Journal of Nutrition & Food Sciences
ISSN: 2155-9600
Koffi et al., J Nutr Food Sci 2013, 4:1
DOI: 10.4172/2155-9600.1000251
Research Article Open Access

Cadmium and Lead Levels in Some Vegetables Sold in Abidjan and Estimated Dietary Intakes in the Ivorian Adult

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Abstract

This study was conducted after the dumping of toxic waste in Abidjan by the ''Probo Koala''. It aimed to determine the level of cadmium and lead in some Abidjan markets vegetables and to assess the dietary intake in the Ivorian adult. To this end, 648 samples of some vegetables were collected from markets in the district of Abidjan during the year 2009 according to the method of the consumer basket. These samples, after wet mineralization were analyzed by atomic absorption spectrophotometry. The average concentration of cadmium is 25.8 ± 15.5 µg/kg. For lead, the concentration is 105.5 ± 80.0 µg/kg. The weekly intakes were estimated at 13.9 ± 8.35 µg/week and 56.9 ± 43.12 µg/week, respectively for cadmium and lead, that is 3.31% and 3.79% of the Tolerable Weekly Intake of these micro pollutants. However, for an adult Ivorian eating mainly vegetables the associated health risks were much higher because the estimated intakes would be 188.8 ± 113.4 and 771.9 ± 585.4 µg/week, respectively for cadmium and lead, which would represent 44.9% and 51.5% of the tolerable weekly intake of these metals.

Keywords: Ivoirian Dietary Intake; Cadmium; Lead; Vegetables

Introduction

Urban agriculture, which covers all agricultural activities practiced in both the city and in its immediate vicinity, is taking more and more momentum in the South in general and in Cote d'Ivoire in particular. Urban agriculture encompasses a wide range of crops among which vegetable crops such as lettuce (72% of producers), onion-leaf (38% of producers) and leafy vegetables (18% of producers) are predominant [1,2]. The food supply remains the essential function of the urban agriculture. For instance, in Yaoundé, Cameroon, intra-urban agriculture contributes to the supply of the city for 38% of food crops (cassava, plantain, maize), 28% of vegetables (tomato, pepper, celery) and 28% of fruit products (mango, pineapple, guava) [3]. Like other crops, urban agriculture is subject to a number of potential contaminants including metal micropollutants such as cadmium, lead, arsenic, chromium, copper and zinc [4,5]. Contamination by metals is the result of rapid urbanization, industrial emissions, exhaust from cars, water for irrigation and pesticides [6-10]. Because of their cumulative effects, toxic metals can have adverse effects on both human health and on the different ecosystems [11]. Regarding human health, food poisoning by lead and cadmium is at the origin of diseases such as autism and neurodegenerative diseases (Alzheimer's, Parkinson's, multiple sclerosis) [12]. Toxic metals are also accountable for minor disturbances such as behavioral disorders in adults and children, sleep disorders, digestive disorders, headaches, mild depressions and skin problems [13]. Many studies on the evaluation of the level of contamination of urban crops were conducted all around the world. All these studies (the most recent as the oldest) agree on the fact that urban crops are contaminated and often at levels much higher than the limits set by international regulatory organizations [7,10,14,15].

Thus, after the dumping of toxic waste (containing mercaptans, organochlorine and hydrogen sulfide) by a Greek ship chartered by the company Trafigura Beheer at several locations in the district of Abidjan, we undertook this study on the level of contamination of vegetables sold in markets in order to estimate the intake of lead and cadmium in the Ivorian adult. The specific objectives of the present study relate to the determination of cadmium and lead concentrations in vegetables found in Abidjan markets, the calculation of dietary intake in micro-pollutants and the comparison of these estimated values to those advocated by international standards.

Material and methods

Sampling

The biological material consisted of samples of some vegetables commonly consumed by the Ivorian adult such as carrots, lettuces, parsley, spinach, cabbage, peppers, tomatoes, peppers and cucumber. Sampling was done on three markets (Adjame, Treichville and Yopougon) of Abidjan District from January to December 2009 at the rate of two samples per month and per specimen. Thus, 648 bulk samples of 5 kg each were collected and sent to the laboratory for analysis.

