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Nutrient and Heavy Metal Content of Three Leafy Vegetables (Talinum fructicosum (L.) Juss., Vernonia amygdalina Delile, Solanum macrocarpon L.) from an Effluent-Receiving Wetland in the Douala Bassa Industrial Development Zone, Cameroon: Implications for

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Objective: Contamination by heavy metals in soil, water, and agricultural products is a significant concern, particularly affecting wetland ecosystems. This investigation aimed to assess the levels of heavy metals (Pb, Cd, Hg, Cu, As, Zn, and Ni) and nutritional values in three highly cultivated leafy vegetables *(Talinum fructicosum (L.) Juss., Vernonia amygdalina Delile, Solanum macrocarpon L.)* collected from a polluted coastal wetland. Additionally, we evaluated the potential health hazards for both adults and children."

Methods: The mature and young leaves with succulent stems were collected during the dry and rainy seasons, transported to the laboratory, processed and then analysed for nutritional contents according to standard methods, and heavy metals was measured with atomic Absorption Spectrophotometer.

Results: The three leafy vegetables were found to be low in fat (0.85±2.19%), protein (3.01±9.06%), ash (0.68±5.03%), and carbohydrates (1.34±4.54%). During both seasons, the Cd (0.45±2.49%), Cu (208.34-927.41%), and Zn (29.39±3554.5%) content in leafy vegetables was extremely high, surpassing the WHO/FAO safe limits. The Hazard Index (HI) values were all greater than (>) one (1) for both adults (32.259±67.31) and children (67.310±489.89). Total carcinogenic health risk (TCR) values for Pb, Cd, and AS due to consumption of the three vegetables for adult (0.008±0.052) and children (0.018±0.109) also exceeded the maximum threshold value of 10−4. From our findings, inhabitants who consume these contaminated vegetables are exposed chronically to metal pollution with carcinogenic and non-carcinogenic risks.

Conclusion: In the light of these finding, policies and regulations should be reinforced regarding the discharge of untreated effluents into the environment and the prohibition of the growing of leafy vegetables should be strengthened.

Introduction

Over the past century, there has been rapid industrial development and urbanization, which has led to an increase in heavy metals in water and soils. Water and sediment contaminated with heavy metals constitute a major environmental problem around the world [1]. Heavy metal contamination of farmland is an even greater problem [2, 3]. The air and soil, from which metals are absorbed by the roots or foliage, are the primary sources of trace metals for plants. A few of the trace metals are vital for plant nourishment, but in a polluted environment, plants can bioaccumulate higher than essential amounts of trace elements that pose a major health risk to people if consumed [4, 5].

Plants have an inherent tendency to absorb harmful compounds, such as heavy metals, which are then passed up the food chain [6]. Vegetables are an important part of the human diet because they contain significant levels of micronutrients that are essential for human health [7, 8]. Vegetables come in a variety of forms; some are edible roots, stems, leaves, fruits, or seeds. Each group makes a unique contribution to human diets worldwide. It has been shown that vegetables grown in soils contaminated with toxic metals from industrial activities absorb these metals and bioaccumulate them in both edible and non-edible parts of the plant in amounts that can cause clinical problems for both humans and animals that consume these metal-rich plants because there is no effective mechanism for their elimination from the human body [9, 10]. In addition, heavy metals are nonbiodegradable, have long biological half-lives, have a high potential to accumulate in different human body parts [11].

Compared to vegetables cultivated in uncontaminated soils, leafy vegetables have been shown to bioaccumulate more metals when grown in heavy metal-contaminated soils [12]. This affects the food value of these vegetables. This is especially significant because the current emphasis on healthy living involves the consumption of nutritive fruits and vegetables as a first line of defence against diseases; nutrients from fruits and vegetables have been shown to be effective in treating some metabolic disorders [13, 14]. Furthermore, because they are a vital source of nutrients for humans, vegetables aid in the fight against malnutrition and food insecurity [15, 16]. When it comes to leafy vegetables, they are easier to collect in the edible sections than in grain or fruit harvests [11]. In most African countries, vegetable production year-round is ensured by cultivation on the banks of wetlands. Wetland soils are rich in water, eliminating the need for off-season irrigation. In Cameroon especially, the average farmers who provide over 90% of the arable crops, fruits and vegetables to our urban and peri-urban populace cannot afford irrigation facilities. Therefore, they mainly produce these vegetables along the banks of wetlands, called ‘lamba’ in the local parlance. At the same time, wetlands in urban and peri-urban areas have been shown to be recipients of most domestic and industrial effluent [17]. In poorly regulated areas, they are basically treated as wastelands. This poses the question of how safe the vegetables animating our urban markets are for human consumption. The present study was carried out on wetlands around the Douala-Bassa Industrial Zone (Douala-Bassa IDZ) in Cameroon, where discharges of effluents, waste dumping and irrigation of vegetable crops with polluted wetland water are common practices [18]. Assessment of potential contamination of vegetables with heavy metals from this industrial zone would shed light on safety of horticulture in urban and peri-urban wetlands worldwide. In this context, the present study was undertaken to investigate the concentration of heavy metals (Pb, Cd, Cu, Zn, Ni, Hg and As) and nutrient composition (moisture, fibers, fat, Proteins, ash and carbohydrates) in commonly grown edible portions of vegetables.

