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Research Article



Potentially Toxic Metals in Cucumber *Cucumis sativus* Collected from Peninsular Malaysia: A Human Health Risk Assessment

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Abstract

The purposes of this study were to assess the concentrations of Fe, Cu, Ni, Pb, and Zn in the cucumber *Cucumis sativus* from four farming areas of Peninsular Malaysia, to assess the HHRA of the five heavy metals in the collected samples. The cucumber was collected between May and December 2016 from Kg Ara Kuda (Penang), Kg. Sitiawan (Perak), Kuala Ketil (Kedah) and Jerantut (Pahang) of Peninsular Malaysia. For the edible fruity cucumber, the ranges of metal concentrations (mg/kg dry weight) from the four sites were 9.56-13.6 for Cu, 39.5-109 for Fe, 0.18-2.19 for Ni, 0.74-2.78 for Pb and 17.5-62.0 for Zn. All the target hazard quotient values for Fe, Cu, Ni, Pb, and Zn in adults and children were found below 1.00 for the health risk assessment. The present investigation found no evidence of non-carcinogenic hazards associated with the intake of cucumber in relation to Fe, Cu, Ni, Pb, and Zn. However, it is important to regularly evaluate the levels of heavy metals in vegetables cultivated in these soils and adopt appropriate remediation procedures to reduce harmful effects on human health.

Introduction

Contamination of vegetables due to wastewater irrigation is a significant issue that poses potential risks to human health. Using wastewater for irrigating vegetables introduces contaminants such as toxic metal ions, dyes, and waterborne pathogenic bacteria into the soil [1-4]. The plant roots can absorb these contaminants and gradually accumulate in the edible parts of the vegetables, making them unsafe for consumption. Furthermore, hazardous

pollutants in wastewater can adversely affect aquatic life and immobilize plant enzymes [5]. Moreover, the contamination of vegetables with potentially toxic metals is often caused by anthropogenic inputs such as sewage sludge and residues from mining and various industries. Improper application of fertilizers and pesticides from atmospheric sources can also contribute to elevated concentrations of pollutants in the soils [5-9].

Human activities, including manufacturing industries,



urbanization practices, and agro-based industries, contribute to the presence of potentially toxic metals in wastewater used for irrigation, further exacerbating the contamination of vegetables [10-15]. This contamination of vegetables not only poses a threat to human health but also has implications for the overall ecosystem.

Vegetable consumption is a significant pathway for potentially toxic metals (PTMs) entering the human body [16]. Improper application of sewage sludge might negatively affect agro-systems' productivity [17]. Excessive levels of trace elements may pose a risk to human health. The presence of heavy metal residues in food crops that are irrigated with wastewater has been extensively documented in China [18]. Eid, et al. [17] found that the sewage sludge they studied might be utilized as a fertilizer in cucumber production systems in Saudi Arabia.

Previous research has documented the presence of metal exposure and toxicities in edible cucumbers. These studies include the works of Alcantara, et al. [19], Romera, et al. [20], Munzuroglu and Geckil [21], Tabaldi, et al. [22], Janicka-Russak, et al. [23], Prakash, et al. [24], Eid, et al. [17], Minich, et al. [25], Stevic, et al. [26], Kabala, et al. [27], Freitag, et al. [28], and Kim, et al. [29]. Romera, et al. [20] conducted a study to investigate the impact of bicarbonate and specific metal ions on the development of increased root Fe(III) reduction capacity in young cucumber plants (*Cucumis sativus* L) cultivated in a nutrient solution. This reaction is a result of Fe shortage in dicotyledons. Their findings indicated that bicarbonate can hinder the growth of root Fe(III), lowering capacity by limiting the accessibility of certain metal ions necessary for this process.

Tabaldi, et al. [22] conducted a study to examine the impact of several metals on the activity of acid phosphatase in cucumber seedlings (*C. sativus* L.) in a laboratory setting. They found that Zn is a stronger acid phosphatase inhibitor from cucumbers than Hg. Zhang, et al. [30] examined the impact of the heavy metal cadmium (Cd) on the root development and the activity of antioxidant enzymes, namely superoxide dismutase (SOD) and peroxidase (POD), in *C. sativus* L. hairy roots. Additionally, they investigated the combined effects of cadmium (Cd) and zinc (Zn) on these parameters. Their findings indicated that concentrations of Cd below 10 mg/L stimulated the development of *C. sativus* hairy roots and specifically increased root diameter within a 5-15 days of root culture. Arata, et al. [31] conducted experiments to examine the effects of elevated levels of lead (Pb), nickel (Ni), and copper (Cu) on the germination and development of *C. sativus*. The analysis revealed that the metals' bioaccumulation data in the seeds indicated the toxicity level of the metals being evaluated.

