

Assessment of the Health Risks Associated with the Ingestion of Heavy Metals (As, Cd, Cr, Pb, Ni, Zn, Hg) in Vegetable Crops in the City of Daloa (Ivory Coast)

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Abstract: In order to assess the health risks associated with the ingestion of heavy metals or trace metal elements (TME) contained in foodstuffs from market garden crops, we sampled the tomato, cabbage, onion and leaves of 'onions and lettuce grown in the lowlands of the town of Daloa. The concentrations of ETM contained in these market garden products were determined by an Atomic Absorption Spectrophotometer (AAS) using three methods such as the flame method (Zn), the oven method (Pb, Cd, As, Cr, Ni) and the hydride (Hg) method. The results obtained showed that the heavy metals studied are present in fruits and vegetables with the most important Zn, Cr and Ni contents. However, metals such as arsenic, mercury and zinc present a concentration higher than that of the standard in force for the foodstuffs studied. Thus, the consumption of market garden products from cultivated soils in the areas studied could present dangers for the exposed population. Indeed, the study of the health risks associated with the ingestion of these vegetables has shown that for arsenic and zinc the determined Danger Quotient are all greater than 1. Which means that these vegetable crops present risks. related to the ingestion of zinc and arsenic. this means that the exposed population is theoretically out of danger. The values obtained from the Health Impact (SI) are all less than 1 for the population surveyed. On the other hand, for the estimated population of the city of Daloa we observe an $IS > 1$.

Keywords: Vegetable Crops, Heavy Metals, Evaluation, Ingestion, Sanitary Risks

1. Introduction

Pollution of the environment and the permanent exposure of human beings to trace metallic elements (TME), wrongly called heavy metals, are today major problems which continue to grow in this world where modernism is growing. 'installs [1]. Compared to other pollutants, TME are non-biodegradable. Certain heavy metals (Fe, Zn, Cu, Mn) are necessary or even essential for living beings, and this at reasonable concentrations in certain environmental matrices. On the other hand, at a high threshold, they (Cd, Pd, Hg) exhibit a more or less strong toxicity which strongly harms most living organisms. Nowadays, with the development of

the way of life in almost all agricultural and industrial sectors, these metallic pollutants come mainly from anthropogenic activities (waste spreading, agriculture, industry, etc.) and natural sources (weathering of rocks, volcanic eruptions) [2].

In the Ivory Coast and as in all the other African countries, market gardening occupies an important place in socio-economic activities because of its strong demand for consumption through their contributions of mineral elements and especially vitamins. Also, market gardening practiced around dams and in lowlands is an activity that is developing more and more in large African cities.

In Daloa, market gardening is often practiced on soil amended with organic dung (cattle waste) and manure (chicken

waste), a practice considered as a simple and inexpensive solution for recycling nutrients [3]. Moreover, like many cities, the permanent use of fertilizers, pesticides and the use of wastewater are widely practiced in urban market gardening. They can constitute a source of metal pollution and a threat to the health of the populations of the city and that of the consumers of the harvested products [4]. All these practices will help to modify the physicochemical parameters of the cultural environment and therefore influence the original bioavailability of heavy metals. In addition, the accumulation of TME in the environment, more particularly in lowlands, presents risks to human health [5]. Indeed, soil pollution (lowlands) by trace metals is a major problem because, unlike other environments (atmosphere and water), the soil has a lower capacity to purify itself [6]. Thus, there are risks of metallic bioaccumulation in these market garden products grown in lowlands, which can cause health threats for the population [7].

This study is a contribution to the assessment quantitative health risk associated with the ingestion TME content in vegetable crops of the town of Daloa is in this context. For us, it will first be a matter of determining the bioaccumulation factors (BCF), then of calculating the Danger Quotients (DQ) for the threshold effects and the Excess Individual Risk (EIR) for the effects. without thresholds and finally to calculate the

Sanitary Impact (SI) to determine the number of cancer cases likely to occur in the population.

2. Materials and Methods

2.1. Presentation of the Different Lowlands of the City of Daloa

Site 1 (Lowlands 1) is located in the *Gbokora* district. On the outskirts we have a chicken farm, a garage and dwellings. Lowlands 2 is located between the *CIE*, the *Baoulé* district and not far from the large market. It is an urbanized area where the market gardening site intertwines with dwellings. Around it, we can see the presence of garages, restaurants, homes from which wastewater and runoff flow into them. Site 3 (Lowlands 3) is supplied by a solid waste landfill in these surroundings. Lowland 4 is mainly used for rice growing because it is regularly flooded by runoff from human activities in the Commerce district. Site 5 (Lowlands 5) located in the *Orly* district. It has a drainage system and receives water from the small market in Orly. On the outskirts of Lowlands 6 (*Orly plateau* area) of the site we have the presence of dwellings, restaurants, stations and the presence of solid waste.

