Cultivos Tropicales, 2022, vol. 43, no. 1, e01
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

http://ediciones.inca.edu.cu

enero-marzo
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas

Original Article

Permissible ranges of Cadmium and Lead in organic manures used in food production

Mirelys Rodríguez-Alfaro[1*]

Olegario Muñiz-Ugarte[2]

Clístenes W. Araújo-do Nascimento[3]

Alfredo Montero-Álvarez[4]

Bernardo Calero-Martín[1]

Francisco Martínez-Rodríguez[2]

[1]Departamento de Suelos y Fertilizantes. Ministerio de la Agricultura, La Habana, Cuba

[2]Instituto de Suelos. Ministerio de la Agricultura, La Habana, Cuba

[3]Universidad Federal Rural de Pernambuco, Recife, Brasil

[4]Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), La Habana, Cuba

[*]Author for correspondence: mirelysra79@gmail.com

ABSTRACT

In Cuba, in order to find national alternatives for agricultural production maintenance, the production and use of organic manures of diverse origins is promoted. However, it is important to maintain a systematic follow-up of their contents in heavy metals (HM), since they can contaminate the food produced with them; as well as to have permissible values of HM in organic manures, which are not currently available in the country. The objectives of this work were to evaluate the cadmium (Cd) and lead (Pb) content in organic manures used for vegetable production and to determine ranges of permissible values of these metals in organic manures. HM extraction in the samples of soils, organic manures, substrates and vegetables studied was carried out with 9 mL of HNO_3 and 3 mL of HCl using a microwave oven, according to USEPA 3051A methodology and determination by Optical Emission Spectrometry. The ranges 140-150 mg kg^{-1} for Pb and 2-3 mg kg^{-1} for Cd were established as permissible values for these metals in organic manures used in food production. Organic manures with high Cd and Pb contents cannot be used to prepare substrates for food production, especially vegetables, because they constitute contamination risks for human health.

Key words: heavy metals, compost, contamination

INTRODUCTION

The production in organoponics of Urban Agriculture is an alternative to a problem of high sensitivity for the population in underdeveloped countries, since it makes possible the supply of fresh vegetables, especially leaves and condiment plants throughout the year (1,2). In Cuba, the use of organic manures (OM) of diverse origins is considered an effective alternative as a new way for food production with low inputs (3,4). However, it is known that these organic materials could be a contaminant source of heavy metals (HM), so it is important to systematically monitor the content of these metallic contaminants, mainly cadmium (Cd) and lead (Pb). The effects caused by the addition of HM in soils and their influence on the development of plants and animals deserve man's attention because they endanger the planet survival (5,6).

Currently, there is an increasing interest in knowing the contents of HM in OM such as manure *compost* of different origins, filter cake (residue from the sugar industry), earthworm humus, chicken manure, bat guano, harvest residues, residual sludge, biosolids and *compost* obtained from various sources; as well as their risks to ecosystems and human health; which provides a measure of the potential danger for their use and management in food production (7). In this sense, the use of organic manures for the production of vegetables in agriculture requires the development of standards for their generation, collection, transport, treatment and use. There are few regulations in this regard in Cuba and there are none on the permissible values of HM in OMs.

The legislation elaboration in this regard requires a long process of research and legal basis that must be complied with. It is necessary to determine not only the permissible values in these materials, but also their maximum permissible loads, both annual and accumulated (8). However, the high demand of OM for food production in the country, mainly by the National Program of Urban, Suburban and Family Agriculture, the high toxicity of these HM (7) and that the permissible values of HM in organic manures are not yet defined in Cuba, justify the objective of the work to establish the ranges for Cd and Pb in organic manures used in food production, particularly in organoponics.

MATERIALS AND METHODS

The work was carried out from 2013 to 2018, at the Soil Institute of the Ministry of Agriculture, with support from the Basic Science and Technique Unit of the Soil Institute in Guantanamo, the Chemical Analysis Laboratory of the Center for Technological Applications and Nuclear Development (CEADEN) of the Ministry of Science Technology and Environment and the Rural Federal University of Pernambuco (UFRPE), Recife, Brazil.

