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Assessment of Trace Metal Contamination (Cd, Hg, Pb, Cr) in Lettuce Grown from Lendeng Market Gardening Area (Rufisque, Senegal)

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Abstract

This study aims to assess the level of trace metal element (TME) contamination in market garden produce specifically lettuce (*Lactuca sativa*) grown in the Lendeng area (Rufisque). Lettuce samples were collected based on availability and proximity to the SOCOCIM cement plant, which is suspected of being a source of metal pollution. Trace metal elements such as cadmium (Cd), mercury (Hg), lead (Pb), and chromium (Cr) were analysed using inductively coupled plasma mass spectrometry (ICP-MS) following acid digestion. Measurement results indicate that total TME concentrations follow this descending order: Hg > Cd > Pb > Cr. Analysis of variance (ANOVA) and the Tukey test reveal a highly significant effect regarding the four TMEs across the different groups studied. However, all measured concentrations remain below the limits authorized by the World Health Organization (FAO/WHO). Nevertheless, regular monitoring of this market gardening area remains essential to prevent any future public health risks in the municipality of Rufisque.

Keywords

Lactuca sativa, TME, Contamination, Lendeng Market Gardening, Rufisque

1. Introduction

In Senegal, specifically in Dakar, market gardening areas serve as sites for various industries while also being traversed by heavy vehicular traffic. Consequently, vegetables grown in these fields may become contaminated by continuous dis-

charges of industrial effluent and vehicle exhaust emissions [1]. Furthermore, these crops are irrigated with water of questionable quality, and soil fertilization relies on the use of animal manure and chemical fertilizers [2]-[4]. Growers use pesticides to combat plant diseases and pests [5] [6]. Agricultural practices in this highly industrialized zone could contribute to contamination of the food chain [7]. Peri-urban agriculture in the Niayes region plays a vital role in supplying the population with agricultural produce [8]. It accounts for over 80% of national vegetable production. This output is primarily intended for the domestic market [9]. Crops located near road networks and industrial facilities are at risk of contamination by pollutants, particularly heavy metals [10]. Such contamination poses a significant problem, as the accumulating metals are non-biodegradable [11] [12]. They exhibit varying degrees of toxicity; at high concentrations, they cause adverse effects on organisms and the environment [13] [14]. To assess this contamination, we studied lettuce grown in the Lendeng market-gardening zone. This area is located in the commune of Rufisque, near the SOCOCIM cement plant. In this zone, the environmental threat posed by trace metal elements is exacerbated by the atmospheric deposition of wind-borne, dry fine particles. The potential for these pollutants to transfer to crops necessitates an assessment of contamination levels in local produce. As lettuce is a major crop in Lendeng, this study aims to evaluate heavy metal levels (Cd, Hg, Pb, Cr) and compare them against health standards governing their consumption.

2. Material and Method

2.1. Study Area

Municipality of Rufisque, located approximately 25 km southeast of Dakar, covers an area of 42 km^2 and had a population of nearly 300,000 in 2022. The city is home to several major facilities notably the SOCOCIM cement plant, the SOCOCIM power plant (Diokoul substation), and the Cap of Biches thermal power plant which play a significant role in the country's electricity generation. Since 1996, Rufisque has been divided into three borough municipalities (Rufisque-West, Rufisque-North, and Rufisque-East). Lendeng area, located in the Rufisque-East borough, is part of the Niayes area; its market gardening area spans 56.83 hectares. This site serves as a major source of vegetable supplies for Dakar and Rufisque. The agricultural activities carried out their foster employment and contribute to the development of economic sectors such as trade, transport, and handicrafts. **Figure 1** shows the Lendeng sampling area in the locality of Rufisque.

2.2. Sample Collection and Preparation

Lettuce (*Lactuca sativa*) is a herbaceous plant species belonging to the Asteraceae family; it is widely cultivated for its tender leaves, which are consumed as a vegetable typically raw in salads. Lettuce absorbs trace metal elements from the soil through its roots [15]. The metals then pass through nutrient transport channels before being translocated to the leaves and stored in cellular vacuoles.