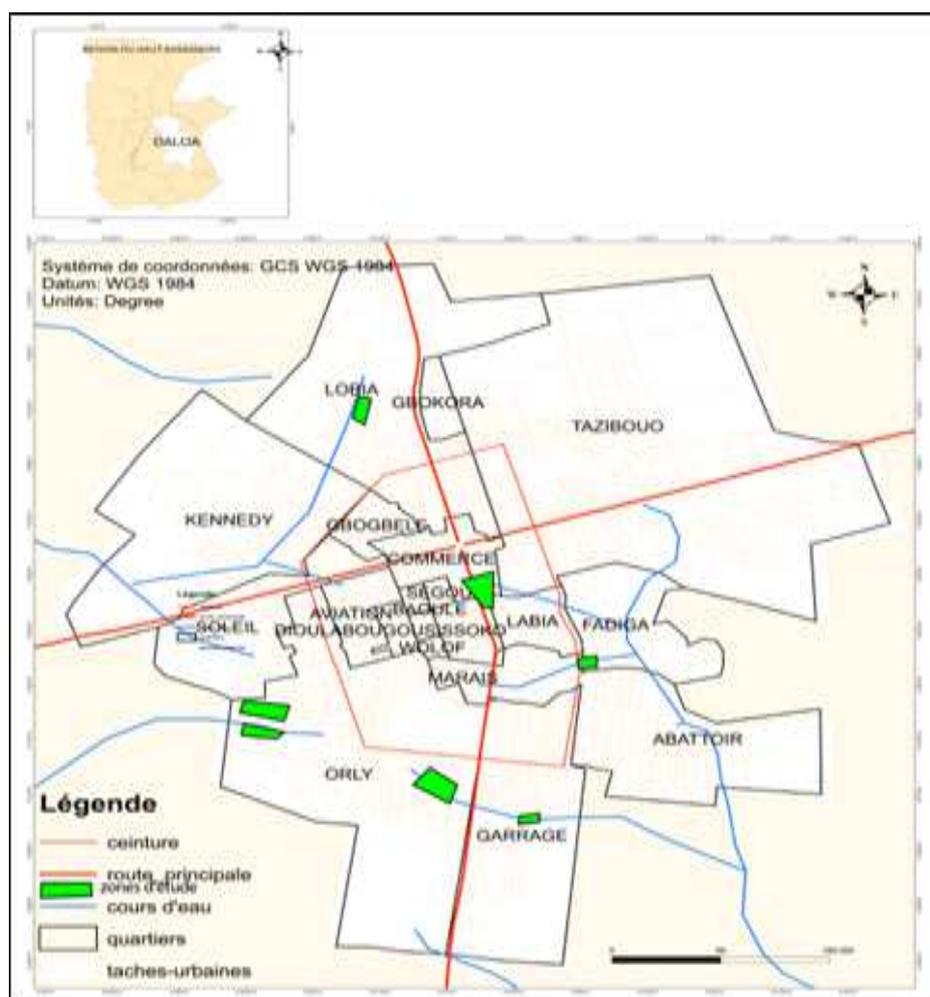


Figure 1. Map of the city of Daloa showing the study areas.

2.2. Methodological Approach

The approach consists on the one hand in quantifying the state of pollution of the food collected at the study sites and on the other hand in evaluating the risks incurred by the populations due to the consumption of these foods.

2.2.1. Food Survey

The dietary survey consists of quantifying the consumption of an individual for generally therapeutic or epidemiological purposes, but sometimes for statistical studies. Indeed, it allows to have a more precise knowledge of eating habits and their consequences. In the case of our study, the food survey can allow us to better appreciate the eating habits of the population of the town of Daloa.

2.2.2. Survey Techniques Used

(i) Food Diary

The food diary provides real-time information over a period of three to seven days of the individual's diet. This technique can be applied in our study to the populations of the said city. It consists of asking the interviewee to note the foods prepared and served over a given period, specifying the quantities (either by weighing or evaluated in measurable units)

(ii) Food Story Through Questioning

Food history by questioning is based on a detailed examination of the individual's usual diet. It is used to reconstitute the average food consumption of the subject over a given period by questioning him on his consumption of the day before, then of the past week. Our study looks at lunch and dinner.