However, the literature lacks reports on the human health risk assessment (HHRA) of PTMs in the edible cucumber *C. sativus*. Therefore, the objectives of this study were to 1) assess the concentrations of Fe, Cu, Ni, Pb, and Zn in the cucumber *C. sativus* from four farming areas of Peninsular Malaysia and 2) assess the HHRA of the five heavy metals in the collected samples.

Materials and methods

The samples *C. sativus* were collected between May and December 2016, from Kg Ara Kuda (Penang), Kg. Sitiawan (Perak), Kuala Ketil (Kedah) and Jerantut (Pahang) of Peninsular Malaysia (Figure 1). The collected samples were stored in clean polyethylene bags and transferred to the laboratory for further analysis. The morphology and classification of the cucumber from the present study were identified according to Chin and Yap [32] and Prohens and Nuez [33,34].

The collected samples were washed with distilled water to remove soil particles. Then, they were cut into small pieces using a clean knife and dried in an oven at 60 °C for 72 hours until they reached constant dry weights. After drying, the vegetable samples were ground using a commercial blender and stored in polyethylene bags until further analysis.

For the determination of heavy metals, all samples stored in acid-washed pillboxes were analyzed by using a flame atomic absorption spectrophotometer (AAS) model Thermo Scientific iCE 3000 series for Fe, Cu, Ni, Pb, and Zn at the Chemistry Department of the Faculty of Science at Universiti Putra Malaysia (UPM). Standard solutions were prepared from 1000ppm stock solution provided by Sigma-Aldrich for the five metals. All data obtained from the AAS were presented on a mg/kg dry weight basis.

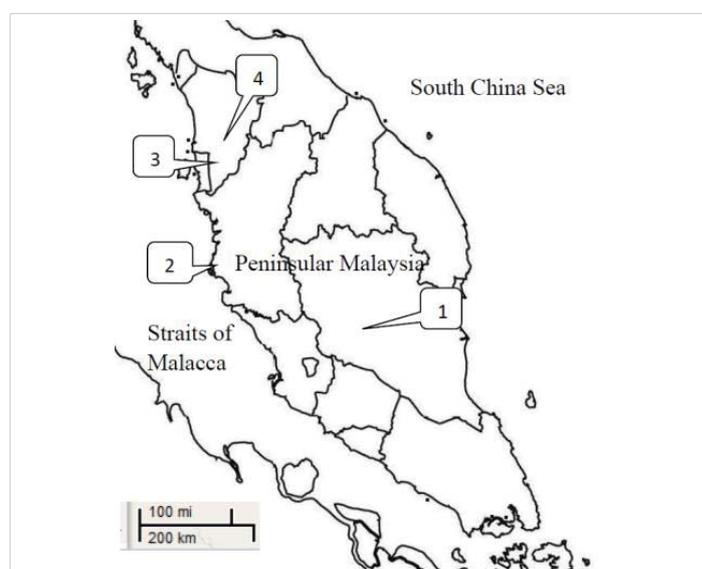


Figure 1: The sampling sites (estimation only) for cucumber *Cucumis sativus* in Peninsular Malaysia (1 = Jerantut; 2 = Sitiawan; 3 = Ara Kuda; 4 = Kuala Ketil).

All the glassware used in this study was acid-washed for quality assurance and quality control to avoid external contamination. Two certified reference materials (CRMs) were used to check for the analytical procedures and accuracy of the method used. The CRMs included were *Lagarosiphon major* N.60 and Peach Leaves (NIST 1547). The recoveries for the CRM *Lagarosiphon major* N.60 were 97.4, 120.2, and 119% for Zn, Cu and Pb, respectively, while CRM Peach Leaves (NIST 1547) were 97.0 and 117% for Ni and Fe, respectively (Table 1).

For the HHR assessment, the present concentrations in dry weight were converted into wet weight because cucumber consumption (or cooking) is assumed to be in wet weight. Therefore, the present concentrations (mg/kg dry weight) of Fe, Cu, Ni, Pb, and Zn were converted to wet weight basis by using a conversion factor of 0.043 [35,36].

The HHR assumes a once-or long-term potential hazardous exposure to metals through consumption of the vegetables. The HHR assessments included estimated daily intake (EDI) and target hazard quotient (THQ) values were calculated by using the following formulas:

$$EDI = (Mc \times CR)/BW$$

where;

Mc = The metal concentration in cucumber (mg/kg wet weight).

CR = The consumption rate of cucumber (345 g/day for adults and 232 g/day for children) and average body weight (55.90 kg for adults and 32.70 kg for children) [37].