Materials and Methods

Study area

Sampling of leafy vegetables for metal levels and nutrient composition was carried out across two (2) seasons (January/February 2022 for the dry season and July/August 2022 for the raining season). The different tributaries that make up a stream and the associated wetland are located in Douala, Littoral Region of Cameroon, between latitudes 5° 44’ 30” to 5° 48’ 30” N and longitudes 10° 52’ 0” to 10° 54’ 30”E. The climate is tropical monsoonal type, wet and hot, characterized by two seasons: one rainy season from mid-March to mid-November and one dry season from mid-November to mid-March, with temperatures between 18 °C and 34 °C, accompanied by heavy precipitation, especially during the rainy season.

The two studied sites where vegetable sampling was done, are sites of different watersheds directly located at about 400 and 150 meters respectively, downstream of the industrial areas. Anthropogenic activities and land uses such as sand mining, waste dumping, and urban housing can be observed. Moreso, they receive effluents from the beer production industry and many other industries that are located not too far from these points (Figure 1).

Figure 1. Map Showing the Study Area.

Vegetables Sampling and Processing

Sample selection

Three (3) of the top highly cultivated leafy vegetables were randomly collected from each site. Plant parts collected included mature and young leaves in replicates of 5 samples per species from 5 different plants of each species during both the dry and rainy seasons. Samples were washed thoroughly with water, placed in polybags and transported to the Life Sciences Laboratory of the University of Buea. Table 1 presents the species sampled from each of the study sites.

Plant species	Family	Common name	Part analysed	Part analysed
			For heavy metals	For nutrients
Talinum fructicosum (L.) Juss.	Talinaceae	Water leaf	Leaves	Leaves
Vernonia amygdalina Delile	Asteraceae		Leaves	Leaves
Solanum macrocarpon L.	Solanaceae	Anchia	Leaves	Leaves

Table 1. Description of Leafy Vegetables Examined for Heavy Metal Concentration.

Sample preparation for Nutrient analysis

For nutritive parameters, mature leaves were collected from plants at sites along the banks of the water course, as described in Sections 2.1 and 2.2.1 above. Five samples of each species were collected from five different plants, making a total of fifteen (15) plant samples. They were placed in sterile packs and transported to the Life Science Laboratory of the University of Buea, where they were washed, drained, oven dried at 50 ^{0}C till constant weight, then later ground. Samples of each species were then homogenized and subsampled into two samples per species for analysis.

Moisture, protein, fat and ash contents were analysed according to the standard methods [19] and crude fibre content was determined according to the method described by [20] while Carbohydrates were determined by subtracting the sum of the percent of protein, moisture, fat, crude fibre and ash from 100% as described by [21].

Sample collection preparation for Heavy metal analysis

The fresh, matured, and young leaves of the vegetables presented in Table 1 (*Solanum macrocarpon, Vernonia amygdalina, and Talinum fructicosum*) were collected in replicates of 5 samples per species from different plants, during both the dry and rainy seasons. The samples were cleaned of debris, washed under slow-running tap water, and then rinsed with distilled water. They were then placed in sterile packs and transported to the laboratory of the Life Sciences University of Buea.

In the lab, samples were oven-dried at 65 ˚C to a constant mass, milled to a fine powder using a blender, and packaged in Ziplock bags until analysis. Two grams of each plant sample were digested with concentrated nitric acid and hydrochloric acid in a ratio of 3:1 until a transparent solution was obtained. An atomic absorption spectrophotometer, the Rayleigh 130B series, was used for the analysis of cadmium, lead, copper, zinc, arsenic, mercury, and nickel concentrations in the samples.

Health risk assessment, Non-cancer risks

Estimated Daily Intake (EDI)

The USEPA model [22, 23] was used to estimate the health risks associated with heavy metal consumption through the leafy vegetable samples. In order to evaluate the potential health risks associated with heavy metals, the estimated daily intake (EDI) was computed using Equation 1 [24]:

$EDI = (Chm \times IR \times EF \times ED)/(ET \times BW)$……. Equation 1

where: chm – mean concentrations of heavy metals in plant samples (mg/kg); IR – daily consumption of leafy plants for adults and children is 2.44E-01 and 1.86E-01 kg/person/ day, respectively (Liu et al. 2021); EF – exposure frequency (365 days/year); ED – exposure duration for adults 30 years, and for children 7 years; ET – exposure time is calculated as 365 × ED; BW – body weight (70 kg for adults and 26 kg for children) [25].