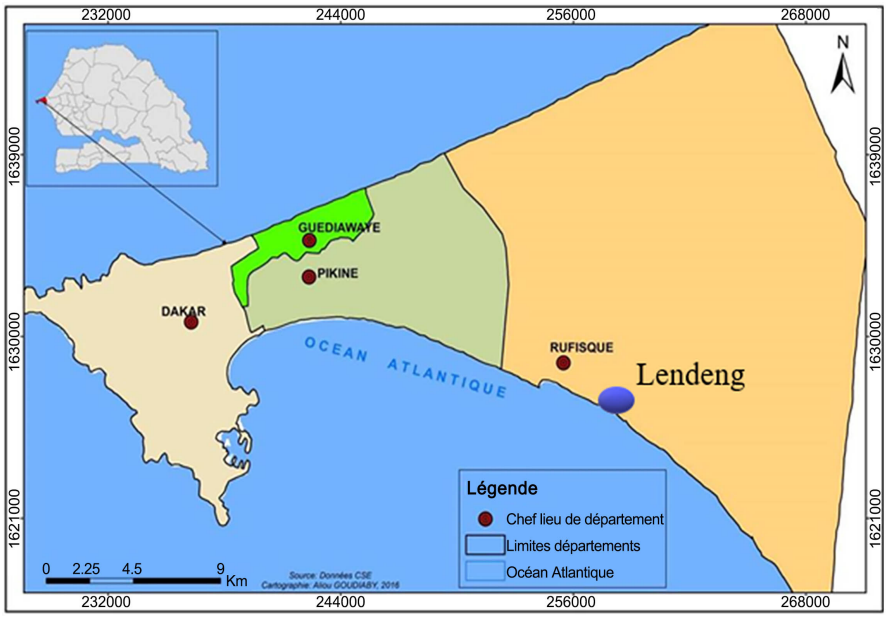


Figure 1. Location of Lendeng area within Rufisque common (Senegal).

This study was conducted in the Lendeng market-gardening zone, selected due to its proximity to emission sources from the SOCOCIM cement plant. Lettuce samples were collected between November 2024 and March 2025 from six lettuce fields selected. This selection ensures representation of the various environmental conditions likely to influence product quality. To prevent contamination, a stainless-steel knife was used to cut the lettuce at the base of the stem. From each field, four plants were collected monthly during the harvest to form a composite sample, which was placed in clean polyethylene bags. In the laboratory, the lettuce was washed with distilled water, cut into small pieces, and oven-dried at 80˚C for 48 hours. The dried material was then ground in an agate mortar, and the fine fraction was used for trace metal element (TME) analysis [16] [17].

2.3. Digestion and Analysis

All chemicals used were of analytical reagent grade and obtained from Merck (Darmstadt, Germany). Ultrapure water (Millipore Milli-Q system) was used throughout the study [18]. All glass and plastic containers and equipment were immersed in a 1.5% (w/v) HNO_3 solution for 24 h and rinsed three times with ultrapure water before use [19]. Various steps were carried out to determine the levels of trace metal elements in the lettuce samples. A 0.2 g sample of the powder was placed in a Teflon tube, followed by the addition of 8 mL of nitric acid (65% - 72%). The Teflon tubes containing the solutions were placed in a microwave oven at 200˚C for 45 minutes for digestion. After mineralization, the tubes were removed from the microwave and allowed to cool in the open air. The solutions were filtered into 100 mL flasks and then transferred to appropriate tubes prior to analysis. The determination was performed at the Water and Fertilizer Quality

Unit (UQEE) laboratory at CERES-Locustox using inductively coupled plasma mass spectrometry (ICP-MS). ICP-MS is an instrumental analysis technique based on the identification and quantification of elements according to their mass [20] [21].

2.4. Statistical Analysis

Statistical software SPSS 29.0 (IBM Corporation, Armonk, NY, USA) was used to analyse the experimental data. A one-way ANOVA was performed, with the significance level set at 0.05 for a 95% confidence interval.

3. Results and Discussion

3.1. Metals Content in Lettuce Samples

The results of the analysis of trace metal elements found in lettuce from the market gardening area in Lendeng (Rufisque) are presented in Table 1. All values are expressed in mg/kg (dry weight). Table 2 shows the mean values and their standard deviations. Analysis of the results reveals that metal levels vary depending on the field and the sampling date. Cadmium (Cd) levels range from 0.597 to 0.672 mg/kg (dry weight), with a mean value of 0.626 mg/kg, for Field 1. For Field 2, values ranged from 0.509 to 0.567 mg/kg, with a mean of 0.539 mg/kg. A range of 0.453 to 0.501 mg/kg, with a mean of 0.483 mg/kg, was observed for Field 3. The mean Cd level for Field 4 is 0.682 mg/kg, with a range of 0.666 to 0.698 mg/kg. Results showed that the Cd concentration for Field 5 ranges from 0.453 to 0.509 mg/kg, with a mean of 0.490 mg/kg. Finally, for field 6, a variation between 0.473 and 0.505 mg/kg was observed, with a mean of 0.484 mg/kg.

Table 1. Metals content in lettuce samples from Lendeng market gardening area.

Lettuce samples	Sampling date	Cd (mg/Kg)	Hg (mg/Kg)	Pb (mg/Kg)	Cr (mg/Kg)
Field 1	November	0.597	0.039	1.080	10.435
	December	0.615	0.040	1.097	9.805
	January	0.612	0.041	1.061	10.614
	February	0.635	0.045	1.031	10.610
	March	0.672	0.040	1.136	10.089
Field 2	November	0.509	0.031	1.448	11.146
	December	0.541	0.036	1.484	11.587
	January	0.536	0.038	1.458	11.335
	February	0.567	0.031	1.502	10.783
	March	0.542	0.034	1.473	10.874