In this study, a non-carcinogenic risk assessment method was based on THQ, a ratio between the estimated contaminant dose and the oral reference dose (RfD), below which there will not be any appreciable risk. The THQ was determined with a formula described by USEPA [38]:

$$THQ = EDI/ RfD$$

where;

EDI = Estimated daily intake calculated previously; RfD

= The oral reference dose. The RfD ($\mu\text{g}/\text{kg}$ wet weight/day) values used in this study were Fe: 700, Ni: 20.0, Cu: 40.0, and Zn: 300, provided by the EPA's Integrated Risk Information System online database [39]. Since RfD for Pb was unavailable according to the EPA's IRIS [39], the present study employed the RfD as 4.00 $\mu\text{g}/\text{kg}$ wet weight/day proposed by FAO/ WHO [40]. It is estimated that if the THQ ratio is more than one, vegetable consumption will result in a non-carcinogenic risk of heavy metals to human health.

Results

The heavy metal concentrations (mg/kg dry weight) in the cucumber collected from the four sites in Peninsular Malaysia are presented in Table 2. For the edible fruity cucumber, the ranges of metal concentrations (mg/kg wet weight) from the four sites were 0.41-0.58 for Cu, 1.70-4.69 for Fe, 0.01-0.09 for Ni, 0.03-0.12 for Pb and 0.75-2.67 for Zn (Table 2). The maximum permissible limits for Cu, Pb and Zn set by the Malaysian Food Act 1983 and Regulation 1985 are 30.0, 2.00 and 100 mg/kg wet weight [41]. Therefore, the Cu, Pb and Zn levels found in the present study's cucumbers are well below the MPLs.

The Fe limit has not been found in the literature. Similarly, the Ni maximum permissible limits (MPL), known as the action level (80 mg/kg WW) for molluscan shellfish (FDA Guidance Document), has been set at 80 mg/kg wet weight [42]. However, the Ni limit for fruit and vegetables has not been found in the literature or is lacking, or validation of the Ni limits is needed. Therefore, comparisons of the MPLs for Fe and Ni are not possible.

Overall, the PTM values are comparable to those reported from Tongling [43], Pearl River Estuary [44,45], and Saudi Arabian markets [46]. However, the present data are significantly lower than those reported from Guangdong, especially for Pb and Zn (Table 2) [47].

The values of EDI and THQ of the five heavy metals in the cucumber for adults and children from the present study are presented in Tables 3,4, respectively. All the THQ values for Fe, Cu, Ni, Pb, and Zn in both adults and children were found below 1.00. This indicates there is no non-carcinogenic risk of Fe, Cu, Ni, Pb, and Zn via the consumption of the cucumber from the present study. Overall, the EDI and THQ values are comparable those reported from Tongling [43], Pearl River Estuary [44,45], and Saudi Arabian markets [46] but are significant lower than those reported from Guangdong especially for Pb and Zn in which the THQ values are higher than 1.0 for both Pb and Zn [47] (Tables 3 and 4).

In general, the THQ values of heavy metals in children are higher than in adults. Zhang, et al. [48] collected greenhouse

Table 1: Comparison of metal concentrations (mg/kg dry weight) between certified and measured values. The certified values are based on certified reference materials were *Lagarosiphon major* N.60 and Peach Leaves (NIST 1547).

	<i>Lagarosiphon major</i> N.60		
	Certified value	Measured value	Recovery (%)
Cu	51.20 ± 1.9	61.54 ± 1.4	120.2
Zn	313 ± 8	304.85 ± 3.4	97.4
Pb	64 ± 4.00	76.3 ± 2.40	119
	Peach Leaves (NIST 1547).		
Ni	0.689	0.81	117
Fe	219.8	211	97.0

Table 2: Mean heavy metal concentrations (mg/kg dry weight) in cucumber *Cucumis sativus* collected from four farms in Peninsular Malaysia. Note: Values in brackets are converted into wet weight basis using a conversion factor of 0.043.

Site	Cu	Fe	Ni	Pb	Zn	SD	Source of irrigation	Reference
Ara Kuda	9.56 (0.41)	109 (4.69)	1.40 (0.06)	0.74 (0.03)	26.1 (1.12)	12-Oct-16	Tube well and stream	This study
Kg Sitiawan	11.1 (0.48)	56.6 (2.43)	1.40 (0.06)	1.39 (0.06)	17.5 (0.75)	17-Nov-16	Domestic wastewater, tube well and stream	This study
Kuala Ketil	12.4 (0.53)	39.5 (1.70)	2.19 (0.09)	2.78 (0.12)	20.0 (0.86)	21-Dec-16	Tube well and stream	This study
Jerantut	13.6 (0.58)	82.0 (3.53)	0.18 (0.01)	1.60 (0.07)	62.0 (2.67)	12-May-16	Private farms, a river, distance from the highway, surrounded by forest.	This study
Tongling, China	0.36	NA	NA	0.018	1.539	Unspecified	mining area	Ding, et al. [41]
Pearl River Estuary, China*	0.52	NA	0.074	0.023	1.615	Unspecified	Reclaimed tidal flat soil	Li, et al. [42]
Chongqing, China	32.2	NA	NA	10.2	57.0	2008-2009	27 supermarkets	Yang, et al. [43]
Guangdong Province, China	17.0	NA	NA	164	806	Unspecified	Polluted sites	Wang, et al. [45]
Saudi Arabian markets	3.21	113	NA	3.67	29.8	2011	Dammam City	Ali and Al-Qahtani [44]