Target Hazard Quotient (THQ)

The target hazard quotient (THQ) was used to assess the non-carcinogenic risk for individual heavy metal caused by consuming leafy vegetables contaminated by heavy metals [26]

$THQ = EDI/RfD$………Equation 2

EDI is the estimated daily heavy metal intake (mg/kg/day) obtained from the previous section and Rf D is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure, taking into consideration a sensitive group during a lifetime [23]. EPA-recommended Rf D values of Hg, Cu, Zn, Ni, As, Cd, and Pb were used in the above equation.

Hazard Index (HI)

The chronic Hazard Index (HI) is used to evaluate the potential risk that various heavy metals bring to human health. It is the sum of all the hazard quotients (THQ) found for each heavy metal for a certain exposure pathway [27].

The following formula was used to calculate the Hazard Index:

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where 1, 2, ..., n are the individual heavy metals or vegetable.

Cancer risks

The Cancer Risk Index (CRI) was calculated by multiplying the estimated daily intake by the oral cancer slope factor (CSF) for corresponding heavy metals (Table 2).

Heavy metal	CSF (mg/kg/day)
Pb	8.50E-03
As	3.66
Ni	0.84
Cd	0.38

Table 2. Cancer Slope Factor Value for Pb, As, Ni and Cd Defined by [23].

As described by Li et al. (2021), the potential for cancer risks associated with consumption of carcinogenic heavy metals in the examined vegetables were calculated following equation 2.

$CRI = EDI \times CSF$.................. Equation 4

Where EDI is the estimated daily intake of metal via consumption of vegetable and CSF the cancer slope factor (CSF), which is the risk produced by a lifetime average dose of 1 mg/kg BW/day and is contaminant specific [28]. The cumulative cancer risk (TCRI) is as assessed from exposure to numerous carcinogenic heavy metals through consumption of a specific variety of vegetable. This risk was assumed to be the sum of the individual heavy metal increment risks. Equation 5 was used for calculation of the TCRI [29]:

Data Analysis

Data obtained were analyzed using R software version 4.1.2 and Microsoft Excel and results were expressed as mean ± standard deviation. P-value < 0.05 was considered significant.

Results and Discussion

Leafy vegetables in the Douala Bassa IDZ are heavily contaminated with Heavy Metals

Findings revealed that vegetables from wetlands in the Douala Bassa IDZ are heavily contaminated with lead, zinc, mercury, copper, and cadmium (Table 3).

Leafy vegetables	Seasons			Heavy metals (mg/kg)				
		Pb	Zn	Hg	Cu	Ni	Cd	As
Vernonia amygdalina	Dry	0.13	3554.5	0.16	332.51	0	2.49	0.02
	rainy	0.34	1792.7	0.3	489.99	0	0.75	0.03

Talinum fructicosum	Dry	0.26	47.82	5.5	508.34	0	0.38	0.05
	rainy	0.47	1335.8	0.18	927.41	0	1.58	0.03
Solanum macrocarpon L.	Dry	0.21	29.39	0.34	208.34	0	0.45	0.06
	rainy	0.36	1122.9	0.06	752.44	0	2.09	0.03
WHO/FAO safe limit in vegetables		0.3	99.4	0.03	73.3	67.9	0.2	0.1

Table 3. Seasonal Concentrations of Heavy Metals in Vernonia Amygdalina, Talinum. fructicosum and Solanum macrocarpon from the effluent receiving wetland around the Douala-Bassa Industrial Zone.

The highest Pb concentration in vegetables obtained from effluent receiving wetland during the dry season was recorded in *T. fructicosum* (0.26 mg/kg) and the least in *V. amygdalina* (0.13 mg/kg). During the rainy season, the highest value was recorded in *T. fructicosum* (0.47 mg/kg) and the least in Solanum macrocarpon (0.36 mg/kg). All concentrations of Pb in the three vegetables during the rainy season were higher than the permissible levels by FAO/WHO in vegetables of 0.3 mg/kg. The high levels of lead in these vegetables' samples may probably be attributed to pollutants in irrigation water, or pollution from highways traffic and industrial sites located around the sample sites [30, 31]. Lead is a highly toxic heavy metal that can affect the kidney, liver, vascular system, and immune system when consumed [32]. Consuming vegetables harvested during the rainy season from this area can also have negative neurological and psychiatric effects, such as suicidal thoughts brought on by depression, inattention, impaired motor and visual intelligence, memory loss, learning difficulties, exhaustion, restlessness, aggression, psychoses, hallucinations, peripheral polyneuropathy, encephalopathy, and lead poisoning [33].

