their accumulation in the biosphere [7]. Studies have shown that soils at refuse dumpsites contain different kinds and concentration of heavy metals, depending on the age, contents and location [8-9]. In recent times, it has been reported that heavy metals from waste dumpsites can accumulate in soils at an environmentally hazardous levels [10-11]. Urban wastes contribution for heavy metals in soils to 28% for copper (Cu), 20 % for zinc (Zn), 38% for cadmium (Cd) and 19% for lead (Pb) [12]. Wastes dumpsites have been used extensively as fertile ground for cultivating varieties of vegetables. The consumption of those vegetables can constitute serious health concern to human and animal [13-14], because of the heavy metals transfer to the crops.

Moreover, industrial development combined with high population growth in the district of Abidjan (Côte d'Ivoire) generated large quantities of solid wastes of about 1.5 million tons per year. Approximately, 70% of that production are dumped at the Akouedo landfill, which was exploited since 1965 and classified as wild landfill. According to [15], Akouedo landfill generate heavy metals pollution with concentrations ranging from 10.3 to 1 500 ppm and 1 and 11.5 ppm, respectively for Pb and Cd. Akouedo landfill was used every seasons for cultivating vegetables such as okra, tomato, eggplant, and maize. This research is aimed to determine the heavy metals concentration in vegetables grown on Akouedo landfill and analyse health risks associated to their consumption.

MATERIALS AND METHODS

The characterization of the degree of contamination of the vegetables produced on the Akouédo landfill was carried out in order to apprehend their level of contamination and to evaluate the potential health risks related to their consumption. Vegetable and soil samples were collected from the abandoned site (AS) and the operating site (OS) of the Akouédo landfill. Five (5) plots of 100 m² were established on each site, four at the corners and

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one at the center. The plots site choice taking account the presence of the vegetables sampled and the representativeness of the whole site.

Vegetables sampling

Tomato *Lycopersicum esculentus* L. (Figure 1A), Okra *Hibiscus esculentus* L. (Figure 1B), Eggplant *Solanum melongena* L. (Figure 1C) and Spinach *Spinacia oleracea* L. (Figure 1D) were considered because they represented the most grown vegetables on the Akouedo landfill. These vegetables are sold on the markets and are part of the food chain. In addition, these three fruiting vegetables and spinach leaves are described as heavy metals accumulators [16-17-18-19-20]. Vegetables sampled included fruiting vegetables (tomato, eggplant and okra) and spinach leaves. At each plot level, the vegetables were randomly harvested and packaged in sealed food bags. All fruits and spinach leaves from the five (5) plots were assembled to form the composite sample for each vegetable at each site. One sample per site and per vegetable species was obtained.

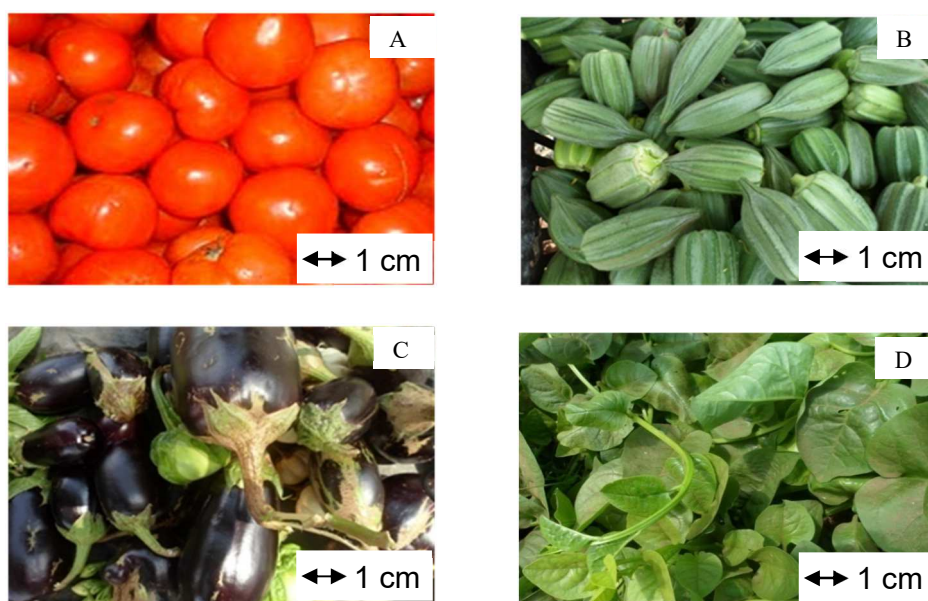


Figure 1: Fruits of tomato (*Lycopersicum esculentus* L.) (A); okra (*Hibiscus esculentus* L.) (B); eggplant (*Solanum melongena* L.) (C) and leaves of spinach (*Spinacia oleracea* L.) (D)

Soil sampling

Soil samples were collected using an auger at depth of 0-30 cm on the five (5) plots established on the abandoned and the operating site. On each plot, one (01) elementary sample of approximately 1.15 dm³ was taken at the center. A composite sample was prepared with five (5) elementary samples obtained on each site. Soil samples were collected in plastic bags, air-dried and ground to pass through a 2 mm sieve.