Note: SD: Sampling date; *: in wet weight basis; NA: data is not available.

Table 3: Values of estimated daily intake (EDI) of heavy metal concentrations in cucumber *Cucumis sativus* collected from four farms in Peninsular Malaysia.

Consumption rate of vegetables (g/day)	Adults					Children				
	Cu	Fe	Ni	Pb	Zn	Cu	Fe	Ni	Pb	Zn
Body weight (kg)	345					323				
	55.9					32.7				
Ara Kuda	2.54	28.9	0.37	0.20	6.91	4.06	46.3	0.59	0.31	11.1
Kg Sitiawan	2.94	15.0	0.37	0.37	4.63	4.70	24.1	0.59	0.59	7.42
Kuala Ketil	3.29	10.5	0.58	0.74	5.32	5.26	16.8	0.93	1.18	8.51
Jerantut	3.61	21.8	0.05	0.42	16.5	5.78	34.8	0.08	0.68	26.3
Tongling mining area, China*	2.23	NA	NA	0.11	9.50	3.57	NA	NA	0.18	15.2
Pearl River Estuary, China*	3.18	NA	0.46	0.14	9.97	5.10	NA	0.73	0.23	15.9
Chongqing, China	8.55	NA	NA	2.71	15.1	13.7	NA	NA	4.33	24.2
Guangdong Province, China	4.51	NA	NA	43.5	214	7.22	NA	NA	69.7	342
Saudi Arabian markets	0.85	29.9	NA	0.97	7.91	1.36	47.9	NA	1.56	12.7

Note: All metal data were converted to wet weight basis using a conversion factor of 0.043 for the calculation of EDI. *: The data were not converted since the data is already in wet weight basis. NA: Data is not available.

Table 4: Values of target hazard quotient (THQ) of heavy metal concentrations in cucumber *Cucumis sativus* collected from four farms in Peninsular Malaysia.

RfD ($\mu\text{g}/\text{kg}$ wet weight/day)	Adults					Children				
	Cu	Fe	Ni	Pb	Zn	Cu	Fe	Ni	Pb	Zn
Ara Kuda	0.063	0.041	0.019	0.049	0.023	0.102	0.066	0.030	0.079	0.037
Sitiawan	0.073	0.021	0.019	0.092	0.015	0.117	0.034	0.030	0.148	0.025
Kuala Ketil	0.082	0.015	0.029	0.184	0.018	0.132	0.024	0.047	0.295	0.028
Jerantut	0.090	0.031	0.002	0.106	0.055	0.144	0.050	0.004	0.170	0.088
Tongling mining area, China*	0.056	NA	NA	0.028	0.032	0.089	NA	NA	0.044	0.051
Pearl River Estuary, China*	0.080	NA	0.023	0.035	0.033	0.127	NA	0.037	0.057	0.053
Chongqing, China	0.214	NA	NA	0.677	0.050	0.342	NA	NA	1.083	0.081
Guangdong Province, China	0.113	NA	NA	10.881	0.713	0.181	NA	NA	17.414	1.141
Saudi Arabian markets	0.021	0.043	Na	0.243	0.026	0.034	0.068	NA	0.390	0.042

NA = data is not available.

surface soils (0–20 cm) and 30 vegetables from Kunming City, Yunnan Province, southwestern China, and analyzed for total Cd, Pb, Cu, Zn, As, Hg, and Cr. They found that the THQ value was greater than one for adolescents, indicating a non-carcinogenic risk of heavy metals in adolescents. To reduce the health risk effects, it is suggested that industrial wastes be treated properly and phyto-extract the overload of heavy metals and metalloids from polluted sites.

Discussion

The low human health risk of potentially toxic metals in cucumber collected from farming sites can be attributable to

controlling and minimizing pre-harvest contamination. By implementing effective measures to control and minimize pre-harvest contamination, the risk of potentially toxic metals in cucumbers collected from farming sites can be reduced to levels that pose low human health risks. Additionally, studies have shown that their concentrations influence the bioaccumulation of metals in vegetables in the soil. For instance, higher levels of metals such as Cd, Fe, and Ni in vegetables were found to be correlated with higher levels of these metals in the soil [49].