Continued

	November	0.501	0.087	1.381	13.059
	December	0.469	0.075	1.462	12.358
Field 3	January	0.498	0.071	1.443	11.649
	February	0.453	0.074	1.447	11.804
	March	0.494	0.078	1.412	11.789
	November	0.698	0.039	0.952	12.377
	December	0.683	0.037	0.957	12.060
Field 4	January	0.695	0.040	0.955	11.729
	February	0.668	0.041	0.949	11.272
	March	0.666	0.038	0.947	11.212
	November	0.509	0.043	0.978	12.642
	December	0.508	0.041	0.989	12.712
Field 5	January	0.453	0.044	0.986	12.039
	February	0.489	0.047	1.010	11.421
	March	0.491	0.040	0.997	12.111
	November	0.491	0.050	1.198	10.805
	December	0.478	0.056	1.208	10.118
Field 6	January	0.473	0.049	1.294	10.977
	February	0.505	0.057	1.205	11.380
	March	0.473	0.053	1.255	10.746

Table 2. Mean metals content found in lettuce samples from Lendeng area.

Lettuce samples	Cd (mg/Kg)	Hg (mg/Kg)	Pb (mg/Kg)	Cr (mg/Kg)
Field 1	0.626 ± 0.029	0.041 ± 0.003	1.081 ± 0.039	10.311 ± 0.354
Field 2	0.539 ± 0.021	0.034 ± 0.003	1.473 ± 0.025	11.145 ± 0.381
Field 3	0.483 ± 0.021	0.077 ± 0.002	1.429 ± 0.042	11.900 ± 0.271
Field 4	0.682 ± 0.023	0.039 ± 0.001	0.952 ± 0.004	11.730 ± 0.510
Field 5	0.490 ± 0.023	0.043 ± 0.003	0.992 ± 0.012	12.185 ± 0.524
Field 6	0.484 ± 0.014	0.055 ± 0.003	1.232 ± 0.041	10.805 ± 0.457

In Field 1, the Hg levels ranged from 0.039 to 0.045 mg/kg, with an average of 0.041 mg/kg. For Field 2, the measured values ranged from 0.031 to 0.038 mg/kg,

with an average of 0.034 mg/kg. A range of 0.071 to 0.087 mg/kg was recorded for Field 3, with an average of 0.077 mg/kg. The average Hg value for Field 4 was 0.039 mg/kg, with a range of 0.037 to 0.041 mg/kg. The results show that the Hg content in Field 5 varied between 0.040 and 0.047 mg/kg, with an average of 0.043 mg/kg. Regarding Field 6, we observed a range of 0.049 to 0.057 mg/kg, with an average of 0.055 mg/kg.

Lead (Pb) is a toxic metal that can affect almost all of the body's organs and systems, leading to serious health problems. Relatively average lead levels were found across all the fields. The highest levels were observed in Field 2 (1.473 mg/kg), followed by Field 3 (1.429 mg/kg), Field 6 (1.232 mg/kg), and Field 1 (1.081 mg/kg). The lowest values were observed in Field 4 (0.952 mg/kg) and Field 5 (0.992 mg/kg).

Chromium (Cr) is the most abundant metal across the six fields studied. The highest average levels were observed in Field 5 (12.185 mg/kg), followed by Field 3 (11.900 mg/kg), Field 4 (11.730 mg/kg), and Field 2 (11.145 mg/kg). The lowest values were found in Field 6 (10.805 mg/kg) and Field 1 (10.311 mg/kg).

3.2. Statistical Analysis with the Lettuce Samples

Results of the analysis of variance (ANOVA) for the four elements found in the lettuce fields are presented in Table 3. For each element, the "between-groups" effect is highly significant ($p < 0.001$), indicating major differences between the groups compared. The F-values, which are particularly high (11.537 - 98.175), confirm that inter-group variability is markedly greater than intra-group variability. Consequently, the null hypothesis of equal means is rejected ($p < 0.05$). Thus, for each of these trace metal elements, there is at least one group whose mean differs significantly from the others.

Table 3. ANOVA between and within lettuce samples at 95% confidence level.

ANOVA						
		Sum of squares	gl	RMS value	F	Sig.
Cd	Between the groups	0.106	5	0.021	30.639	<0.001
	Within the groups	0.010	14	0.001	-	-
	Total	0.115	19	-	-	-
Hg	Between the groups	0.003	5	0.001	95.449	<0.001
	Within the groups	0.000	9	0.000	-	-
	Total	0.003	14	-	-	-
Pb	Between the groups	0.711	5	0.142	98.175	<0.001
	Within the groups	0.017	12	0.001	-	-
	Total	0.729	17	-	-	-

Continued

	Between the groups	12.028	5	2.406	11.537	<0.001
Cr	Within the groups	4.170	20	0.209	-	-
	Total	16.199	25	-	-	-

Tukey's comparison test was applied to determine between which levels significant differences existed; distinct letters were assigned to means showing significant differences. Table 4 presents the results of the Tukey (HSD) test at the 5% significance level for cadmium (Cd). This test divides the six fields (Fields 1 through 6) into two distinct homogeneous subsets based on their means. The first subset comprises the fields with the lowest means (Fields 3, 6, 5, and 2), ranging from 0.48267 to 0.53933. The second groups the fields with the highest means (Fields 1 and 4), ranging from 0.62620 to 0.68200. Although some differences between groups may appear small, the statistical cut off established by the test rigorously accounts for variances and sample sizes (N) to validate the significant separation of these subsets.