Description of variants and sampling

For the study, beds 3 m long by 1 m wide were formed for each case, at the Soil Institute and at the Basic Science and Technology Unit of the Soil Institute in Guantánamo. The description of the variants is shown in Table 1.

Table 1. Variant characteristics

Variant	Substratum composition	Crops	
		Leafy vegetables	**Fruit vegetables**
I	50 % soil Red Ferrallitic typical (SRFT) + 50 % organic manure (vermicompost)	Lettuce (*Lactuca sativa, L. var. BH-15*)	Pepper (*Capsicum annuum, L. var. LPD-2*)
II	50 % SRFT + 50 % organic manure (compost of beef manure)	Chard (*Beta vulgaris, L. var. White Ribbed*)	Radish (*Raphanus sativus, var. Tropical PS-9*)
III	50 % SRFT + 50 % organic manure (compost of crop residues)		
IV	50 % SRFT + 50 % organic manure (compost of MSW, domestic waste).		
V	50 % soil Brown Sialitic fluffy (SBSF) + 50 % organic manure (compost of crop residues)		
VI	50 % SBSF + 50 % organic manure (compost of beef manure and vegetable residues)		
VII	50 % SBSF + 50 % organic manure (compost of beef manure)		
VIII	50 % SBSF + 50 % organic manure (compost of MSW, domestic trash**).		
IX	50 % soil Brown Sialitic calcic (SBSC) + 50 % organic manure (compost of MSW, crop residues)***)		
X	50 % SBSC + 50 % organic manure (compost of beef manure)		
XI	50 % SBSC + 50 % organic fertilizers (MSW compost from household garbage**)		
XII	50 % SBSC + 50 % organic fertilizers (MSW compost from household garbage*)		

SFRT: typical red Ferrallitic soil, SBSF: fluffy Sialitic Brown soil and SBSC: calcic Sialitic Brown soil. MSW: Municipal solid waste. (*) MSW from CEPRU "Sur Isleta". (**)MSW from CEPRU "Los Cocos". (***) MSW from CEPRU "Vilonio".

Soils used to prepare variants were classified according to the Cuban Soil Classification [9] and they were taken from areas of small or secondary forests, with a history of not having been fertilized, nor used for agriculture and livestock; as well as being far from sources of contamination by HM in a period of 50 years or more, which guaranteed a minimum alteration by anthropic action. The municipal solid waste (MSW) *compost* from domestic garbage used as organic manures in variants IV, VIII, IX, XI and XII were obtained from MSW from the Municipal Solid Waste Processing Centers (CEPRU according the Spanish acronyms) "Sur Isleta" and "Los Cocos", which process classified domestic garbage before forming the donkeys for compost production, and from the CEPRU "Vilonio" which only processes harvest waste, in Guantánamo province. The cow dung compost corresponding to variant XI came from the organoponic "Las Margaritas", located in the Marianao, Havana municipality and the remaining organic manures from the Organic Fertilizer Production Center from Cotorro, in Havana.

In each substrate prepared, crops referred to in Table 1 were sown in succession in the following order (lettuce-chard and pepper-radish). Soils and organic manures were sampled at the time of substrate preparation, in a random manner. Substrate samples were taken at a depth of 0-20 cm at the beginning of sowing and vegetables at the time of harvest. Both substrates and plants were sampled in a zigzag pattern along each bed, according to the standard [(10]). In all cases, three composite samples of between 15 and 20 single samples each were taken. Soils, substrates and organic manures sampled were air-dried and passed through a 2 mm sieve according to the Cuban standard [(11)]. Plant samples were washed, dried in an oven at 45 ºC to constant weight and ground to 74 m size.