Factors such as the geochemical composition of the

soil, levels of metals in the organic matter and sulphides of the soil, and solubility and interchangeable geochemical fractions of the surrounding soils can influence the bioaccumulation of metals in vegetables [5]. Furthermore, the bioavailability of metals in the soil can vary depending on the specific type of metal. For example, studies have shown that the bioavailability of Zn in vegetables can be assessed by the combined concentrations of Zn in the surrounding soils. Meanwhile, vegetable metal levels may not always be strongly related to those in the habitat topsoils.

Based on the THQ values, it has been determined that the levels of Cd, Fe, Ni, and Zn in cucumbers collected from farming sites pose low human health risks. This is supported by studies showing that the THQ values for these metals in cucumbers were all below 1. This indicates that consuming cucumbers from these farming sites would not result in non-carcinogenic risks to consumers, including children and adults. Furthermore, studies have reported that the levels of Fe in lettuce are significantly higher than in other vegetables but still below the threshold for adverse effects. Therefore, the potential human health risks from potentially toxic metals in cucumbers collected from farming sites are low when effective pre-harvest contamination control measures are implemented. However, there is always a need to continuously monitor and assess the levels of potentially toxic metals in cucumbers and other vegetables and implement effective measures to minimize contamination risks.

The levels of potentially toxic metals in cucumbers collected from farming sites have been found to pose low human health risks. However, it is important to note that continued monitoring and implementation of effective measures to minimize contamination risks are still necessary to ensure the safety of cucumbers and other vegetables for human consumption. Therefore, based on the available evidence, it can be concluded that the risk of high human health risks from potentially toxic metals in cucumbers collected from farming sites is minimal.

Finally, the biomonitoring of PTMs in the edible cucumber is crucial for several reasons. Firstly, cucumbers are widely consumed as a food source by humans, making it essential to ensure their safety and quality. Secondly, cucumber plants have the ability to absorb and accumulate PTMs from contaminated soil and water, making them potential indicators of environmental pollution. Thirdly, the presence of PTMs in cucumbers can harm human health, as these metals can be toxic and may lead to various health issues, such as heavy metal poisoning and organ damage. Therefore, by monitoring PTMs in cucumber plants, we can identify and mitigate potential risks to human health and the environment. Furthermore, PTM monitoring in cucumber for wastewater and soil analysis is important

for environmental management and remediation. It allows us to identify areas that may be contaminated with PTMs, determine the extent of contamination, and develop strategies for remediation and pollution control.

Conclusion

In sum, the HHRA of metals in the cucumbers investigated in the present study indicated no non-carcinogenic risks of Fe, Cu, Ni, Pb, and Zn from consuming the cucumbers. Nevertheless, the findings emphasized the need for routine monitoring and management to avoid cucumber contamination from the wastewater irrigation system. In conclusion, effective pre-harvest control measures can minimise the risk of PTM contamination in cucumbers collected from farming sites.

Author contributions

Conceptualisation, C.K.Y.; methodology and validation, C.K.Y. and A.Y.; formal analysis, A.Y. and Z.S.; investigation, C.K.Y.; resources, M.C.O.; data curation, C.K.Y. and M.C.O.; writing—original draft preparation, C.K. Y.; writing—review and editing, W.M.S., R.N., H.O., Y.H., C.S.L., AD.S., K.K., W.H.C. and K.A.A. All authors have read and agreed to the published version of the manuscript.