Procedure of the investigation: After having indicated to the investigator his age, weight, height, sex and profession, the subject describes his diet. For each intake, the investigator identifies the foods consumed, estimates their frequency and the weight of the portions (expressed in quantity per day). Thus, we have been oriented according to our objectives research after investigation to vegetables such as: lettuce, cabbage, the leaves of onions, onion and tomato.

2.3. Sampling Methods

2.3.1. Sampling of Fruit and Vegetables

Six areas were defined for the sampling of vegetables, fruits (tomato, onion), onion leaves, cabbage and lettuce. In each zone, taking into account the presence of the four species to be studied, vegetables, fruits and leaves were freshly harvested inside each plot in a random manner. Each of the vegetables, fruits and leaves was packaged in hermetically sealed food bags. Then, composite samples were made for each product. The choice of areas of research's motivated not only per our reason for the presence of landfill, garage motorcycle but also p our reasons of accessibility of certain foodstuffs and also the strong movement of gear two or four wheels.

2.3.2. Preparation of the Samples

The samples of vegetables, fruits and leaves were cut into

a uniform size to facilitate drying of the pieces. The cut pieces were dried at 105°C for 24 h. The dried samples were ground in a porcelain mortar. Finally, the samples were placed in labeled petri dishes and dried to constant weight in billed silica gel desiccators until complete digestion of the samples. After this grinding phase, powder samples were obtained.

2.4. Methods for the Determination of Heavy Metals in Target Matrices

2.4.1. Determination of TME

The solutions obtained after acid digestion of the plant samples were assayed with an atomic absorption spectrophotometer (AAS) at well-defined wavelengths at National Laboratory for Support to Agricultural Development of Ivory Coast.

2.4.2. Assay Methods

(i) Flame Method (Zn)

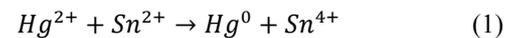
The atomic absorption of flame is a method which makes it possible to determine essentially the metals in solution. This elemental analysis method requires that the measurement be made from an analyte (element to be determined) transformed into the state of free atoms. Each mineral is introduced into the apparatus by the capillary tube which aspirates approximately 2 mL/min of each sample which will be sprayed on the optical path of the apparatus. The sample is sprayed into the flame (atomic excitation source) while forming an atomic cloud which is traversed by monochromatic light.

(ii) Four Method (Pb, Cd, As, Cr, Ni)

Between 10 and 20 µL of solution are taken by the automatic injector to be injected into the graphics tube. Once deposited, this drop is dried and then sprayed onto the optical path of the device, forming an atomic cloud, which is crossed by the monochromatic light characteristic of the element to be quantified.

(iii) Hydride Method (Hg)

The water or mineralized sample is aspirated and mixed with tin chloride in a gas-liquid separator where the mercuric ion is reduced to gaseous elemental mercury according to the following reduction reaction:



The generated cold mercury vapors are entrained by a stream of nitrogen directly towards the detector to be quantified.

2.5. Calculation of the Bioaccumulation Factor (BCF)

Bioaccumulation is defined as being the accumulation of a contaminant in the tissues of a living organism following its absorption from its living environment or its consumption of contaminated prey [8]. Bioaccumulation occurs when an organism absorbs a contaminant faster than it eliminates it. It

designates the ratio between the concentration of a given compound in the tissues of an organism and its concentration in the environment that surrounds it or in the tissues of living organisms on which this organism feeds. Bioconcentration factors (BCF) are calculated by the following formula:

$$BCF = \frac{[C_o]}{[C_e]}$$

C_o : concentration of trace elements of the organism contained in fruits and vegetables;

C_e : environmental concentration (soil). Both are expressed in mg/kg.

If $BCF > 1$, there is metallic bioaccumulation.

2.6. Food Risk Assessment Methodology

The assessment strategy established for the process of assessing the risks of adverse health effects arising from human exposure to toxic substances in food is based on an internationally recognized assessment model [9]. The application of this risk assessment model may vary due to one or more factors (risk tale, type of product, magnitude of exposure, etc.). The problem statement requires the development of a precise model.

In our study, the risk that we consider arises only from exposure through ingestion, that is to say through food [10]. The methodology used can be broken down into three main stages: identification of the potential danger, assessment of exposure of the population and characterization of the dietary risk.

2.6.1. Danger Identification

It is the determination of the potential adverse health effects resulting from exposure to a substance. The danger is highlighted, by examining the data on toxicity, on the results of toxicity tests in laboratory animals, and on knowledge about its effects on human health through the literature of a go. And by the detection of substances contained in foodstuffs intended for human consumption on the other hand.