Extraction and determination of HM contents in soils, substrates, organic manures and plants

Extraction of the pseudo-total Cd and Pb contents in the soil, substrate, organic fertilizer and plant samples was performed using the procedure described in USEPA Standard 3051A [(12)]. 0.50 g of each sample was weighed and added 12 mL of *aqua regia* invert, a mixture of pure nitric (HNO_3) and hydrochloric (HCl) acids for analysis (Merck PA), in a 3:1 ratio. A microwave oven was used for digestion (*Mars Xpress Microwave*), where, for soil, substrate and organic fertilizer samples, 10 minutes were set to reach a maximum temperature of 175 ºC, 10 minutes for maintenance and 15 minutes for the cooling process; while for plants, 15 minutes were set to reach a maximum temperature of 180 ºC, 10 minutes for maintenance and 15 minutes for cooling. An Optical Emission Spectrometer (ICP-OES/Optima 7000, Perkin Elmer) was used to determine the Cd and Pb contents.

For data analysis, the IBM-SPSS 20 statistical package was used with simple descriptive statistics parameters, the population mean and the standard deviation as a dispersion measure. The permissible values for each element, in fresh mass, according to the Food *Codex* [(13)] were used as a comparative reference for leafy vegetables and fleshy fruits and roots. For soils, the permissible limits described [(14)] were used, and for substrates and OMs, those appearing in the Standards were used [(15)].

Determination of permissible values for Cd and Pb in organic manures

In order to determine the permissible ranges of Cd and Pb in the OMs used for vegetable production, an adaptation of the methodology for obtaining critical values of microelements in soils, described by Trierweiler and Lindsay in 1969, was used [(16)]. The adaptation of this methodology consisted of separating statistically and graphically the OMs that contaminated the vegetables used as indicator plants for Cd and Pb contamination from the OMs that did not contaminate. A relationship was established between two pairs of quantitative variables using descriptive statistics with the IBM-SPSS

20 statistical package. One variable was the content of Cd and Pb in the organic manures, which was related to the content of these metals in leafy vegetables (lettuce and chard) and subsequently to the content in vegetables with fleshy fruits and roots (bell pepper and radish), always using the permissible values of the Food *Codex* [13].

RESULTS AND DISCUSSION

PM content in organic manures, soils and substrates

Table 2 shows the Cd and Pb content in organic manures used in each variant and their comparison with the maximum permissible limits corresponding to the standard [15]. The values of Cd and Pb in the organic manures, with the exception of the compost obtained from MSW from household garbage, are below the permissible limits, which affirms that these organic manures, from the point of view of their HM contents, can be used in the production of vegetables in organoponics, without causing harm to human health.

Table 2. Cd and Pb contents in the organic manures

Variant	Organic manure, soils	HM (X ± s) (mg kg^{-1})	
		Cd	Pb
I	Vermicompost	1,42 ± 0,01	88,63 ± 2,23
II	*Compost* of beef manure	1,89 ± 0,06	98,24 ± 6,08
III	*Compost* of crop residues	1,94 ± 0,10	100,10 ± 1,03
IV	*Compost* of MSW, domestic waste (*)	7,80 ± 0,28	465,83 ± 9,01
V	*Compost* of crop residues	1,96 ± 0,07	137,60 ± 2,10
VI	*Compost* of beef manure and vegetable residues	1,92 ± 0,01	134,93 ± 5,09
VII	*Compost* of beef manure	3,02 ± 0,05	150,24 ± 4,30
VIII	*Compost* of MSW, domestic trash (**)	6,15 ± 0,13	460,80 ± 9,33
IX	*Compost* of MSW, crop residues (***)	1,91 ± 0,09	139,10 ± 2,96
X	*Compost* of beef manure	3,04 ± 0,23	151,51 ± 5,03
XI	*Compost* of MSW, domestic waste (*)	3,63 ± 0,35	151,74 ± 1,06
XII	*Compost* of MSW, domestic waste (**)	4,60 ± 0,29	437,52 ± 8,01
SRFT		<1,00	24,35 ± 3,02
SBSF		<1,00	36,95 ± 2,95
SBSC		<1,00	46,09 ± 3,05
PML[a]		*3*	*180*
PML[b]		*3*	*150*