Table 4. Post hoc tests (homogeneous subsets for cadmium).

Cd			
Tukey B[a,b]			
Field	N	Subset for p = 0.05	
		1	2
Field 3	3	0.48267	-
Field 6	3	0.48367	-
Field 5	4	0.48975	-
Field 2	3	0.53933	-
Field 1	5	-	0.62620
Field 4	2	-	0.68200

Group means are displayed for homogeneous subsets. **a.** Uses harmonic mean sample size = 3.077. **b.** Group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 5 presents the Tukey test results comparing mean mercury (Hg) levels across six different fields. The fields are categorized into four distinct homogeneous subsets, indicating whether mercury values share similar or different statistical groupings based on overlap. Subset 1 (lowest values): Field 2 and Field 4 share similar means. Subset 2: Field 4, Field 1, and Field 5 overlap, indicating similar Hg levels. Subset 3: Field 6 forms a distinct group with a higher mean (0.055333). Subset 4 (highest value): Field 3 has the highest mean (0.076500) and stands alone

in this group.

Table 5. Post-hoc tests (homogeneous subsets for mercury).

Hg					
Tukey B[a,b]					
Field	N	Subset for p = 0.05			
		1	2	3	4
Field 2	3	0.033667	-	-	-
Field 4	2	0.039500	0.039500	-	-
Field 1	3	-	0.041333	-	-
Field 5	2	-	0.042500	-	-
Field 6	3	-	-	0.055333	-
Field 3	2	-	-	-	0.076500

Group means are displayed for homogeneous subsets. **a.** Uses harmonic mean sample size = 2.400. **b.** Group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 6 presents the results of a Tukey test grouping the fields into homogeneous subsets at the 5% significance level for lead (Pb). The fields are classified into four distinct groups (columns 1 to 4) based on increasing mean values; this shows that Field 4 and Field 5 have the lowest values, while Field 3 and Field 2 have the highest. Subset 1: Field 4 (0.952) and Field 5 (0.9915). Their means do not differ

Table 6. Post-hoc tests (homogeneous subsets for lead).

Pb					
Tukey B[a,b]					
Field	N	Subset for p = 0.05			
		1	2	3	4
Field 4	2	0.95200	-	-	-
Field 5	2	0.99150	-	-	-
Field 1	4	-	1.08125	-	-
Field 6	3	-	-	1.23233	-
Field 3	3	-	-	-	1.42867
Field 2	4	-	-	-	1.47300

Group means are displayed for homogeneous subsets. **a.** Uses harmonic mean sample size = 2.769. **b.** Group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

significantly. Subset 2: Field 1 (1.08125). It is statistically different from the first and subsequent subsets. Subset 3: Field 6 (1.23233). It forms a distinct intermediate group. Subset 4: Field 3 (1.42867) and Field 2 (1.473). Their means are the highest and do not differ from each other.

Table 7 presents a Tukey test comparing the mean chromium levels across the six fields. This test classifies the fields into three homogeneous subsets. Fields sharing the same column (subset) have similar values, whereas Field 1 and Field 5 are statistically different because they do not overlap in any common column. Subset 1 comprises Field 1 (10.31), Field 6 (10.81), and Field 2 (11.14); this group has the lowest mean values. Subset 2 comprises Field 2 (11.14), Field 4 (11.73), and Field 3 (11.90). Subset 3 comprises Field 4 (11.73), Field 3 (11.90), and Field 5 (12.19); this group has the highest mean values. The harmonic mean is 4.286 because the sample sizes (N) per field ranging from 4 to 5 are not perfectly balanced.

Table 7. Post hoc tests (homogeneous subsets for chromium).

Cr				
Tukey B[a,b]				
Field	N	Subset for p = 0.05		
		1	2	3
Field 1	5	10.31060	-	-
Field 6	4	10.80525	-	-
Field 2	4	11.14475	11.14475	-
Field 4	4	-	11.73025	11.73025
Field 3	5	-	11.90000	11.90000
Field 5	5	-	-	12.18500