2.6.2. Food Risk Characterization

The characterization of the dietary risk makes it possible to estimate by calculation the health risks to which a population exposed to a particular pollution of anthropogenic or natural origin is subjected [11]. It expresses the expected risk as a function of the exposures.

(i) Calculation of the Daily Exposure Dose (DED)

According to the Ile de France regional health observatory [12], this daily exposure dose is obtained by the following formula:

$$DED = \frac{C_i \times Q_i}{p} \times F$$

DED: Daily exposure dose (mg/kg/day);

C_i : Mean concentration of TME in food i (mg/kg);

Q_i : Quantity of food consumed by an individual per day in kg;

p : Average body mass of the target (exposed individual) in kg;

F : Frequency or rate of exposure: annual number of hours or

days of exposure.

The average body weight of an adult is conventionally equal to 60 kg [13].

(ii) Computing the Danger Quotient (DQ) to the Effect to Thresholds

The Danger Quotient is the ratio of the daily exposure dose (exposure received) of the individual or population and the Acceptable Daily Dose.

$$DQ = \frac{DED}{ADD}$$

DQ: Danger quotient (without unit);

DED: Daily exposure dose (mg/kg);

ADD: Acceptable daily dose (mg/kg).

This result only makes it possible to conclude on the potential for the appearance of effects but not on their importance. Indeed, when:

- $DQ < 1$, this means that the exposed population is theoretically out of danger, that is to say that this exposed population is not likely to develop the health effects studied.
- $DQ > 1$, this means that the toxic effect can occur without it being possible to predict the probability of this event occurring.

(iii) Calculation of the Individual Excess Risk (IER) for Effects Without Thresholds

This calculation is carried out in the case of non-threshold effects (substances with a carcinogenic effect). It results from the product of the daily dose received by the individual by the acceptable daily dose attributable to the substance for a route and an effect considered [11]. It is obtained by the following formula:

$$IER = DED \times \frac{T}{Tp} \times EUR$$

IER: Excess individual risk (mg^2/kg^2);

EUR: Excess unit risk of the metal (mg/kg/day).

DED: Daily exposure dose (mg / kg);

T: Duration of exposure (years);

T_p : weighting time (entire life, in years);

In the Ivory Coast, life expectancy is estimated at 58 years (www.population/cote-divoire). Be $T_p = 58$ years old and a person's exposure to a substance starts at age 15. Then the exposure time is: $T = T_e = T_p - 15 = 43$ years).

(iv) Calculation of the Sanitary Impact (SI)

The Sanitary impact is calculated from the IER previously defined and the size "N" of the population considered by the following formula [14]

$$SI = N \times IER$$

The population of the city of Daloa is estimated at 255,354 inhabitants [15]. The surveyed population is 70 people. The sanitary risk assessment will focus on these two population sizes (N and N'). With $N=255,354$ and $N'=70$.

3. Results and Discussion

3.1. Results

3.1.1. Estimation of the Amount of Food Consumed

The survey carried out noted that the supply of food products (vegetables) to households is done, for the most part, directly from the fields of the populations. Food consumption data obtained from the survey population are shown in Table 1. Let Q be this quantity.

Table 1. Proportion of food consumed daily in a ration (kg/d).

Frequencies	2-3 times a week		1 time per day		
Vegetables	Cabbage	Lettuce	Tomato	Onion	L. onion
Q (kg/d)	0,27	0,12	0,15	0,10	0,11

*L. onion: Leaf onion.

3.1.2. TME Content in Fruits and Vegetables

The concentrations of TME in market gardening crops produced in the lowlands of the town of Daloa are given in the figure above.

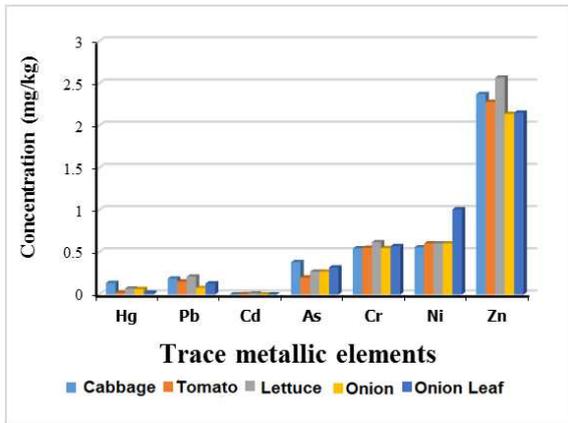


Figure 2. Proportion of food consumed daily in a ration (kg/d).

Analysis of the results obtained reveals that the metal contents are very disparate and vary according to the sampling site but also according to the plant species. This analysis allows us to classify the TME studied into three groups.