References

- Jolly YN, Akter S, Kabir MJ, Mamun KM, Abedin MJ, Fahad SM, Rahman A. Heavy Metals Accumulation in Vegetables and Its Consequences on Human Health in the Areas Influenced by Industrial Activities. *Biol Trace Elem Res.* 2024 Jul;202(7):3362-3376. doi: 10.1007/s12011-023-03923-6. Epub 2023 Oct 28. PMID: 37897594.
- Ji L, Ma K, Xie TN, Chen L, Li H, Jia B. Evaluation of Heavy Metal Distribution Characteristics and Ecological Risk of Soil of Vegetable Land for Hong Kong in Ningxia. *Environ Sci.* 2024; 45(6):3512-3522.
- Hassan J, Rajib MMR, Khan MN-E-A, Khandaker S, Zubayer M, Ashab KR, Kuba T, Marwani HM, Asiri AM, Hasan MM, Islam A, Rahman MM, Awual MR. Assessment of heavy metals accumulation by vegetables irrigated with different stages of textile wastewater for evaluation of food and health risk. *J Environ Manage.* 2024; 353:120206.
- Francis Gbedemah S, Attasse Gbeasor A, Selorm Hosu-Porbley G, Kusi Frimpong L, Amfo-Otu R, Kofi Adanu S, Doe EK. Analysis of heavy metals and pathogen levels in vegetables cultivated using selected water bodies in urban areas of the Greater Accra Metropolis of Ghana. *Heliyon.* 2024; 10(7):27924.
- Yap CK, Yaacob A, Tan WS, Al-Mutairi KA, Cheng WH, Wong KW, Edward FB, Ismail MS, You C, Chew W, Nulit R, Ibrahim MH, Amin B, Sharifinia M. Potentially Toxic Metals in the High-Biomass Non-Hyperaccumulating Plant *Amaranthus viridis*: Human Health Risks and Phytoremediation Potentials. *Biology.* 2022; 11(3):389. doi: 10.3390/biology11030389.
- Singh R, Singh PK, Madheshiya P, Khare AK, Tiwari S. Heavy metal contamination in the wastewater irrigated soil and bioaccumulation in cultivated vegetables: Assessment of human health risk. *J Food Comp Anal.* 2024; 128:106054.
- Ismael DS, Goran SMA. Health risk assessment of heavy metals in some vegetables-Erbil City-Kurdistan Region of Iraq. *Environ Monit Assess.* 2024 Apr 3;196(5):417. doi: 10.1007/s10661-024-12542-0. PMID: 38570421.