Zinc is an essential nutrient for human health. Zinc is used in preventive trials and the treatment of diarrhea, pneumonia, the common cold, respiratory infections, and malaria. Sufficient zinc is essential for maintaining immune system function. The level of Zn in the studied vegetables from the polluted wetland ranged between 29.39 mg/kg and 3554.5 mg/kg, with the highest recorded in *V. amygdalina* and the least in *T. fructicosum* during the dry season. In the rainy season, the range was from 1792.7 mg/kg to 1122.9 mg/kg, with the highest recorded in *V. amygdalina* and the least in S. macrocarpon. All concentrations of Zn obtained in this study except those of *T. fructicosum* and *S. macrocarpon* during the dry season exceeded the permissible levels set by FAO/ WHO in vegetables of 99.4 mg/kg. Consumption of vegetables from this site could cause nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, headaches, and inhibition of copper absorption, which sometimes produce copper deficiency and associated anaemia [34].

Mercury (Hg) concentration ranged from 0.16 mg/kg in *Vernonia amygdalina* to 505 mg/kg in *Talinum fructicosum* during the dry season and from 0.06 mg/kg in Solanum macrocarpon to 0.3 mg/kg in *Vernonia amygdalina* during the rainy season, with the total concentration of mercury higher in the dry season than in the rainy season. All concentrations of Hg obtained in this study were above the permissible levels by FAO/WHO in vegetables of 0.03 mg/kg, with a very high concentration obtained in *Talinum fructicosum* in the dry season.

In addition to being necessary for iron-dependent bodily pigmentation, copper is a vital element that also keeps the central nervous system healthy, avoids anemia, and is linked to the body's processes involving zinc and iron [35]. In excess, copper in the body can be the origin of organic diseases such as gastroenteritis with nausea and intestinal irritations [31, 36]. The Cu level in vegetables from the wetland in the current study ranged between 208.34 mg/kg in Solanum macrocarpon and 508.34 mg/kg in *Talinum fructicosum* during the dry season and from 489.99 mg/kg in *Vernonia amygdalina* to 927.41 mg/kg in *T. fructicosum* during the rainy season. The Cu level in vegetables from the wetland in the current study ranged between 208.34 mg/kg in *S. macrocarpon* and 508.34 mg/kg in *T. fructicosum* during the dry season and from 489.99 mg/kg in

Vernonia amygdalina to 927.41 mg/kg in *T. fructicosum* during the rainy season. The Cu levels in the vegetables presented in this study were all higher than WHO/FAO safe limits of 73.3 mg/kg, with the Cu level concentrations higher during the rainy season than in the dry season. The elevated concentrations of copper in plant tissue reflect man-made pollution [37].

Cadmium is a non-essential element in foods. High concentrations of cadmium cause severe diseases such as tubular growth, kidney damage, cancer, diarrhea, and incurable vomiting [38]. The level of cadmium in leafy vegetables ranges from 0.38 mg/kg in *T. fructicosum* to 2.49 mg/kg in *V. amygdalina* during the dry season and from 0.75 mg/kg in *Vernonia amygdalina* to 2.09 mg/kg in *S. macrocarpon* during the rainy season. The concentration of cadmium was higher during the rainy season than the dry season, except in S. macrocarpon, which was vice versa.

Nutrients

The nutritional content of *Talinum fructicosum* (L.) Juss., *Vernonia amygdalina* Delile and Solanum macrocarpon L. for both the dry and rainy seasons is shown in Figure 2.

Figure 2. Nutrient Content of Selected Leafy Vegetables During the Dry and Rainy Seasons. Comparison between nutrients content of the dry and rainy seasons for the same plant, the peaks bearing: **(P<0.01) are strongly significant and *(P<0.001) are extremely significant.**

The moisture content of the leafy vegetables ranged from 72.02±0.19% in *Vernonia amygdalina* to 78.96±0.52% in *T. fructicosum* during the dry season, and from 82.10±0.21% in *V. amygdalina* to 90.01±0.60% in *T. fructicosum* during the rainy season. These vegetables require proper care for preservation due to their susceptibility to deterioration, as seen by their relatively high moisture contents, particularly in the case of *T. fructicosum* [39]. The moisture content of all the leafy vegetables was lower in the dry season compared to the rainy season. The weight in the rainy season is higher than that in the dry season, and the increase in rainfall promotes the accumulation of fresh weight in roots, stems, and leaves [40]. Higher moisture content may mobilize water-soluble enzymes and co-enzymes that are involved in metabolic processes in these leafy vegetables [41].

The crude fibre content ranged from 8.83±0.46% in *Talinum fructicosum* to 16.43±3.19% in *Vernonia amygdalina* during the dry season, and from 4.19±0.22% in *Talinum fructicosum* to 10.51±2.04% in *Vernonia amygdalina* during the rainy season. This is similar to values reported for other vegetables [42]. The fibre content of each of the leafy vegetables were lower in the rainy season compared to dry season. The high crude fibre content in these vegetables may be employed in the management of diabetes, obesity, colon cancer and gastrointestinal disorders [43].