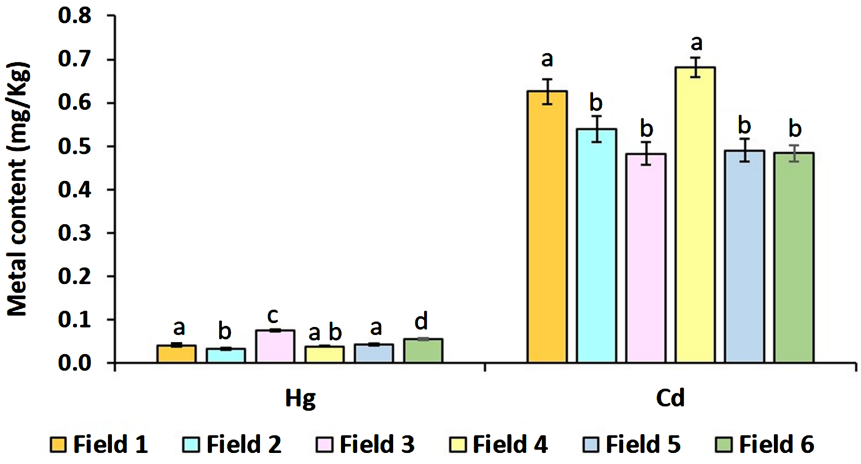
Group means are displayed for homogeneous subsets. **a.** Uses harmonic mean sample size = 4.286. **b.** Group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Figure 2 shows the trace metal concentrations in lettuce samples grown in the six fields of the Lendeng area. Lowercase letters (a, b, c) indicate statistical differences. Within a given graph and for a specific metal, two fields sharing the same letter do not show a significant difference. Conversely, different letters indicate a statistically significant difference at the 5% level ($p < 0.05$), determined by Tukey's multiple comparison test (one-way ANOVA, 95% confidence level).

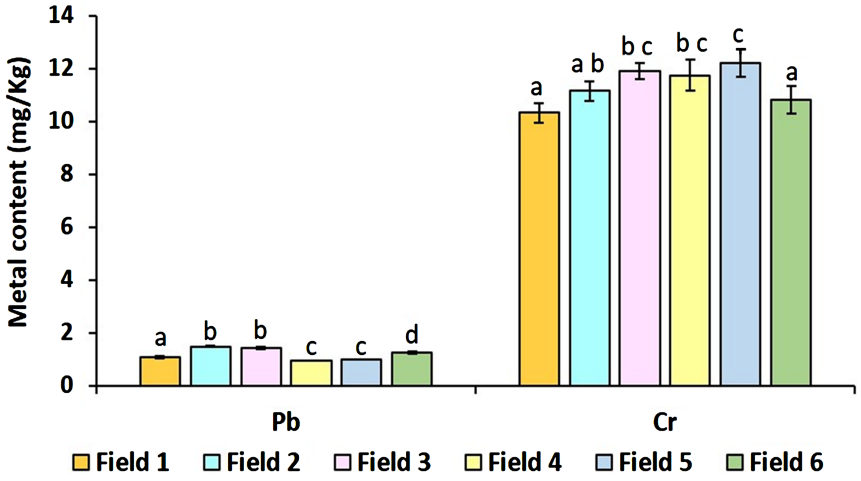
3.3. Comparison of Results of the Present Study with FAO/WHO Permissible Levels

Metals level measured in this study were compared with the maximum permissible levels recommended by the Food and Agriculture Organization of the United

Nations (FAO/WHO) [22]. The water content of the lettuces studied was 95%. The dry to fresh weight conversion factor was set at 0.05. The results of the metal analysis for the lettuce, expressed in mg/kg fresh weight after conversion, are presented in Table 8. Authors such as Wang *et al.* (2021) found lettuce water content levels of 95.73% [23].



(a)



(b)

Figure 2. Heavy metal contents in lettuce samples grown in different fields of the Lendeng area: (a) Hg and Cd; (b) Pb and Cr. Different Latin letters within the same element indicate significant differences among the results compared by means of the Tukey-b test ($p < 0.05$) for one-way ANOVA analysis.

Table 8. Comparison of results of the present study with FAO/WHO Values.

Lettuce	Cd (mg/Kg)	Hg (mg/Kg)	Pb (mg/Kg)	Cr (mg/Kg)
Lendeng area	0.024 - 0.034	0.002 - 0.004	0.048 - 0.074	0.516 - 0.609
FAO/WHO	0.2	-	0.3	-

Cadmium levels remain well below the maximum limit (0.2 mg/kg fresh

weight) set by the FAO/WHO. However, scientific literature notes that lettuce has a high capacity to bio-accumulate cadmium from soil or fertilizers [24] [25]. Notably, there is no specific maximum limit for mercury as a contaminant in lettuce under major international standards. Heavy metal content in plants depends primarily on the level of soil contamination and the plant species [26]-[28]. Lead levels found in the lettuce are below the standard (0.3 mg/kg fresh weight) established by the FAO/WHO. Lead contamination in the lettuce likely originates from atmospheric industrial dust fallout [29]-[31]. Other authors, such as Beatrice Ambo Fonge *et al*. (2021), found higher lead concentrations (1.31 - 1.36 mg/kg) in head cabbage from the Northwest Region of Cameroon [32]. Similarly, Dagne Bekele Bahiru (2021) found lead levels ranging from 0.42 to 6.55 mg/kg in lettuce (*Lactuca sativa*) samples from the Akaki River area in central Ethiopia [33]. However, there is no specific maximum limit for chromium in fresh lettuce. Indeed, total chromium is assessed as part of the overall environmental quality of soil or irrigation water [34]-[36]. The likely sources of this contamination in the lettuce are the proximity of the SOCOCIM cement plant, the exposure of the fields to road traffic, and the use of fertilizers [37]-[39]. Nevertheless, the assessment of these trace metal elements shows levels that comply with the thresholds set by international food standards (FAO/WHO) for leafy vegetables such as lettuce. Thus, lettuce grown in the Lendeng area is safe for consumption, provided there is regular monitoring of soil quality.