Evaluation of the mass of heavy metals accumulated in vegetables

Evaluation of average crop production

To evaluate average crop yields (P), three plots of 10 × 10 m² were established for each crop. Depending on crop production cycles, different harvest intervals have been defined. Thus, for okra and tomato, the harvests were done every three days, ten times a month. As for the eggplant, the harvest was made every two weeks. The harvested vegetables were weighed to determine the fresh mass. :

The total areas of the different crops and the average yields were used to estimate the average production of the different crops according to the relation 1:

$$P = \left(\frac{\sum ri}{N} \right) * A \quad (1)$$

P = Average production (t) ;

ri = Plot yield (i) ;

N = Total of plots ;

A = Total area (ha).

Heavy metals mass estimating

Heavy metals accumulated mass in the vegetables produced on the Akouédo landfill was estimated from the average production of vegetables. The evaluation of the dry weight of vegetable-fruit consisted of washing the fresh vegetables harvested with tap water and rinsed with distilled water. Then these fruit vegetables were cut and then put in a mass crucible (m_1). The whole (crucible and vegetable) was weighed (m_2) and placed in an oven at 105 ° C for 24 hours [20-21]. After drying, the crucibles were removed and weighed again (m_3). The ratio (β) of the dry mass relative to the fresh mass of the vegetables was calculated according to relation 2:

$$\beta = \left(\frac{m_3 - m_1}{m_2 - m_1} \right) * 100 \quad (2)$$

$m_3 - m_1$ = dry mass of vegetable ;

$m_2 - m_1$ = fresh mass of vegetable.

The ratio value for each fruit vegetable was used to determine the dry mass of the average fruit vegetable production. Heavy metals accumulated mass in vegetables were calculated from the relation 3:

$$M = P * \beta * [HM] \quad (3)$$

M = Mass of heavy metal accumulated in vegetables (g) ;

P = Average production (kg) ;

β = The ratio of the dry mass relative to the fresh mass of vegetable ;

[HM] = Heavy metal concentration in vegetable (mg/kg dw).

Soil samples pretreatment and analysis

The soil samples were dried in the open air, then crushed and sieved using a 2 mm diameter AFNOR screen. Then, an intermediate sampling was carried out on the fraction sieved according to the technique of the quarterings so as to minimize the risks of error on the composition of the grounds related to their heterogeneity and to obtain the mass of residues necessary for the analyzes [22].

The bioavailable fraction of heavy metals was determined on the soil samples. The analyses were performed according the standard NFX 31-120 relating to the extraction with ammonium acetate (1.0 mol / l) and ethylene diaminetetraacetic acid (EDTA) (0.01 mol / l). Concentrations of Cd and Pb were determined using graphite furnace atomic absorption spectrophotometer (GFAAS) and Cu, Ni and Zn were determined using a flame atomic absorption spectrophotometer (FAAS) [23].

Vegetables samples pretreatment and analysis

The vegetables samples harvested were washed with tap water and rinsed with distilled water. The vegetables samples have been cut into homogeneous size and were dried at 105 ° C for 24 hours. Then, the dried samples were milled and then dried to constant weight.

The mineralization of the vegetables samples was done according to a method derived from the NFX 31-151 standard. The dry vegetable samples powder were digested with solution mixed with 100 ml of hydrochloric acid (37% HCl) and 100 ml of distilled water. Concentrations of Cd and Pb were determined using graphite furnace atomic absorption spectrophotometer (GFAAS) and Cu, Ni and Zn were determined using a flame atomic absorption spectrophotometer (FAAS) [23].

Bioconcentration Factor

The Bioconcentration Factor (BCF) was used to determine the quantity of metal trace elements that is absorbed by the plant from the soil. This is an index of the ability of a plant to accumulate a particular metal with respect to its concentration in the soil [24-25] and is calculated using the following formula 4:

$$BCF = [Metal]_{vegetable} / [Metal]_{soil} \quad (4)$$

RESULTS**Heavy metals concentration in the soil**

The concentrations of the bioavailability heavy metals in the soils show that Zn and Pb have the highest levels at both sites (Figure 2). These concentrations are in the range of 426 mg / kg (Operating site) and 432 mg / kg (Abandoned site) for Zn and 62.7 mg / kg (Abandoned site) and 66.4 mg / kg (Operating site) for the Pb. In contrast, Cu, Ni and Cd are weakly concentrated in the soils of the Akouédo landfill.