The fat content was lower in *Talinum fructicosum* (1.79±0.35%) and higher in *S. macrocarpon* (2.19±0.0%3) during the dry season and lower in *Talinum fructicosum* (0.85±0.17%) and higher in *V. amygdalina* (1.38±0.07%) during the rainy season. These values show that these leafy vegetables are poor sources of fat. This confirmed the findings of many authors who have shown that leafy vegetables are poor sources of lipid [44-46]. Nevertheless, a diet that provides 1-2% of a person’s caloric energy as fat is considered sufficient for them, as consuming too much fat can cause aging, cancer, and cardiovascular diseases [47]. Therefore, the lipid content in these vegetables is sufficient for their nutritional and nutraceutical properties, which probably explains their use in the local cuisine [48]. The protein content in the leafy vegetables during the dry season varied from 6.34 ±0.01% in *Talinum fructicosum* to 9.06 ±1.21% in Solanum macrocarpon and from 3.01±0.01% in *Talinum fructicosum* to 5.24±0.70% in Solanum macrocarpon during the rainy season. Fresh leafy vegetables have a low protein content during the rainy season. The leaves of Solanum macrocarpon and *Vernonia amygdalina* appear to be better sources of dietary protein than Talinum fructicosum.

The ash content during the dry season ranged from 1.06% in *Vernonia amygdalina* to 5.03% in Talinum fructicosum, and from 0.68% in *Vernonia amygdalina* to 2.39% in *Talinum fructicosum* during the rainy season.

[49] have reported a very high ash content in *Talinum fructicosum* (12.2%), which is higher when compared to that of the sample analyzed in this work. The ash content in *Vernonia amygdalina* is very low, which is similar to that of [50] who reported a low ash content in Vernonia amygdalina. The ash content was higher in the dry season compared to the rainy season in all the species. These values indicate that these leafy vegetables may be considered good sources of minerals when compared to values obtained by [48].

The carbohydrate content in the leafy vegetables during the dry season was lower in *Talinum fructicosum* (2.82 ±0.16%) and higher in *Vernonia amygdalina* (4.54 ±0.18%)., During the rainy season, the pattern was reversed (1.34±0.08% in waterleaf and 2.90±0.11% in bitterleaf). The seasonal trend in carbohydrate concentration during both seasons was consistent with findings by [51] that low carbohydrate contents are a common phenomenon with leafy vegetables in Africa. Low-carbohydrate diets have beneficial effects on weight loss and cardiovascular risk factors [52], which could explain why these vegetables form a central part of African cuisine.

Health risk assessment

Estimated Daily Intake of heavy metals. The EDI is used to calculate how heavy metals in leafy plants affect the health of adults and children. Table 5 lists the EDI of heavy metals that are both carcinogenic and non-carcinogenic for adults and children (Table 4).

	EDI (mg/kg) for adult						
Leafy vegetables	Seasons	Zn	Pb	Hg	Cu	Cd	As
Vernonia amygdalina Delile	Dry	12.18	4.46×10^{-5}	5.49×10^{-5}	1.1	0.008	6.86×10^{-5}
	rainy	6.14	1.17×10^{-4}	1.03×10^{-4}	1.68	0.002	1.02×10^{-5}
Talinum fructicosum (L.) Juss.	Dry	0.16	8.91×10^{-4}	1.89×10^{-3}	1.74	0.001	1.71×10^{-5}
	rainy	4.57	1.61×10^{-4}	6.17×10^{-5}	3.18	0.005	1.03×10^{-5}
Solanum. macrocarpon L.	Dry	0.1	7.20×10^{-5}	1.17×10^{-4}	0.71	0.001	2.06×10^{-5}
	rainy	3.85	1.23×10^{-4}	2.06×10^{-5}	2.52	0.007	1.03×10^{-5}
Total daily intake from vegetables (mg/day)		27	0.001	0.002	10.93	0.024	0.0001
EDI (mg/kg) for Children							
Vernonia amygdalina Delile	Dry	25.43	9.30×10^{-5}	1.15×10^{-4}	2.38	0.018	1.43×10^{-5}
	rainy	12.82	2.43×10^{-4}	2.15×10^{-4}	3.5	0.005	2.15×10^{-5}
Talinum fructicosum (L.) Juss.	Dry	0.34	1.86×10^{-4}	3.93×10^{-3}	3.64	0.003	3.58×10^{-5}
	rainy	9.56	3.36×10^{-4}	1.29×10^{-4}	6.63	0.011	2.15×10^{-5}
Solanum. macrocarpon L.	Dry	0.21	1.50×10^{-4}	2.43×10^{-4}	1.49	0.003	4.29×10^{-5}

	rainy	8.03	2.58×10^{-4}	4.29×10^{-5}	5.38	0.015	2.15×10^{-5}
Total daily intake from vegetables (mg/day)		56.39	0.0013	0.005	23.02	0.055	0.0001
Maximum Tolerable Daily Intake (MTDI) (mg/day)		60 - 65	0.21	0.04	2.5 - 3	0.02–0.07	0.13

Table 4. Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) Values of Heavy Metals Seasonally Via Consumption of Leafy Vegetable for Adults and Children.