4. Conclusion

Lettuce grown in the Lendeng market gardening zone shows trace metal levels below the standards established by the FAO/WHO for vegetables. However, the presence of cadmium (Cd), mercury (Hg), lead (Pb), and chromium (Cr) can be attributed to the proximity of major roads and the SOCOCIM cement plant, as well as the use of fertilizers. Although these levels currently comply with standards, the presence of these pollutants should prompt the environmental and health authorities of Rufisque to implement appropriate preventive measures to ensure public safety. Furthermore, regular monitoring of trace metals in environmental matrices (soil, water, and vegetables) should be established to prevent any future accumulation in the food chain.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Cissé, D., Ndiaye, B., Tidiane Dione, C., Diagne, I., Hane, M., Diouf, S., *et al*. (2025) Determination of Pesticides in Marine Sediments from Dakar Coast (Senegal) by Gas Chromatography-Tandem Mass Spectrometry (GC/MSMS). *International Journal of Current Microbiology and Applied Sciences*, **14**, 226-232. https://doi.org/10.20546/ijcmas.2025.1402.021

[2] Gebreyohannes, F. and Hagos, K.H. (2019) Determination of Selected Heavy Metals

Content and Health Risk Assessment of Cabbage Cultivated in Elalla Farmland, Mekelle, Ethiopia. *Chemistry and Materials Research*, **11**, 16-21.

[3] Khan, Z.I., Ugulu, I., Ahmad, K., Yasmeen, S., Noorka, I.R., Mehmood, N., *et al*. (2018) Assessment of Trace Metal and Metalloid Accumulation and Human Health Risk from Vegetables Consumption through Spinach and Coriander Specimens Irrigated with Wastewater. *Bulletin of Environmental Contamination and Toxicology*, **101**, 787-795. https://doi.org/10.1007/s00128-018-2448-8

[4] Smical, A., Hotea, V., Oros, V., Juhasz, J. and Pop, E. (2008) Studies on Transfer and Bioaccumulation of Heavy Metals from Soil into Lettuce. *Environmental Engineering and Management Journal*, **7**, 609-615. https://doi.org/10.30638/eemj.2008.085

[5] Kanda, M., Wala, K., Djaneye-Boundjou, Ahanchede, A. and Akpagana, K. (2006) Utilisation des pesticides dans les périmètres maraîchers du cardon littoral togolais. *Journal de la Recherche Scientifique de l'Université de Lomé* (*Togo*), *Série A*, **8**, 19-26.

[6] Abdulai, A.N., Konje, C.N., Achiri, T.D., Tarla, D.N. and Nsobinenyui, D. (2019) Pesticide Use Practices by Market Gardeners in the Santa Area of the North West Region of Cameroon. *International Journal of Plant & Soil Science*, **26**, 1-11. https://doi.org/10.9734/ijpss/2018/v26i630060

[7] Singh, S. and Kumar, M. (2006) Heavy Metal Load of Soil, Water and Vegetables in Peri-Urban Delhi. *Environmental Monitoring and Assessment*, **120**, 79-91. https://doi.org/10.1007/s10661-005-9050-3

[8] Dione, M., Dione, S., Ndiaye, B., Hane, M., Cisse, D., Dione, C., *et al*. (2024) Determination of Physico-Chemical Parameters of Well Water in the Central Niayes Area of Mboro (Senegal). *Science Journal of Chemistry*, **12**, 86-93. https://doi.org/10.11648/j.sjc.20241205.11

[9] Diallo, M.D., Ngamb, T., Tine, A.K., Guisse, M., Ndiaye, O., Saleh, M.M. and Guisse, A. (2015) Caractérisation agropédologique des sols de mboltime dans la zone des Niayes (Sénégal). *Agronomie Africaine*, **27**, 57-67.

[10] Meskelu, T., Senbeta, A.F., Keneni, Y.G. and Sime, G. (2024) Heavy Metal Accumulation and Food Safety of Lettuce (*Lactuca sativa* L.) Amended by Bioslurry and Chemical Fertilizer Application. *Food Science & Nutrition*, **12**, 7449-7460. https://doi.org/10.1002/fsn3.4363

[11] Abah, J., Mashebe, P., Ubwa, S.T. and Denuga, D.D. (2014) Some Heavy Metals Content of Cabbage and Soil Cultivated in the Bezi Bar Farm Area of Katima Mulilo, Namibia. *American Journal of Chemistry*, **4**, 101-108.