The first group contains only zinc. Indeed, the zinc contents determined in these products (cabbage, tomato, lettuce, onion and onion leaves) are all greater than 100 mg/kg with a maximum content in lettuce which is 372,53 mg/kg.

Then we have nickel and chromium. They all have concentrations obtained in the various market garden products of between 2 and 10 mg/kg. The maximum levels of chromium and nickel were obtained in lettuce (3,18 mg/kg) and onion leaves, 9,27 mg/kg, respectively.

Finally, arsenic, cadmium, mercury and lead are part of the third group of parameters with concentrations determined between 0 and 2 mg / kg. The maximum levels of cadmium (0,03 mg/kg) and lead (0,63 mg/kg) were obtained in lettuce and those for arsenic (1,42 mg/kg) and mercury (0,37 mg/kg) in cabbage.

In addition, the sequence of TME studied in market garden products is as follows:

- Cabbage: Zn > Ni > Cr > As > Pb > Hg > Cd
- Onion leaves: Zn > Ni > Cr > As > Pb > Cd > Hg
- Lettuce: Zn > Cr > Ni > As > Pb > Hg > Cd
- Onions: Zn > Ni > Cr > As > Pb > Hg > Cd
- Tomatoes: Zn > Ni > Cr > As > Pb > Cd > Hg

3.1.3. Calculation of the Bioaccumulation Factor (BCF)

Tables 2, 3 and 4 below shows the results of the bioconcentration factor in fruits and vegetables.

The contents obtained for the various ETMs studied allowed us to calculate the Bioconcentration Factors (BCF). The results obtained are all less than 1 (BFC<1). However, the calculated BCF value for lead in lettuce is very close to 1 (0,98).

Table 2. Trace metallic elements in soil and vegetables.

TME	Concentration in soil (mg/kg)	Concentration in plant (mg/kg)				
		Cabbage	Tomato	Lettuce	Onion	Onion L.
As	5,79	1,42	0,59	0,87	0,87	1,09
Cd	0,39	nd	0,01	0,03	nd	nd
Cr	22,72	2,52	2,57	3,18	2,55	2,76
Ni	20,15	2,63	3,02	3,05	3,03	9,27
Pb	0,64	0,55	0,43	0,63	0,2	0,35
Zn	627,11	236,5	191,70	372,5	137,12	141,8
Hg	0,59	0,37	nd	0,18	0,16	nd

Table 3. Bioaccumulation factor values in vegetables.

TME	BCF				
	Cabbage	Tomato	Lettuce	Onion	Onion L.
As	0,24	0,10	0,15	0,15	0,18
Cd	nd	0,02	0,07	nd	nd
Cr	0,11	0,11	0,14	0,11	0,12
Ni	0,13	0,15	0,15	0,15	0,46
Pb	0,86	0,67	0,98	0,31	0,55
Zn	0,37	0,31	0,59	0,22	0,23
Hg	0,63	nd	0,29	0,27	nd

Table 4. Threshold values of metallic trace elements in vegetables.

TME	WHO standards in vegetables		
	Normal	Tolerable in crops	Toxic or excessive
As	1 - 1,7	0,2	5 - 20
Cd	0,05 - 0,2	0,05 - 0,5	5 - 30
Cr	-	-	-
Ni	-	-	-
Pb	5 - 10	0,5 - 10	30 - 300
Zn	27 - 150	50 - 100	100 - 400
Hg	nd	0,2	1 - 3

* nd: not determined.

3.1.4. Evaluation du Risque Sanitaire Lie à l'Exposition Alimentaire de la Population

(i) Identification of Risks

The analyzes of the vegetable species that we carried out made it possible to highlight 5 metallic trace elements (As, Zn, Cd, Ni and Pb) in all of the foods collected or grown in the study areas. The exceedances of edibility standards focused exclusively on metallic trace elements, in particular arsenic, cadmium, nickel, lead, zinc.

(ii) Risk Characteristic

i) Calculation of the DED and the DQ

The trace elements selected for the quantitative sanitary risk assessment are arsenic, cadmium, lead, nickel and zinc. This is because of their presence in measurable quantities in market gardening crops in the town of Daloa. Also, the availability of their Toxicological Reference Value (TRV) and their toxic effects on human health. This assessment concerns

the oral route and concerns chronic exposures only. The TRV used for this study are those derived mainly from epidemiological studies in humans, the most protective and therefore the weakest and the most recent revision years. Thus, according to the report of the National Institute of Industrial Environment and Risks [11] for threshold effects, the ATSDR [16] recommends for Cd→ $2 \cdot 10^{-4}$ mg/kg/day, As→ $3 \cdot 10^{-4}$ mg/kg/day [13], Pb→ $3.5 \cdot 10^{-3}$ mg/kg/day, Ni→ the $2 \cdot 10^{-2}$ mg/kg/day [17] and Zn→ $3 \cdot 10^{-1}$ mg/kg/day [13].