8. Chinnannan K, Somagattu P, Yammanuru HK, Reddy U, Nimmakayala P. Health risk assessment of heavy metals in soil and vegetables from major agricultural sites of Ohio and West Virginia. *Biocatal Agric Biotechnol*. 2024; 57:103108.
9. Ugulu I, Khan ZI, Bibi S, Ahmad K, Munir M, Memona H. Evaluation of the Effects of Wastewater Irrigation on Heavy Metal Accumulation in Vegetables and Human Health in the Cauliflower Example : Heavy Metal Accumulation in Cauliflower. *Bull Environ Contam Toxicol*. 2024 Feb 28;112(3):44. doi: 10.1007/s00128-024-03858-1. PMID: 38416161.
10. K?z?lo?lu FM, Turan M, ?ahin Ü, Ku?lu Y, Dursun A. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica oleracea* L. var. botrytis) and red cabbage (*Brassica oleracea* L. var. rubra) grown on calcareous soil in Turkey. *Agric Wat Manage*. 2008; 95(6):716-724. doi: 10.1016/j.agwat.2008.01.008
11. Hamilton AJ, Mebalds MI, Aldaoud R, Heath M. Physical, Chemical and Microbial Characteristics of Wastewater from Carrot Washing in Australia. *J Veget Sci*. 2006; 11(3):57-72. doi: 10.1300/j484v11n03_06
12. Eissa MA, Negim O. Heavy metals uptake and translocation by lettuce and spinach grown on a metal-contaminated soil. doi: 10.4067/s0718-95162018005003101.
13. Sharma A, Katnoria JK, Nagpal AK. Heavy metals in vegetables: screening health risks involved in cultivation along wastewater drain and irrigating with wastewater. *Springerplus*. 2016 Apr 19;5:488. doi: 10.1186/s40064-016-2129-1. PMID: 27218003; PMCID: PMC4837749.
14. Malchi T, Maor Y, Tadmor G, Shenker M, Chefetz B. Irrigation of root vegetables with treated wastewater: evaluating uptake of pharmaceuticals and the associated human health risks. *Environ Sci Technol*. 2014 Aug 19;48(16):9325-33. doi: 10.1021/es5017894. Epub 2014 Jul 24. PMID: 25026038.
15. Manasfi R, Brienza M, Ait-Mouheb N, Montemurro N, Perez S, Chiron S. Impact of long-term irrigation with municipal reclaimed wastewater on the uptake and degradation of organic contaminants in lettuce and leek. *Sci Total Environ*. 2021 Apr 15;765:142742. doi: 10.1016/j.scitotenv.2020.142742. Epub 2020 Oct 3. PMID: 33097266.
16. Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environ Pollut*. 2008 Apr;152(3):686-92. doi: 10.1016/j.envpol.2007.06.056. Epub 2007 Aug 27. PMID: 17720286.
17. Eid EM, Alrumman SA, El-Bebany AF, Hesham AE, Taher MA, Fawy KF. The effects of different sewage sludge amendment rates on the heavy metal bioaccumulation, growth and biomass of cucumbers (*Cucumis sativus* L.). *Environ Sci Pollut Res Int*. 2017 Jul;24(19):16371-16382. doi: 10.1007/s11356-017-9289-6. Epub 2017 May 26. PMID: 28550630.
18. Wang Y, Qiao M, Liu Y, Zhu Y. Health risk assessment of heavy metals in soils and vegetables from wastewater irrigated area, Beijing-Tianjin city cluster, China. *J Environ Sci (China)*. 2012;24(4):690-8. doi: 10.1016/s1001-0742(11)60833-4. PMID: 22894104.
19. Alcántara E, Romera FJ, Canete M, De la Guardia MD. Effects of heavy metals on both induction and function of root Fe(III) reductase in Fe-deficient cucumber (*Cucumis sativus* L.) plants. *J Exp Bot*. 1994; 45(281):1893-1898.
20. Romera FJ, Alcántara E, De la Guardia MD. Influence of bicarbonate and metal ions on the development of root Fe(III) reducing capacity by Fe-deficient cucumber (*Cucumis sativus*) plants. *Physiologia Plantarum*. 1997;101(1):143-148.
21. Munzuroglu O, Geckil H. Effects of metals on seed germination, root elongation, and coleoptile and hypocotyl growth in *Triticum aestivum* and *Cucumis sativus*. *Arch Environ Contam Toxicol*. 2002 Aug;43(2):203-13. doi: 10.1007/s00244-002-1116-4. PMID: 12115046.
22. Tabaldi LA, Ruppenthal R, Cargnelutti D, Morsch VM, Pereira LB, Schetinger MRC. Effects of metal elements on acid phosphatase activity in cucumber (*Cucumis sativus* L.) seedlings. *Environ Exp Bot*. 2007; 59(1):43-48.
23. Janicka-Russak M, Kaba?a K, Burzy?ski M, K?obus G. Response of plasma membrane H⁺-ATPase to heavy metal stress in *Cucumis sativus* roots. *J Exp Bot*. 2008;59(13):3721-8. doi: 10.1093/jxb/ern219. Epub 2008 Sep 26. PMID: 18820260; PMCID: PMC2561156.
24. Prakash O, Talat M, Hasan SH, Pandey RK. Enzymatic detection of heavy metal ions in aqueous solution from vegetable wastes by immobilizing pumpkin (*Cucumis melo*) urease in calcium alginate beads. *Biotechnol Bioprocess Eng*. 2008; 13(2):210-216.
25. Minich AS, Minich IB, Chursina NL, Ivanitskiy AE, Butsenko ES, Rozhdestvenskiy EA. Morphogenesis and productivity of *Cucumis sativus* L. hybrids under the thermic polyethylene films modified by coating of metals by magnetron sputtering. *Horticult Sci*. 2016; 43(2):59-66.
26. Stevic N, Korac J, Pavlovic J, Nikolic M. Binding of transition metals to monosilicic acid in aqueous and xylem (*Cucumis sativus* L.) solutions: a low-T electron paramagnetic resonance study. *Biometals*. 2016 Oct;29(5):945-51. doi: 10.1007/s10534-016-9966-9. Epub 2016 Aug 8. PMID: 27502949.
27. Kaba?a K, Janicka-Russak M, Reda M, Migocka M. Transcriptional regulation of the V-ATPase subunit c and V-PPase isoforms in *Cucumis sativus* under heavy metal stress. *Physiol Plant*. 2014 Jan;150(1):32-45. doi: 10.1111/ppl.12064. Epub 2013 May 30. PMID: 23718549.
28. Freitag S, Krupp EM, Raab A, Feldmann J. Impact of a snail pellet on the phytoavailability of different metals to cucumber plants (*Cucumis sativus* L.). *Environ Sci Process Impacts*. 2013 Feb;15(2):463-9. doi: 10.1039/c2em30806a. Epub 2012 Dec 21. PMID: 25208711.
29. Kim S, Lee S, Lee I. Alteration of phytotoxicity and oxidant stress potential by metal oxide nanoparticles in *Cucumis sativus*. *Wat Air Soil Poll*. 2012; 223(5):2799-2806.
30. Zhang Y, Shi H, Po E, Tsang K. [Influences of heavy metal cadmium alone and in combination with zinc on the growth and activities of antioxidant enzymes of *Cucumis sativus* hairy roots]. *Sheng Wu Gong Cheng Xue Bao*. 2009 Jan;25(1):60-8. Chinese. PMID: 19441228.
31. Arata S, Giacco E, Agrone C, Lodi A. Effect of heavy metals on germination and growth of *Cucumis sativus*. *J Biol Res*. 2011; 84(1):18-19.
32. Chin HF, Yap EE. *Malaysian vegetables in colour: A complete guide*. Kuala Lumpur: Tropical Press; 1999.
33. Prohens J, Nuez F. *Vegetables I: Asteraceae, Brassicaceae, Chenopodiaceae, and Cucurbitaceae*. New York: Springer; 2008.
34. Prohens J, Nuez F. *Vegetables II: Fabaceae, Liliaceae, Solanaceae, and Umbelliferae*. New York: Springer; 2008.
35. Yaacob A, Yap CK, Nulit R, Omar H, Al-Shami SA, Bakhtiari AR. Assessment of health risks of the toxic Cd and Pb between leafy and fruit vegetables collected from selected farming areas of Peninsular Malaysia. *Integr Food Nutr Metabolis*. 2018; 5(3):1-9.
36. Yaacob A, Yap CK, Nulit R, Omar H, Al-Shami SA, Bakhtiari AR. A Comparative study of Health Risks of Fe and Ni in the Vegetables Collected from Selected Farming Areas of Peninsular Malaysia. *J Aquat Pollut Toxicol*. 2018; (1):21.
37. Wang X, Sato T, Xing B, Tao S. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. *Sci Total Environ*. 2005 Nov 1;350(1-3):28-37. doi: 10.1016/j.scitotenv.2004.09.044. Epub 2005 Jan 28. PMID: 16227070.
38. USEPA (United States Environmental Protection Agency). *Risk-based Concentration Table*. United States Environmental Protection Agency, Washington, DC; 2000.
39. IRIS (Integrated Risk Information System). *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*. US