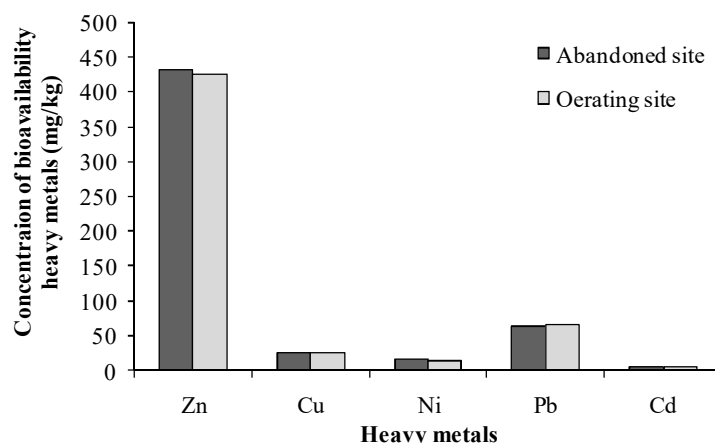


Figure 2. Concentration (mg/kg) of bioavailability heavy metals in the soils of Akouedo landfill

Heavy metals concentration in the vegetables

The heavy metals concentration in the fruits and leaves of the vegetables were higher for Zn (1.91-13.50 mg/kg dw) and Cu (0.50-8.50 mg/kg dw) (Table 1). However, the concentrations of Zn and Cu obtained in the different vegetables were very low compared to the sanitary standard.

The Pb concentration recorded in the tomato fruits harvested on the abandoned site (0.36 mg / kg Pb dw)) and those of okra taken from abandoned site (0.57 mg / kg Pb dw)) and operating site (0.35 mg / kg Pb dw)) were higher than the sanitary standard (0.3 mg / kg Pb dw).

The concentration of Ni and Cd were the lowest and ranged, respectively from 0.20 to 0.68 mg / kg Ni dw and from 0.01 to 0.13 mg / kg Cd dw. Those concentrations were very low compared to the sanitary standard.

Table 1. Heavy metals concentration (mg / kg Pb dw) in the vegetables crops

Heavy metals	Sampling sites	Vegetables				Standard FAO/ OMS (2011)
		Tomato (<i>Lycopersicum esculentus</i> L.)	Okra (<i>Hibiscus esculentus</i> L.)	Eggplant (<i>Solanum melongena</i> L.)	Spinach (<i>Spinacia oleracea</i> L.)	
Zn	Abandoned site	2.24	13.10	3.75	13.50	50
	Operating site	1.91	6.82	4.18	9.79	
Cu	Abandoned site	0.47	8.50	1.06	0.56	40
	Operating site	0.50	1.06	11.5	1.88	
Ni	Abandoned site	0.34	0.41	0.30	0.62	66.9
	Operating site	0.20	0.35	0.35	0.68	
Pb	Abandoned site	0.36	0.57	0.25	0.25	0.3
	Operating site	0.25	0.35	0.18	0.29	
Cd	Abandoned site	0.06	0.07	0.01	0.13	0.2
	Operating site	0.03	0.10	0.06	0.05	

Bioconcentration factor (BCF)

The Bioconcentration Factor (BCF) ranged from 0.001 (Cd) to 0.343 (Cu) and from 0.002 (Pb) to 0.447 (Cu), respectively on the abandoned and operating site (Figure 3). The BCF values were higher for Cu on the abandoned site for okra (0.343) and operating site for eggplant (0.447). Generally, Pb presented the lowest BCF value for all vegetables on the two sites.