The results of the estimation of DED and DQ per ingestion of vegetables and fruits in adults were reported in Tables 5, 6, 7, 8 and 9. For tomato, onion and onion leaves the frequency of consumption is $F = 1$ while for cabbage and lettuce the frequency is $F = 3/7 = 0,43$.

a. Arsenic (As)

For As, the calculated danger quotients are all greater than 1 ($DQ \gg 1$). (Table 5). In addition, the danger quotient from consuming cabbage has the highest value.

Table 5. Daily exposure dose and danger quotient in adults for arsenic.

Vegetable species	Concentration (mg/kg)	ADD (mg/kg)	Weight (kg)	DED* 10^{-3} (mg/kg/day)	DQ
Cabbage	1,42	$3 \cdot 10^{-4}$	60	2,75	9,16
Tomato	0,59	$3 \cdot 10^{-4}$	60	1,49	4,96
Lettuce	0,86	$3 \cdot 10^{-4}$	60	0,74	2,47
Onion	0,86	$3 \cdot 10^{-4}$	60	1,44	4,80
Onion L.	1,09	$3 \cdot 10^{-4}$	60	2,01	6,7

b. Cadmium (Cd)

For Cd, the calculated Danger quotients are less than 1 ($DQ < 1$) (Table 6).

Table 6. Daily exposure dose and danger quotient in adults for cadmium.

Vegetable species	Concentration (mg/kg)	ADD (mg/kg)	Weight (kg)	DED* 10^{-3} (mg/kg/day)	DQ
Cabbage	<0,002	$2 \cdot 10^{-4}$	60	nd	nd
Tomato	0,007	$2 \cdot 10^{-4}$	60	0,01	0,08
Lettuce	0,027	$2 \cdot 10^{-4}$	60	0,02	0,11
Onion	<0,002	$2 \cdot 10^{-4}$	60	nd	nd
Onion L.	<0,002	$2 \cdot 10^{-4}$	60	nd	nd

c. Nickel (Ni)

For Ni, the calculated hazard quotients are all less than 1 ($DQ < 1$) (Table 7). However, the danger quotient of ingesting nickel by consuming onion leaves is very close to 1 ($DQ = 0,85$).

Table 7. Daily exposure dose and danger quotient in adults for nickel.

Vegetable species	Concentration (mg/kg)	ADD (mg/kg)	Weight (kg)	DED* 10^{-3} (mg/kg/day)	DQ
Cabbage	2,63	$2 \cdot 10^{-2}$	60	5,08	0,25
Tomato	3,02	$2 \cdot 10^{-2}$	60	7,56	0,37
Lettuce	3,05	$2 \cdot 10^{-2}$	60	2,62	0,13
Onion	3,03	$2 \cdot 10^{-2}$	60	5,05	0,25
Onion L.	9,27	$2 \cdot 10^{-2}$	60	16,99	0,85

d. Lead (Pb)

For Pb, the calculated DQ are all less than 1 (Table 8).

Table 8. Adult Daily Exposure Dose and Hazard Quotient for Lead.

Vegetable species	Concentration (mg/kg)	ADD (mg/kg)	Weight (kg)	DED*10 ⁻³ (mg/kg/day)	DQ
Cabbage	0,55	3,5.10 ⁻³	60	1,06	0,30
Tomato	0,43	3,5.10 ⁻³	60	1,08	0,31
Lettuce	0,63	3,5.10 ⁻³	60	0,54	0,15
Onion	0,19	3,5.10 ⁻³	60	0,33	0,09
Onion L.	0,35	3,5.10 ⁻³	60	0,65	0,18

e. Zinc (Zn)

For Zn, the calculated DQ are all greater than. Except in the onion and its leaves because DQ<1 (Table 9).

Table 9. Daily exposure dose and hazard quotient in adults for zinc.