The results for Cd, Cu, and Hg were above the Rf D value in all plants for adults and children during both the dry and rainy seasons. The intake of Ni and Pb for adults and children during both seasons from the consumption of studied plants was below the Rf D limit (USEPA 2012). A higher intake of As and Zn during the dry season from the consumption of *T. fructicosum* and *S. macrocarpon* was found for both children and adults, whereas a higher intake of Zn was found for *T. fructicosum* and *S. macrocarpon* during the dry season and plants. Therefore, the health risk of heavy metals through the consumption of leafy plants could be a great concern for the local population.

Non-carcinogenic health risk (THQ) and HI were much higher than the reference values and indicated significant health risks for both adults and children.

The non-carcinogenic health risk (THQ) of the heavy metals examined through leafy plant consumption for both adults and children who live in the study area is shown in Table 5.

Leafy vegetables	Seasons	Zn	Pb	Hg	Cu	Cd	As	HI = ∑THQ
			Adults					
Vernonia amygdalina Delile	Dry	40.62	0.11	5.48	28.5	8.54	0.23	83.49
	rainy	20.49	0.29	10.29	42	2.57	0.34	75.98
Talinum fructicosum (L.) Juss.	Dry	0.55	0.22	188.57	43.57	1.3	0.57	234.8
	rainy	15.27	0.4	6.17	79.49	5.42	0.34	107.09
Solanum. macrocarpon L.	Dry	0.34	0.18	11.66	17.86	1.54	0.69	32.26
	rainy	12.83	0.31	2.06	64.49	7.17	0.34	87.2
Children								
Vernonia amygdalina Delile	Dry	84.76	0.23	11.45	59.47	17.81	0.48	174.2
	rainy	42.75	0.61	21.46	87.63	5.36	0.71	158.53
Talinum fructicosum (L.) Juss.	Dry	1.14	0.46	393.46	90.91	2.72	1.19	489.89
	rainy	31.85	0.84	12.88	165.86	11.3	0.71	223.45
Solanum. macrocarpon L.	Dry	0.7	0.38	24.32	37.26	3.22	1.43	67.31
	rainy	26.78	0.64	4.29	134.57	14.95	0.71	181.95

Table 5. Target Hazard Quotient (THQ) and Hazard Index (HI) for Adults and Children Exposed to Vegetables from Sites within the Douala Bassa IDZ.

If the calculated THQ value is < 1, indicates the consumption of the vegetables is presumed safe. If the calculated THQ > 1, indicates the potential health risk due to the consumption of the products with increasing probability as the consumption increases [29,53]; [31]. The calculated HI is compared to standard levels: the population is assumed to be safe when HI < 1 and in a level of concern when 1 < HI < 5 [22].

The target hazard quotient (THQ) of Zn was within the ranges of 0.34 to 40.623 mg/kg and 12.83 to 20.49 mg/kg during the dry and rainy seasons, respectively, for adults, with the highest values recorded in *Vernonia amygdalina* (40.62 mg/kg and 20.49 mg/kg during the dry season and the rainy season, respectively). For children, it ranged from 5.36 to 14.95 mg/kg during the dry season and 26.78 to 42.75 mg/kg during the rainy season. The highest values were recorded in *Vernonia amygdalina* (84.76 mg/kg and 42.75 mg/kg for the dry and rainy seasons, respectively). The THQ of lead for adults ranged from 0.11 to 0.22 mg/kg during the dry season and from 0.29 to 0.40 mg/kg during the rainy season, with the highest values recorded in *T. fructicosum* (0.22 mg/kg and 0.40 mg/kg for the dry and rainy seasons, respectively). In children, THQ ranged from 0.23 to 0.46 mg/kg and 0.61 to 0.84 mg/kg during the dry and rainy seasons, respectively, with the highest THQ obtained in *T. fructicosum* (0.46 mg/kg and 0.84 mg/kg during the dry and rainy seasons, respectively).