MSW: Municipal solid waste. (*) MSW from CEPRU "Sur Isleta". (**) MSW from CEPRU "Los Cocos". (***) MSW from CEPRU "Vilonio". SFRT: soil typical red Ferrallitic; SBSC: Sialitic Calcic Brown soil; SBSF: soil Sialitic Brown Fluffy [8]. PMLa: maximum permissible limit for substrates [15]. PMLb: permissible limit for soil [14]

In the case of MSW compost from household garbage, the Cd and Pb contents are above the established limits because they contain products that are sources of HM; for this reason, these organic materials should not be used for food production. However, depending on their HM content, they can be used in nurseries, forestry and ornamental plants. Similar results were found in other research [17], in which it is reported that Pb contents in the earthworm humus obtained from MSW are higher than in those obtained from cow dung and cattle manure, a phenomenon that is related to materials present in MSW that are polluting sources of HM. The Cd and Pb contents in the SRFT, SBSF and SBSC soils used to prepare variants are below the maximum permissible limits, so they are not contaminated.

Table 3 shows variants studied, as well as the corresponding permissible limits. The variants where the organic fertilizer used is contaminated (Table 2), the substrate also presents contents above the maximum permissible limits established for substrates [15].

Table 3. Cd and Pb contents in the substrates prepared for each variant

Variant	**Composición del sustrato**	**HP (X ± s) (mg kg^{-1})**	
		Cd	**Pb**
I	50 % SFRT + 50 % organic fertilizer (earthworm humus)	<1,00	66,46 ± 6,85
II	50 % SFRT + 50 % organic fertilizer (cow manure compost)	<1,00	98,06 ± 8,37
III	50 % SFRT + 50 % organic fertilizer (compost from harvest residues)	<1,00	65,36 ± 6,12
IV	50 % SFRT + 50 % organic fertilizer (MSW compost from household garbage*).	9, 61 ± 0,63	1 501,50 ± 10,60
V	50 % SBSF + 50 % organic manure (MSW compost from harvest residue)	<1,00	132,16 ± 8,07
VI	50 % SBSF + 50 % organic fertilizer (cattle manure and vegetable waste compost).	<1,00	76,56 ± 7,78
VII	50 % SPSM + 50 % organic fertilizer (cattle manure compost)	2,60 ± 0,10	251,72 ± 28,00
VIII	50 % SBSF + 50 % organic fertilizer (MSW compost from household garbage**)	9, 15 ± 0,59	352,00 ± 5,02
IX	50 % SBSC + 50 % organic fertilizer (MSW compost from crop residues***)	1,95 ± 0,93	145,00 ± 9,62
X	50 % SBSC + 50 % organic fertilizer (cattle manure compost***)	5,48 ± 0,95	399,60 ± 10,69
XI	50 % SBSC + 50 % organic fertilizers (MSW compost from household garbage***)	5,86 ± 0,32	305,90 ± 8,61
XII	50 % SBSC + 50 % organic fertilizers (MSW compost from household garbage*)	5,61 ± 0,63	1 301,5 ± 21,07
*PML**		*8*	*300*

PML*: permissible limit for substrates [15]. SFRT: typical red Ferrallitic Ferrallitic soil, SBSF: fluffy Sialytic Brown soil and SBSC: calcic Sialytic Brown soil. MSW: Municipal solid waste. (*) MSW from CEPRU "Sur Isleta". (**)MSW from CEPRU "Los Cocos". (***)MSW from CEPRU "Vilonio".