Vegetable species	Concentration (mg/kg)	ADD (mg/kg)	Weight (kg)	DED*10 ⁻³ (mg/kg/day)	DQ
Cabbage	236,53	3 10 ⁻¹	60	0,46	1,53
Tomato	191,70	3 10 ⁻¹	60	0,48	1,6
Lettuce	372,53	3 10 ⁻¹	60	0,320	1,07
Onion	137,12	3 10 ⁻¹	60	0,23	0,76
Onion L.	141,88	3 10 ⁻¹	60	0,26	0,87

ii) Calculation of Individual Excess Risk (IER) for Effects Without Thresholds

The EIR is the basis for calculating the health impact. The Excess unit risk (EUR) for arsenic is 1,5 mg/kg/day [18]. The calculated IER values for the toxic contaminant arsenic are in the order of 10⁻³ and range from 0 to 4.10⁻³ mg²/kg² (Table 10). Maximum values were obtained in cabbage (3,05.10⁻³ mg²/kg²) and onion leaves (2,23.10⁻³ mg²/kg²).

Table 10. Excess individual risk in adults for arsenic.

Vegetable species	EUR (mg/kg/day)	T (years)	Tp (years)	DED*10 ⁻³ (mg/kg/day)	IER*10 ⁻³ (mg ² /kg ²)
Cabbage	1,5	43	58	2,75	3,05
Tomato	1,5	43	58	1,49	1,65
Lettuce	1,5	43	58	0,74	0,82
Onion	1,5	43	58	1,44	1,6
Onion L.	1,5	43	58	2,01	2,23

iii) Calculation of the Sanitary Impact (IS)

Table 11. Sanitary impact (SI) in adults for Arsenic.

Vegetable species	EIR*10 ⁻³ (mg ² /kg ²)	S (N)*10 ²	SI (N')
Cabbage	1,5	43	58
Tomato	1,5	43	58
Lettuce	1,5	43	58
Onion	1,5	43	58
Onion L.	1,5	43	58

The results of Table 11 show that the number of cancer cases likely to occur in the surveyed population is very low SI (N') <1. On the other hand, taking into account the size of the population of the city of Daloa, the number of cases of cancers likely to occur becomes significant with a maximum value which was obtained in cabbage (7,78.10²).

3.2. Discussion

3.2.1. Influence of the Pollution of Cultivable Soils on the Level of TME in Vegetables

Our study has shown that the trace elements studied are present in market garden products. However, the determined cadmium contents are practically at a trace level. The study carried out on the market gardening sites of Cocody and

Marcory in Ivory Coast [19] reports Cd contents higher than ours in plants (0,12 - 0,41 mg/kg). They are also lower than that obtained by Tankari and *col.* [20] in the Gounti yena valley in Niamey in Niger.

The average nickel concentration in the vegetables studied is 4,2 mg/kg with maximum levels (9,23 mg/kg) obtained in the onion leaves. This concentration value is lower than the Ni data obtained in vegetables in Côte d'Ivoire (11,98 - 41,69 mg/kg) and in Dhaka (4,62 - 23,68 mg/kg) in Bangladesh [21]. The average Pb concentrations detected in lettuce and Gounti yena cabbage leaves varying from 0,20 mg/kg to 0,63 mg/kg are lower than the values indicated in vegetables in Côte d'Ivoire (8,69 - 20,30 mg/kg) and India (21,59 - 57,63 mg/kg) but relatively higher than the Pb levels reported in plants (0,01 - 0,02 mg/kg) in Lagos in Nigeria [20].

The chromium concentrations obtained in tomatoes, cabbages, lettuce, onions and onion leaves are less than 3,5 mg/kg with a maximum concentration in lettuce lower than those reported in Tatigarh (34,83 - 96,30 mg/kg) in India [22].

Arsenic, which has non-threshold effects, has concentrations determined in the fruits and vegetables studied of between 0,5 and 1,5 mg/kg.

Our study found high levels of zinc in all the market garden products studied, including tomatoes, cabbage, lettuce, onion and onion leaves. Also, they are relatively superior to those obtained in plants from Lagos in Nigeria [23]. Significantly close to the Zn concentrations in vegetables (3-17 mg/kg) from Titagarh in West Bengal in India [22], and are much lower than those determined in vegetables (225,56 to 299,33 mg/kg) from Marcory and Cocody in Côte d'Ivoire [19].

The assimilation of trace elements, precisely Zn, by vegetables occurs preferentially in all study areas. This is explained on the one hand by the fact that originally the trace elements (Fe, Zn and Cu) are present in greater quantity in the earth's crust [24], and on the other hand, by their essential roles in the phenomena of growth, chemical metabolism, photosynthesis and redox. Trace elements are very important for plants which will absorb them in the soil solution unlike toxic metals (Cd, As and Pb). However, the high levels of Zn in vegetables, fruits and leaves are linked to their strong accumulation in the lowlands of the *Gbokora*, *Garage*, *Abattoir 2*, *Orly 2*, *Orly plateau* and the one in front of the city's presidential residence of Daloa. This is due to the decomposition of household, industrial and biomedical waste brought in by the city's sewage disposal systems. They only become toxic at high doses (>100 mg/kg for Zn) [25].