Reagents

The reagents used included distilled water at 18 MΩ^{-1}, nitric acid at 65% (Merck), hydrogen peroxide and standard solutions of lead and cadmium 1g /L (Normex).

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Received November 13, 2013; **Accepted** December 27, 2013; **Published** December 31, 2013

Citation: Koffi KM, Kouadio AI, Biego GHM, Saki SJ, Ake AY, et al. (2013) Cadmium and Lead Levels in Some Vegetables Sold in Abidjan and Estimated Dietary Intakes in the Ivorian Adult. J Nutr Food Sci 4: 251. doi: 10.4172/2155-9600.1000251

Instrumentation

The measuring equipment was an atomic absorption spectrophotometer (Varian Spectra-A110) equipped with a graphite furnace (GTA-110). The determination of cadmium and lead was performed at 2.7 nm and 283.3 nm and concentrations were determined from calibration lines established with three points: 5 µg/L, 10 µg/L and 20 µg/L for lead and 0.5 µg/L, 1 µg/L and 2 µg/L for cadmium [16-18].

Mineralization of samples

An aliquot of 0.5 g of crushed vegetable was digested in a microwave digester (Milestone Ethos) with 7 mL of nitric acid (65%) and 2 mL of hydrogen peroxide (30%). For 10 minutes, the rise in oven temperature from 30°C to 300°C has been gradual. The temperature was then stabilized at the optimum temperature for 10 minutes before being lowered to 30°C for 45 minutes. The minéralisât was then transferred into a 25 mL volumetric flask and completed to the mark with demineralized water at 18 $M\Omega^{-1}$ and kept refrigerated prior to analysis [18].

Quality assurance of the results

The quality control of micro pollutants analysis was conducted according to the standard NFV03-110 [19]. This program involves determining the limits of detection and quantification, calculating the coefficient of variation for the tests of repeatability and reproducibility, and determining the percentage recovery of a metered addition of each micro-pollutant.

Estimated weekly dietary intake of micro-pollutants in the Ivorian adult

The toxicological risk assessment is based on the comparison of the Tolerable Weekly Intake (TWI) of a toxic element set by the Joint FAO/WHO Experts on Food Additives with the Estimated Weekly Intake (EWI) in a study. TWI values recommended in a 60 kg adult are 150 and 1500 µg/week, respectively for cadmium and lead [20]. The weekly intakes were calculated using data from the consumption of vegetables crops established by the group FAO/WHO on the program of monitoring and evaluation of contaminants in food [21]. These data indicate that the amount of total food consumed and vegetables by an Ivorian adult are respectively 7317.1 g/week and 539 g/week.

Micropollutants intakes were then calculated using the following formula:

Estimated Weekly Intake (EWI, µg/week)=C X Q

C: concentration of micropollutant found in food (µg/kg)

Q: weekly amount of fresh vegetables consumed by an adult (kg/week).

Statistical Analysis

Data were expressed as mean ± standard deviation. Data were analysed by ANOVA at α=0.05. Comparison of means was performed by Tukey test and difference was considered significant at $p<0.05$. Statistica 7.1 sofware is used for statistical analysis.

Results

Quality assurance of the results

The results of the quality control program are reported in Table 1. The coefficients of variation of repeatability tests are respectively 4.6% and 1.7% for cadmium and lead. These coefficients are 4.8% and 4.4%, respectively for cadmium and lead for the reproducibility tests. The percentages recovery of standard additions is respectively 97 ± 3.2% and 96 ± 4.1% for cadmium and lead. The limits of detection are 2.10 µg/L and 3.02 µg/L for cadmium and lead. These results account for the reliability, accuracy and sensitivity of the technique of analysis.