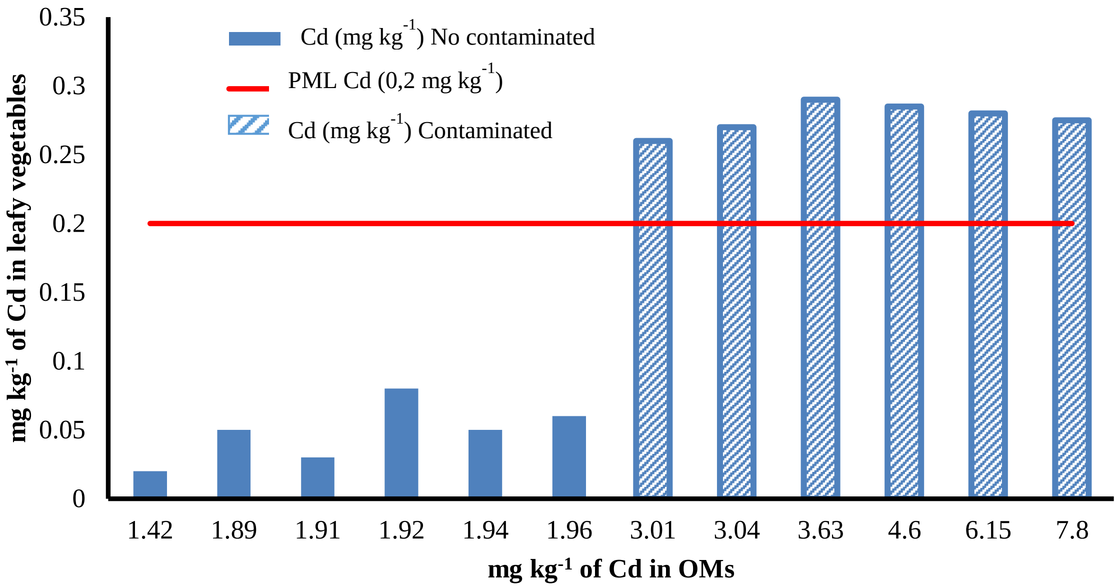
From the above, it is derived that the contamination of the substrates is due to the organic manures, since the soils are below the LPM. HM concentration in substrates was variable due to the heterogeneity of materials. Variability is an important element to consider because the real values, in some points, could be higher than those obtained [18].

The result allows affirming that these contaminated substrates cannot be used in food production because HM can be translocated to vegetables produced with them and directly affect living organisms. HM, especially Cd and Pb, affect various organs and tissues, producing chronic renal insufficiency, increased cholesterol, bone, testicles, placenta, liver, lungs, heart, and the central and peripheral nervous system; they can even cause cancer and finally death [19-21].

Cultivos Tropicales, 2022, vol. 43, no. 1, e01
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

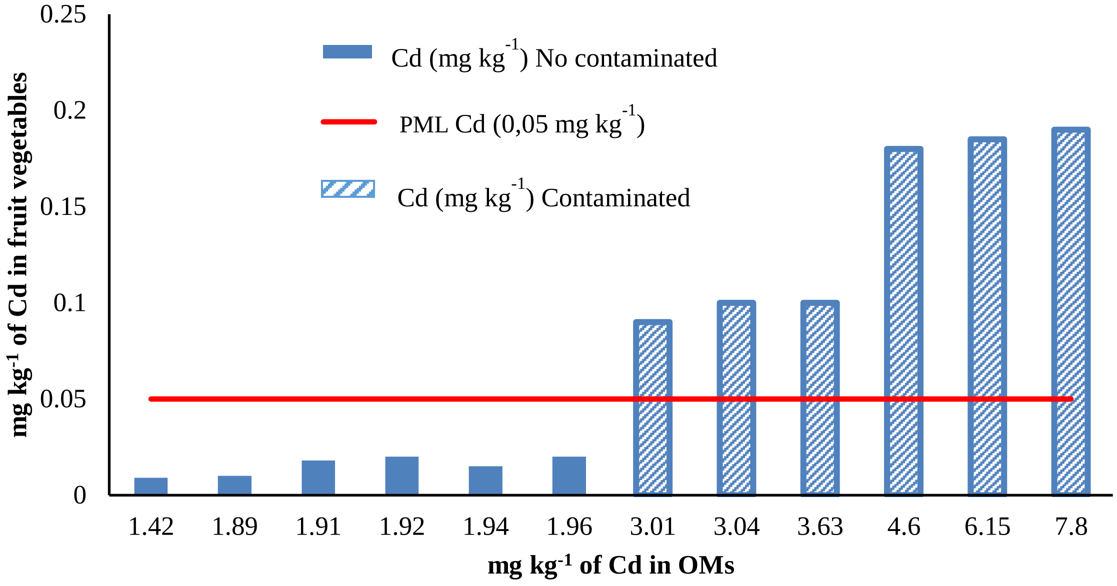
Permissible values of Cd and Pb in organic manures