In mercury, THQ ranged between 5.49 and 188.57 mg/kg during the dry season and between 2.06 and 10.29 mg/kg during the rainy season. The highest THQ of Hg for adults was observed in *Talinum fructicosum* (188.57 mg/kg during the dry season) and in *V. amygdalina* (10.29 mg/kg during the rainy season). In children, Hg-related THQ ranged from 11.45 to 393.46 mg/kg and 4.29 to 21.46 mg/kg during the dry and rainy seasons, respectively, with the highest THQ obtained in *T. fructicosum* (393.46 mg/kg) during the dry season and in *V. amygdalina* (21.46 mg/kg) during the rainy season. The THQ of copper for adults was within the range of 17.86 to 43.57 mg/kg during the dry season and between 42.0 and 79.49 mg/kg during the rainy season, and the highest target hazard quotient was observed in *Talinum fructicosum* (84.76 mg/kg and 26.78 mg/kg) during both the dry and rainy seasons, respectively. In children, the THQ ranged between 37.26 and 90.92 mg/kg and 87.63 and 165.86 mg/kg during the dry and rainy seasons, respectively, with the highest THQ recorded in *T. fructicosum* (90.91 mg/kg during the dry season and 165.86 mg/kg during the rainy season).

The THQ value of Cd ranged between 1.30 and 8.54 mg/kg for the dry season and 2.57 and 7.17 mg/kg during the rainy season for adults. In children, it was in the range of 2.72–17.81 mg/kg and 5.36–14.95 mg/kg for the dry and rainy seasons, respectively. *V. amygdalina* and *S. macrocarpon* recorded the highest THQ during the dry and rainy seasons, respectively, for both adults and children.

The target hazard quotient (THQ) of As for adults was within the range of 0.23 to 0.69 mg/kg during the dry season, while during the rainy season all the vegetables recorded 0.343 mg/kg, with the highest values recorded in *S. macrocarpon* (0.69 mg/kg) and *Vernonia amygdalina* (0.34 mg/kg) during the dry and rainy seasons, respectively. For children, it ranged from 0.48 to 1.43 mg/kg during the dry season, while during the rainy season, all three vegetables recorded 0.715 mg/kg, with the highest values recorded *S. macrocarpon* at 1.43 mg/kg during the dry season and 0.71 mg/kg for *S. macrocarpon* and T. fructicosum, both recording the same concentration during the rainy season.

The THQ value is a complex parameter used for the estimation of potential health risks associated with long-term exposure to chemical pollutants [54]. From the results in the present study for both

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adults and children, the THQ of Pb and Cd in *Talinum fructicosum* and *S. macrocarpon* for both adults and children during the dry and rainy seasons were less than 1, except in *T. fructicosum* and *S. macrocarpon* during the dry season (1.192 mg/kg and 1.43 mg/kg, respectively), which were greater than 1. Children consuming *T. fructicosum* and *S. macrocarpon* harvested from the study site during the dry season may be at risk of either lead or cadmium toxicity. The THQ of Zn, Cu, Hg, and Cd in *T. fructicosum* and *S. macrocarpon* for both adults and children during both the dry and rainy seasons were all greater than 1, which indicates a level of concern that the population may be at risk of either Cu, Hg, or Cd toxicity.

On the other hand, the results of HI in adults and children in both the dry and rainy seasons were in the range of 32.26 to 234.80 mg/kg and 75.978 to 107.09 mg/kg for adults during the dry and rainy seasons, respectively. While for children, they were in the range of 67.31 to 489.89 mg/kg in the dry season and 158.53 to 223.45 mg/kg during the rainy season. The highest HI value in adults during the dry and rainy seasons was recorded in *Talinum fructicosum* (234.79 mg/kg and 107.09 mg/kg, respectively), whereas the highest HI value in children was recorded in *Talinum fructicosum* during both seasons (489.89 mg/kg and 223.45 mg/kg for the dry and rainy seasons, respectively) (Table 6).

	Adult				
Leafy vegetables	Seasons	Pb	Cd	As	TCRI
Vernonia. Amygdalina Delile	Dry	3.79×10^{-6}	0.052	2.51×10^{-5}	0.052
	rainy	9.91×10^{-6}	0.016	3.76×10^{-5}	0.016
Talinum fructicosum (L.) Juss.	Dry	7.58×10^{-6}	0.008	6.27×10^{-5}	0.008
	rainy	1.37×10^{-5}	0.033	3.76×10^{-5}	0.033
Solanum. macrocarpon L.	Dry	0.61×10^{-5}	0.009	7.53×10^{-5}	0.01
	rainy	1.05×10^{-5}	0.044	3.76×10^{-5}	0.044
Children					
Leafy vegetables	Seasons	Pb	Cd	As	TCRI
Vernonia. Amygdalina Delile	Dry	7.91×10^{-6}	0.109	5.24×10^{-5}	0.109
	rainy	2.07×10^{-5}	0.032	7.85×10^{-5}	0.033
Talinum fructicosum (L.) Juss.	Dry	1.58×10^{-5}	0.016	13.09×10^{-5}	0.018
	rainy	2.86×10^{-5}	0.069	7.85×10^{-5}	0.07
Solanum. macrocarpon L.	Dry	1.28×10^{-5}	0.02	15.71×10^{-5}	0.021
	rainy	2.19×10^{-5}	0.091	7.85×10^{-5}	0.092

Table 6. CRI and Cumulative Cancer Risks (TCRI) for the Adult and Children's Inhabitants of the Study area Through Consumption of Leafy Vegetables.