[12] Mukhtar Balal, R., Ayyaz Javed, S., Tauseef Jaffar, M., Sadaf, A., Ahamad Paray, B. and Singh, R. (2024) Heavy Metal Toxicity Induced by Sewage Water Treatment in Three Different Vegetables (Lettuce, Spinach and Cabbage) Was Alleviated by Brassinosteroid and Silicon Supplementation. *Journal of King Saud University—Science*, **36**, Article ID: 103310. https://doi.org/10.1016/j.jksus.2024.103310

[13] FAO, & UNEP (2021) Global Assessment of Soil Pollution: Summary for Decision Makers. Food and Agriculture Organization of the United Nations (FAO).

[14] Faurat, A., Azhayev, G., Shupshibayev, K., Akhmetov, K., Boribay, E. and Abylkhassanov, T. (2024) Assessment of Heavy Metal Contamination and Health Risks in "Snow Cover-Soil Cover-Vegetation System" of Urban and Rural Gardens of an Industrial City in Kazakhstan. *International Journal of Environmental Research and Public Health*, **21**, Article No. 1002. https://doi.org/10.3390/ijerph21081002

[15] Nepal, A., Antonious, G.F., Gyawali, B.R., Webster, T.C. and Bebe, F. (2024) Assessing the Bioaccumulation of Heavy Metals in Cabbage Grown under Five Soil

Amendments. *Pollutants*, **4**, 58-71. https://doi.org/10.3390/pollutants4010005

[16] Abrham, F. and Gholap, A.V. (2021) Analysis of Heavy Metal Concentration in Some Vegetables Using Atomic Absorption Spectroscopy. *Pollution*, **7**, 205-216.

[17] Mekuria, A., Gemeda, S., Ture, E. and Getachew, B. (2024) Determination of Heavy Metal Contaminants in Leafy Vegetables (Ethiopian Cabbage) Cultivated around Dilla Town. *Frontiers*, **4**, 142-149. https://doi.org/10.11648/j.frontiers.20240404.14

[18] Ndiaye, B., Ndiaye, M., Cid, B.P., Diop, A., Diagne, I., Cissé, D., *et al*. (2020) Trace Metals in Mussels *Mytilus galloprovincialis* from Dakar Coast (Senegal). *American Journal of Analytical Chemistry*, **11**, 137-145. https://doi.org/10.4236/ajac.2020.113011

[19] Ndiaye, B., Ndiaye, M., Cid, B.P. and Diop, A. (2015) Distribution of Inorganic and Total Mercury in Marine Sediments from Two Coastal Areas Delimited by Atlantic Ocean: Galician Rías (NW Spain) and Coast of Dakar (Senegal). *Asian Journal of Chemistry*, **27**, 2707-2711. https://doi.org/10.14233/ajchem.2015.18869

[20] de Souza, M.J., Barciela-Alonso, M.C., Aboal-Somoza, M. and Bermejo-Barrera, P. (2021) Determination of the Trace Element Contents of Fruit Juice Samples by ICP OES and ICP-MS. *Brazilian Journal of Analytical Chemistry*, **9**, 49-61. https://doi.org/10.30744/brjac.2179-3425.ar-87-2021

[21] Gour, P., Sethi, R. and Dashora, P. (2026) Advanced Modes of Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) for Reducing Spectral Interferences on Matrix Based in Food Matrices. *Journal of Advanced Scientific Research*, **17**, 14-19. https://doi.org/10.55218/jasr.2026170403

[22] FAO/WHO Codex Alimentarius Commission (2001) Food Additives and Contaminants. Joint FAO/WHO Food Standards Programme; ALINORM 01/12A, 1-289. http://www.fao.org/3/a-x8723e.pdf

[23] Wang, W., Ma, Y., Fu, L., Cui, Y. and Majeed, Y. (2021) Physical and Mechanical Properties of Hydroponic Lettuce for Automatic Harvesting. *Information Processing in Agriculture*, **8**, 550-559. https://doi.org/10.1016/j.inpa.2020.11.005

[24] Assy, H.C. and Yapi, D.Y.A. (2025) Niveau de contamination des produits maraîchers par les métaux lourds issus des décharges sauvages dans le district d'Abidjan (Côte d'Ivoire). *European Scientific Journal, ESJ*, **21**, 225-245. https://doi.org/10.19044/esj.2025.v21n24p225

[25] Cadiogan, C.R. (2026) Mercury Levels, Soil Properties and Farming Practices in Cabbage-Growing Farms of Buguias, Benguet: A Monitoring Report for Semi-Temperate Conventional Farming in Northern Philippines. *Mountain Journal of Science and Interdisciplinary Research* (*Formerly Benguet State University Research Journal*), **86**, 35-49. https://doi.org/10.70884/mjsir.v86i1.611

[26] Diop, T., Diarra, A., Diallo, M.A., Dione, M.M. and Diop, A. (2023) Impact d'une décharge urbaine sur la contamination métallique des sols: Cas de la décharge de mbeubeuss (Dakar). *International Journal of Biological and Chemical Sciences*, **16**, 2992-3002. https://doi.org/10.4314/ijbcs.v16i6.41