On the other hand, there is no bioaccumulation of zinc in the fruits and vegetables studied. We can explain it by very high concentrations of zinc in the lowlands of vegetable crops. Also, tomato, cabbage, lettuce, onion and onion leaves did not bioaccumulate the TME studied, including As, Cd, Hg, Ni, Pb and Znc.

In addition, the contents of TME accumulated in plants are at a level of concentration generally encountered in plants but the concentrations of Hg in cabbages, As and Zn in all crops would be greater than the concentration tolerated in crops therefore could present a risk of toxicity for humans [26].

On the other hand, the concentrations of Cd and Pb in the fruits and vegetables collected are lower than the tolerable dose in the crops.

3.2.2. Summary of the Risk Assessment

(i) Risk Assessment for Threshold Effects: "DQ"

The results obtained during this study for threshold effects reflect the relevance of the quantitative assessment of health risks. Indeed, for danger quotients greater than 1 ($DQ > 1$), the risk of the appearance of pathology in the population can be certain. However, for As and Zn the determined DQ are all greater than 1 which means that these vegetable crops present risks related to the ingestion of Zn and As.

Cd, Ni, Zn (onion and onion leaf) and Pb, on the other hand, have calculated danger quotients of less than 1 ($QD < 1$). Hence

the ingestion of lead and cadmium contained in these vegetable crops in the town of Daloa may give rise to concerns but the occurrence of pathologies would be unlikely.

(ii) Risk Assessment for Non-threshold Effects: EIR and SI

For a population ingesting these vegetable crops from the different sites studied, the EIR obtained are greater than 10^{-5} [9], [12], [14]. This translates to high probabilities of individual appearance of skin cancer in the population linked to the ingestion of arsenic by consuming market garden products, in particular cabbages, tomatoes, onions, onion leaves and lettuce.

In addition, the results obtained from the Sanitary Impact (SI) are all less than 1 for the population surveyed. It should be noted that these results do not reflect the absence of the possibility of the occurrence of cancer cases. On the other hand, for the estimated population of the city of Daloa this result is greater than 1. This is due to the size of the population considered.

These different results within the same population justify the relevance of the debates regarding the use of the health impact in the Quantitative Assessment of Sanitary Risks (ASR). Some experts claim that the risks calculated in a human health risk assessment are not based on the size of the exposed population. This is the reason why thresholds of acceptable risks are defined, in particular by the US-EPA. This legitimate desire to set equivalent acceptability thresholds whatever the exposed population makes it possible to demand the same level of risk whatever the situation. For others, on the other hand, from a scientific point of view, all available data should be taken into account, and not just the threshold of acceptability.

4. Conclusion

At the end of this study, it emerges that the soils of market gardening in the city of Daloa are enriched in trace metallic element (TME) such as As, Hg, Cr, Ni, Zn, Pb and Cd contained in the waste that are dumped there. We will therefore remember that anthropogenic activities strongly contribute to the pollution of the environmental environments of the city of Daloa. In addition, the analysis of the foods consumed (cabbage, lettuce, tomato, onions and onion leaves) enabled us to observe metal pollution in these study sites. In particular, arsenic, chromium, mercury, nickel, lead and zinc have been found. However, there is no bioaccumulation of these TME studied in market garden products. On the other hand, we note the presence of arsenic, mercury and zinc above the levels tolerated in plants. In addition, the consumption of these market garden products could constitute dangers for the population due to the ingestion of arsenic and zinc. Also, there is a high probability of occurrence of skin cancer cases in the population of the city of Daloa which translates into numbers of cases greater than 1.

The study of risk analysis is an essential tool in the fight against all pathologies because it makes it possible to highlight the long-term dangers of a situation that is difficult

to control. Our work has made it possible to carry out the risk assessment, one of the three fundamental phases of risk analysis; the other two, namely management and communication with the public, must be pursued in order to help decision-makers understand the risks associated with TME and adopt ecological behavior in their decision-making. Likewise, repeated pollution awareness campaigns are essential in order to draw the population's attention to the dangers of these TME.

As a research perspective, it is important to understand the mechanisms of plant exposure by soil type and the speciation of contaminants in products that contribute to human exposure to a hazard. Many questions remain unanswered. What are the effects of toxic metals on the physiology and development of plants? How does a toxic element reach its molecular target? One of the answers is the knowledge of the multiple physicochemical (speciation) forms of heavy metals.

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