- Environmental Protection Agency. [Internet]. <http://cfpub.epa.gov/ncea/cfm/recorddisplay.cfm?deid=22567#Download>. Accessed 2020 May 27.
40. FAO/WHO. Guidelines for the Safe Use of Wastewater and food stuff; Volume 2: No1 14, pp 988. Wastewater Use in Agriculture. World Health Organization, Geneva; 2013.
 41. MFR (Malaysian Food Regulations). Food Act 1983 (Act 281) & Food Regulations. International Law Book Services: Kuala Lumpur, Malaysia; 1985; 43-44.
 42. US FDA/CFSAN. National Shellfish Sanitation Program. Guide for the Control of Molluscan Shellfish. Guidance Documents Chapter II. Growing Areas: 04. In Action Levels, Tolerances, and Guidance Levels for Poisonous or Deleterious Substances in Seafood. U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition: College Park, MD, USA; 2007.
 43. Ding Z, Li Y, Sun Q, Zhang H. Trace Elements in Soils and Selected Agricultural Plants in the Tongling Mining Area of China. *Int J Environ Res Public Health*. 2018 Jan 25;15(2):202. doi: 10.3390/ijerph15020202. PMID: 29370134; PMCID: PMC5858271.
 44. Li Q, Chen Y, Fu H, Cui Z, Shi L, Wang L, Liu Z. Health risk of heavy metals in food crops grown on reclaimed tidal flat soil in the Pearl River Estuary, China. *J Hazard Mater*. 2012 Aug 15;227-228:148-54. doi: 10.1016/j.jhazmat.2012.05.023. Epub 2012 May 14. PMID: 22657103.
 45. Yang QW, Xu Y, Liu SJ, He JF, Long FY. Concentration and potential health risk of heavy metals in market vegetables in Chongqing, China. *Ecotoxicol Environ Saf*. 2011 Sep;74(6):1664-9. doi: 10.1016/j.ecoenv.2011.05.006. Epub 2011 May 20. PMID: 21601282.
 46. Ali MHH, Al-Qahtani KM. Assessment of some heavy metals in vegetables, cereals and fruits in Saudi Arabian markets. *Egypt J Aquat Res*. 2012; 38:31-37.
 47. Wang QR, Cui YS, Liu XM, Dong YT, Christie P. Soil contamination and plant uptake of heavy metals at polluted sites in China. *J Environ Sci Health A Tox Hazard Subst Environ Eng*. 2003 May;38(5):823-38. doi: 10.1081/ese-120018594. PMID: 12744435.
 48. Zhang H, Huang B, Dong L, Hu W, Akhtar MS, Qu M. Accumulation, sources and health risks of trace metals in elevated geochemical background soils used for greenhouse vegetable production in southwestern China. *Ecotoxicol Environ Saf*. 2017 Mar;137:233-239. doi: 10.1016/j.ecoenv.2016.12.010. Epub 2016 Dec 19. PMID: 27951423.
 49. Yaacob A, Yap CK, Nulit R, Omar H, Aris AZ, Latif MT. Health risks of essential Cu and Zn via consumption of vegetables and relationships with the habitat topsoils from three farming areas of Peninsular Malaysia. In: Yap CK, ed. *Soil Pollution: Sources, Management Strategies and Health Effects*. New York, USA: Nova Science Publishers; 2019. Chapter 9; 229-260.
 50. Islam MS, Ahmed MK, Habibullah-Al-Mamun M. Apportionment of heavy metals in soil and vegetables and associated health risks assessment. *Stochastic Environ Res Risk Assess*. 2016; 30(1):365-377.

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