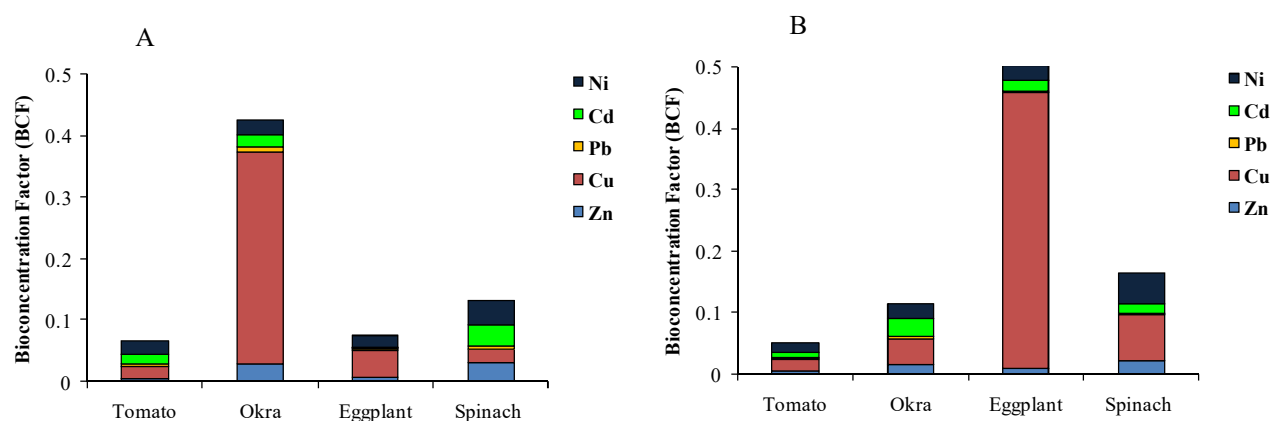


Figure 3: Bioconcentration Factor (BCF) values (A: Abandoned site; B: Operating site)

Heavy metals mass accumulated in vegetables produced

The average quantity of vegetables produced per farming season was high on the abandoned site. On that site, Tomato was most produced (3.36 ± 0.53 ton per farming season).

Table 2. Quantity of vegetables produced per farming season

Sampling sites	Vegetables production (ton per farming season)		
	Tomato (<i>Lycopersicum esculentus</i> L.)	Okra (<i>Hibiscus esculentus</i> L.)	Eggplant (<i>Solanum melongena</i> L.)
Abandoned site	3.36 ± 0.53	1.34 ± 0.12	0.22 ± 0.06
Operating site	2.53 ± 0.37	0.96 ± 0.21	0.09 ± 0.01

The mass of Pb accumulated in the vegetables production showed that the value obtained on the abandoned site was the highest for all the vegetable (Table 3).

Table 3. Mass (g) of Pb accumulated in the fruit vegetables produced on the Akouédo landfill

Sampling sites	Tomato (<i>Lycopersicum esculentus</i> L.)	Okra (<i>Hibiscus esculentus</i> L.)	Eggplant (<i>Solanum melongena</i> L.)
Abandoned site	0,32	0,35	0,01
Operating site	0,20	0,15	< 0,009

DISCUSSION

The vegetables produced on the Akouédo landfill soil concentrated heavy metals. The cultivation site is a wild landfill, exploited for more than five decades. Many types of solids waste, included industrial, household and hospitals of the district of Abidjan are dumped. The decomposition of these different solids wastes would cause the heavy metals transfer into the cultivated soils. The Akouédo landfill heavy metals contaminated soils were reported by [15-26-27]. Another source of vegetables contamination on the landfill could be the atmospheric depositing. That source could be due to the emissions of the vehicles flow and the waste incineration. According to [28], the car traffic and air humidity contributed significantly to the emission of heavy metals into the environment and consequently to their accumulation by vegetables located in the surrounding zone.

Moreover, the heavy metals concentration obtained in the vegetables harvested on the landfill depend on the types of vegetables and the level of pollution of the growing site. Concentrations of Zn and Cu, although lower than the sanitary standard, remain the highest in vegetables. These concentrations of Zn and Cu would be attributed to their nutrient character. In return, the heavy metals concentration obtained for the vegetables were similar to those recorded by [29] for tomato and okra in India, [30] and [31] for eggplant, respectively in India and Nigeria.

The high levels of Pb, recorded in tomato and okra fruits, could be due to their ability to accumulate that heavy metal. According to [32], tomato had a high degree of tolerance for Pb, Zn and Cu. Others authors such as [31] and [16], obtained for Pb 81.8 mg / kg dw in tomato and 9.4 mg / kg dw in okra, respectively.

Among the heavy metals analyzed, Pb presented concentrations above the sanitary standard reported by [33]. In addition, spinach leaves recorded Pb concentrations relatively equal to the sanitary standard. The concentrations of Cd were higher than those obtained by [20] on the vegetables cultivated on the market gardening in Abidjan. The high concentration of Pb and Cd recorded in the spinach leaves from Akouédo landfill would likely be related to the nature of that site. In addition, the consumption of those heavy metals contaminated vegetables, including tomato and okra, could pose a threat to the health of populations. Indeed, the consumption

of those vegetables contaminated with Pb could exposes consumers to several diseases such as anemia, cancer, gastrointestinal disorders, disorders of the nervous system and kidneys [12-34-35].

CONCLUSION

The study showed high contamination of heavy metals in the soil and the vegetables grown on the Akouedo landfill. The heavy metals concentration in the fruits and leaves of the vegetables were higher for Zn and Cu. However, the concentrations of Zn and Cu obtained in the different vegetables were very low compared to the sanitary standard. The Pb concentration recorded in the tomato and okra fruits were higher than the sanitary standard. The consumption of those vegetables presented public health concerns.

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