Parameters (CV in %)	Cadmium	Lead
Repeatability (CV in %)	4.60	1.70
Reproducibility (µg/L)	4.80	4.40
Detection limit (µg/L)	2.10	3.02
Quantification limit	10.1	12.1
Recovery percentage (%)	97.0 ± 3.2	96.0 ± 4.1

Table 1: Results of validation tests.

Vegetable	Cadmium		Lead	
	Average	[Min - Max]	Average	[Min - Max]
Tomato	18.6 ± 12.3[ab]	[4.1 – 26.3]	74.8 ± 28.1[b]	[18.5 – 128.8]
Chili	9.8 ± 3.6[a]	[4.1 – 17.4]	115.0 ± 66.0[d]	[13.8 – 219.4]
Lettuce	9.3 ± 5.0[a]	[1.0 – 19.4]	191.9 ± 84.7[e]	[1.0 – 19.4]
Spinach	26.3 ± 17.8[b]	[2.8 – 270.7]	126.8 ± 82.6[d]	[29.9 – 364.6]
Cabbage	15.2 ± 8.8[a]	[1.0 – 37.8]	84.9 ± 66.4[c]	[17.5 – 204.5]
Cucumber	10.9 ± 9.5[a]	[1.0 – 48.0]	125.0 ± 76.9[d]	[17.5 – 234.8]
Pepper	54.9 ± 48.3[d]	[1.0 – 151.1]	43.4 ± 38.6[a]	[13.4 – 139.1]
Carrot	46.0 ± 31.2[cd]	[6.7 – 17.5]	47.4 ± 38.8[a]	[2.4 – 129.8]
Parsley	44.4 ± 34.0[c]	[2.1 – 17.9]	128.9 ± 95.9[d]	[12.4 – 281.2]
Mean vegetable	25.8 ± 15.5	[1.0 – 270.7]	105.5 ± 80.0	[1.0 – 373.9]

The means followed by the same letters in a given column are not significantly different at p≤5%.

Table 2: Limit values and average concentrations of lead and cadmium found in the vegetables analyzed (Concentration in µg/kg of fresh vegetables).

Concentrations of metallic micro-pollutants

The concentrations of cadmium and lead found in the vegetables analyzed are presented in Table 2. Of 225 samples submitted for analysis, respectively 87.5% and 92.4% have concentrations of cadmium and lead equal or greater than the detection limits. The concentrations of cadmium vary between 1.0 µg/kg and 270, 7 µg/kg of fresh product with an average of 25.8 ± 15.5 µg/kg. Lead is found in vegetables at values between 1.0 µg/kg and 373.9 µg/kg of fresh product with an average of 105.5 ± 80.0 µg/kg. The highest concentrations of cadmium are determined in pepper (54.9 µg/kg of fresh product), carrot (46.0 µg/kg of fresh product) and parsley (44.4 µg/kg of fresh product), while chili (9.8 µg/kg fresh product) and lettuce (9.3 µg/kg of fresh product) are the less contaminated by cadmium. Regarding lead, the majority of vegetables analyzed are contaminated. Only pepper (43.4 µg/kg of fresh product) and carrot (47.43 µg/kg of fresh product) have relatively low levels.

Weekly dietary intakes

Table 3 presents the values of TWI and estimated intakes of cadmium and lead. The calculated values are 13.9 ± 8.35 and 56.9 ± 43.12 µg/week, respectively for cadmium and lead. In an extreme case of a person eating only vegetables, estimated intakes would be 188.8 ± 113.4 and 771.9 ± 585.4 µg/week.

Discussion

Concentrations of metallic micro-pollutants

The concentrations of lead and cadmium found in the samples

	Share of vegetable in total consumption		Individual eating only vegetables	
Quantity of food consumed (g/week)	539		7317.1	
	Cadmium		**Lead**	
Acceptable Weekly Intake (AWI, µg/week)	150		1500	
	Cadmium	**Lead**	**Cadmium**	**Lead**
Estimated Weekly Intake (EWI, µg/kg)	13.9 ± 8.35	56.9 ± 43.1	188.8 ± 113.4	771.9 ± 585.4
EWI/AWI (%)	9.26	3.79	125.86	51.46