[27] Somda, M.K., Samake, S., Kabore, D., Nikiema, M., Mogmenga, I., Dabire, Y., *et al*. (2019) Assessment of Heavy Metals and Microbial Pollution of Lettuce (*Lactuca sativa*) Cultivated in Two Sites (Paspanga and Tanghin) of Ouagadougou, Burkina Faso. *Journal of Environmental Protection*, **10**, 454-471. https://doi.org/10.4236/jep.2019.103026

[28] Baassiri, K., Antonios, D. and Milane, A. (2025) Heavy Metal Contamination in Lebanese Lettuce: Quantification and Health Risk Assessment. *Journal of Food Composition and Analysis*, **137**, Article ID: 106871.

https://doi.org/10.1016/j.jfca.2024.106871

[29] Bakhoum, M., Ndiolene, A., Ndiaye, N., Diallo, M.A. and Diop, T. (2025) Evaluation du niveau de contamination en éléments traces métalliques des légumes feuilles cultivés au voisinage de la décharge urbaine de Mbeubeuss (Dakar). *Journal of Applied Biosciences*, **205**, 21642-21649.

[30] Zhou, X., Sun, J., Tian, Y., Yao, K. and Xu, M. (2022) Detection of Heavy Metal Lead in Lettuce Leaves Based on Fluorescence Hyperspectral Technology Combined with Deep Learning Algorithm. *Spectrochimica Acta Part A*: *Molecular and Biomolecular Spectroscopy*, **266**, Article ID: 120460. https://doi.org/10.1016/j.saa.2021.120460

[31] Galal, T.M., Khalafallah, A.A., Elawa, O.E. and Hassan, L.M. (2018) Human Health Risks from Consuming Cabbage (*Brassica oleracea* L. var. *capitata*) Grown on Wastewater Irrigated Soil. *International Journal of Phytoremediation*, **20**, 1007-1016. https://doi.org/10.1080/15226514.2018.1452186

[32] Fonge, B.A., Larissa, M.T., Egbe, A.M., Afanga, Y.A., Fru, N.G. and Ngole-Jeme, V.M. (2021) An Assessment of Heavy Metal Exposure Risk Associated with Consumption of Cabbage and Carrot Grown in a Tropical Savannah Region. *Sustainable Environment*, **7**, 1-19. https://doi.org/10.1080/27658511.2021.1909860

[33] Bahiru, D.B. (2021) Evaluation of Heavy Metals Uptakes of Lettuce (*Lactuca sativa* L.) under Irrigation Water of Akaki River, Central Ethiopia. *American Journal of Environmental Science and Engineering*, **5**, 6-14. https://doi.org/10.11648/j.ajese.20210501.12

[34] Ahou, F.K., Kouame, G.K., Ladji, M. and Yorayebien, S.C. (2025) Assessment of the Contamination of *Lactuca sativa* by Metal Trace Elements. *African Journal of Environmental Science and Technology*, **19**, 390-396. https://doi.org/10.5897/ajest2025.3397

[35] Alain, T.K., Luc, B.T., Ali, D., Moumoni, D., Zongo, I. and Zougmoré, F. (2021) Assessment of Heavy Metal Concentration and Evaluation of Health Risk of Some Vegetables Cultivated in Loumbila Farmland, Burkina Faso. *Journal of Environmental Protection*, **12**, 1019-1032. https://doi.org/10.4236/jep.2021.1212060

[36] Ndiaye, B., Ndiaye, M., Cid, B.P., Diop, A., Diagne, I., Cissé, D., *et al*. (2022) Quality of Well Water Used for Market Gardening from Lendeng Area Located in Common of Rufisque (Senegal). *Journal of Agricultural Chemistry and Environment*, **11**, 277-284. https://doi.org/10.4236/jacen.2022.114019

[37] Ndiaye, B., Ndiaye, M., Perez Cid, B., Diop, A., Diagne, I., *et al*. (2022) Physicochemical Parameters and Trace Metal in Marine Sediment from Bargny Coast (Senegal). *American Journal of Ap-plied Chemistry*, **10**, 114-119.

[38] Wognin, A.S., Ouattara, M.B., Assi-Clair, B.J. and Koffi-Nevry, R. (2022) Evaluation des niveaux de contamination bactériologique de la laitue selon les sites de production et de vente dans les sites de maraîchage d'Abidjan et zone périurbaine. *International Journal of Biological and Chemical Sciences*, **16**, 1580-1592. https://doi.org/10.4314/ijbcs.v16i4.18

[39] Dan-Badjo, A., Guero, Y., Lamso, N., Barage, M., Balla, A., Sterckeman, T., *et al*. (2013) Évaluation des niveaux de contamination en éléments traces métalliques de laitue et de chou cultivés dans la vallée de Gounti Yena à Niamey, Niger. *Journal of Applied Biosciences*, **67**, 5326-5335. https://doi.org/10.4314/jab.v67i0.95056