Cancer Risk Index below 10-4(0.001) indicates no cancer risks exist from consumption of these vegetables (MEPPRC. Technical guidelines for risk assessment of contaminated sites. China Environmental Science Press: Beijing: China, 2014; USEPA Regional Screening Levels (RSLs). Online: Available at

The hazard index shows when a population is at risk. From the results in the present study for both adults and children, it was observed that the HI values for all the samples under study were greater than (>) 1, which indicates that there is a high risk of disease associated with consuming vegetables harvested from the studied wetlands in the Douala Bassa IDZ, consistent with findings by Pazaljia et al. (2023).

Carcinogenic health risk from consumption of leafy vegetables from the study sites is significant

The results on cancer risks for Pb, Ni, As, and Cd are presented in Table 6. The cancer risk for adults and children varied from minimum values of 3.79×10^{-6} and 7.91×10^{-6}, respectively, for Pb during the dry season and from 9.91×10^{-6} to 1.37×10^{-5} in *V. amygdalina* and *T. fructicosum* during the rainy season. Calculated cancer risks from consumption of As ranged from 0.008 to 0.109 in *T. fructicosum* and V. amygdalina, respectively, during the dry season, and from 0.016 to 0.091 in *V. amygdalina* and *S. macrocarpon* during the rainy season, respectively. Compared to the other three metals (Pb and As), Cd appeared to be the most dangerous contaminant, followed by As and Pb.

Table shows the TCRI values calculated to assess the total carcinogenic health risk of heavy metals from the consumption of leafy vegetables cultivated along the effluent-receiving wetland around the Douala Bassa IDZ. For adults, TCRI ranged from 0.008 to 0.052 during the dry season and from 0.016 to 0.044 during the rainy season, while for children, it ranged from 0.018 to 0.109 and from 0.033 to 0.092 for the dry and rainy seasons, respectively. *V. amygdalina* had the highest values, while *T. fructicosum* had the lowest values.

The cancer risks of cadmium was above the threshold range of 1×10^{-4} [23], which may lead to the development of cancers related Cadmium for consumers of Talinum. fructicosum, Solanum macrocarpon, *Vernonia amygdalina* in both adults and children.

All the cancer risk values for lead and arsenic were below the 1×10^{-4} threshold, which shows that the consumption of Talinum. fructicosum, Solanum macrocarpon, and *Vernonia amygdalina* from the studied wetland does not present any risk of developing a lead-related or arsenic-related cancer.

High TCRI values for analysed samples from the polluted wetlands indicated that the local population consuming leafy plants from this area is exposed to a significantly increased carcinogenic risk.

Many scientists have reported cancer risk due to vegetables consumption from polluted environment due to urbanization and industrialization. The Douala region of Cameroon which is densely populated, has experienced rapid urbanization and industrialization in recent years leading to Metal contamination of soil and translocation in vegetables [55]. More even, [56] reported that heavy metal contamination form urbanization and industrialization may cause serious hazard problems for humans in this area; especially, children when working on water soil and plant in an industrial area at the southern of Cairo, Egypt. Similar findings are also reported by [57] when working with selected heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) in soils from wetlands spatial distribution, ecological and health risks assessment in Lagos Nigeria. The health risk assessment also confirmed that exposure to Cd and As presented the greatest non-carcinogenic risk (> 1), while Cr exposure was associated with the highest cancer risk (> E04), from urban vegetable gardening irrigated with polluted water originating from industrial activities, as reported by [58] in China.

In conclusion, results show a clear and functional relationship between anthropogenic activities, effluent discharges, and leafy vegetable contamination in and around the Douala-Basa IDZ. The three leafy vegetables contain essential nutrients like crude fibre and moisture, which make them ideal for obesity-free and diabetes-friendly diets and can explain their importance in local cuisine. The HI values greater than (>) one (1) for the three vegetables studied for both adults and children indicate significant health risks associated with their consumption. TCRI values for Pb, Cd, and AS due to consumption of *Talinum fructicosum* and Solanum macrocarpon from the study area also exceeded the maximum threshold value of 10^{-4}, suggesting significant risks exist from consumption of these vegetables, especially if potential bioaccumulation is factored in. Therefore, consumption of vegetables from the effluent-receiving wetland around the Douala Bassa industrial zone could be one of the contributing factors to the heavy metal-related disease burden among the local population.

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