Table 3: Estimated weekly intakes of cadmium and lead in the Ivorian adult and contribution rates to the acceptable weekly intake.

analyzed are comparable to those of the literature. In fact, in 1999 Biego [22] determined the concentrations of essential and toxic microelements in foods consumed in France. The levels of cadmium and lead were respectively 28.9 µg/kg and 48.8 µg/kg of fresh product [22]. It's noted that the concentration of lead found in this study was higher than that found by [22]. Six years later, the concentrations found in the same products were much lower and equal to 10.8 µg/kg and 15.0 µg/kg [23]. Another study conducted in Canada by Beausoleil on the level of cadmium and lead in vegetables gave values much lower ranging between 2 and 8 µg/kg [24].

Moreover, we note that cadmium is mainly found in pepper (54.9 µg/kg), carrot (46.0 µg/kg) and parsley (44.4 µg/kg). Many studies show a link between the level of contamination of soil and the vegetables grown. In 1992, Boon and Soltanpour [25] determined the lead content of some vegetables from areas heavily contaminated by materials from mines. The concentrations ranged from 41,000 to 45,000 µg/kg fresh weights for lettuce and spinach and 5000 µg/kg fresh weight for the cabbage. These results were confirmed by Finster et al. [26] in vegetables grown in urban gardens in Chicago.

As regards the order of distribution of micro-pollutants in vegetables, we note for cadmium the following order:

Root vegetables (46.0 µg/kg)>leafy vegetables (26.7 µg/kg)>fruit vegetables (23.5 µg/kg)>vegetable flowers (15.2 µg/kg)

Contrary to our results, Wolnik et al. [27] established that cadmium accumulates much more in leafy vegetables.

Concerning lead, the order of contamination is as follows:

Leafy vegetables (149.19 µg/kg)>fruit vegetables (89.71 µg/kg)>vegetable flowers (84.84 µg/kg)>root vegetables (47.43 µg/kg)

These results are also dissimilar to those of Emongor [28] that showed that lead accumulates more in roots than in leaves. For the evaluation of the health risks consumers, recent data from literature indicate estimated intakes of cadmium and lead much lower than those calculated in our study. The survey conducted in France by Leblanc et al. [23] is an obvious example. Weekly intakes from this study were 45.5 µg and 12.6 µg, respectively for cadmium and lead. In 1998, Biego et al. [14] found much higher values (25.9 µg/week and 45.5 µg/week, respectively for cadmium and lead). In Spain, lead and cadmium weekly intakes in adult were estimated at 9.1 µg/week and 26.6 µg/week [29]. The Tolerable Weekly Intake of cadmium and lead are set at 150 µg/week and 1500 µg/week by the Joint FAO/WHO Expert Committee on Food Additives and Contaminants [20]. The estimated weekly intake in the Ivorian adult from the consumption of vegetables account for 9.26% and 3.79% of the PTWI values of these metals. Assuming an adult eating only vegetables, the calculated values (188.8 ± 113.4 µg/week and 771.9 ± 585.4 µg/week respectively for cadmium and lead) would represent 125.86 and 51.5% of the PTWI of these metals. These data are still lower than TWI (Table 3) but in that case the associated health risks could be more significant.

Conclusion

This study revealed the presence of lead and cadmium in most vegetables sold in markets in the district of Abidjan. However, the contribution rates to the Tolerable Weekly Intakes in Cadmium and lead are relatively low. Although the toxicological risks for consumers seem apparently low, they could be significant if taken into account input from other sources of contamination (water, air, meat, etc.). Given that the toxicological consequences for environment and human health may be irreversible, the authorities should strengthen control measures and introduce a more efficient environmental policy able to reduce significantly the level of food contamination.

Acknowledgement

The authors gratefully acknowledge the Central Laboratory for Food, Hygiene and Agro-Industry (LCHAI), National Laboratory for Agriculture Development Support (LANADA) of Ivory Coast, Department of Animal Production and Fish Resources for the funding.

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