Figures 1 and 2 show the relationship between Cd contents in OMs and its content in leafy and fleshy fruit and root vegetables grown with the application of them. When the Cd concentration in the organic fertilizer is equal to or higher than 3 mg kg^{-1}, its content in both leafy and fleshy fruit or root vegetables grown with the use of this organic fertilizer exceeds the maximum limit established by the Food *Codex* used as an evaluation criterion [13], which makes them unfit for human consumption; on the contrary, when the Cd content in the organic fertilizer is lower than 2 mg kg^{-1} it does not constitute a risk of contamination to vegetables. For this reason, 2-3 mg kg^{-1} of Cd in organic manures can be considered as the permissible range of the metal in these products, which indicates that only OMs with Cd concentrations below the lower value of the range can be used in vegetable production.



PML Cd: limit value for leafy vegetables [13]

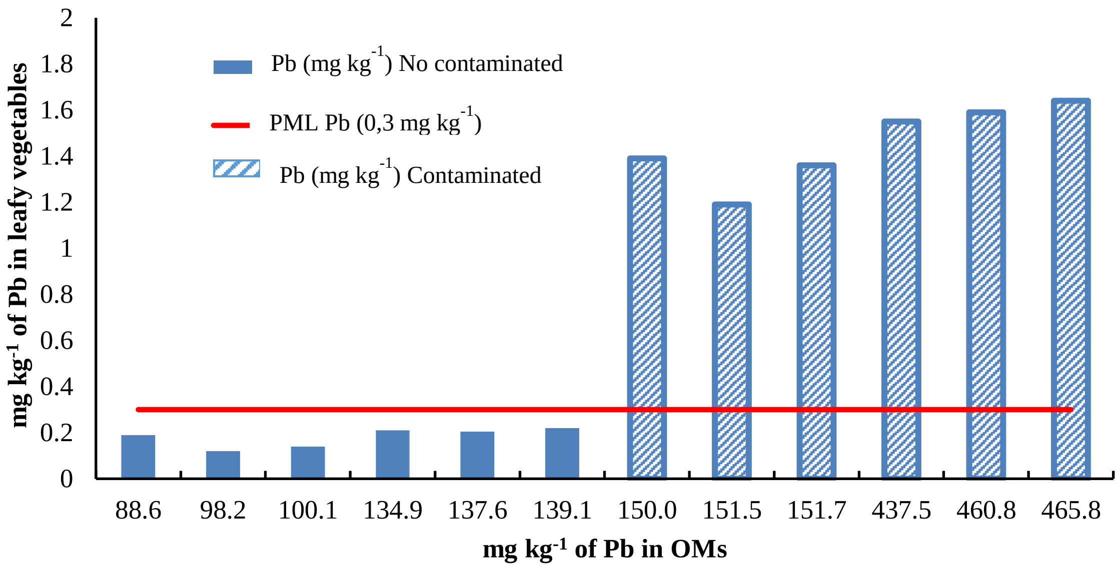
Figure 1. Relationship between Cd contents in leafy vegetables with the content in the OMs



PML Cd: limit value for fleshy fruit and root vegetables [13]

Figure 2. Relationship between Cd contents in fleshy fruit and root vegetables with the content in the OMs

In the Pb case (Figure 3), concentrations equal to or higher than 150 mg kg^{-1} in compost contaminate leafy vegetables, in accordance with the maximum permissible limits for PM in fresh vegetables. However, when the Pb value in compost is lower than 140 mg kg^{-1}, no contamination of crops occurs. Thus, it can be stated that 140-150 mg kg^{-1} Pb in OMs is the Pb permissible range in these organic products, which indicates that only OMs with Pb contents in OMs below the lower value of the range can be used in the production of leafy vegetables.

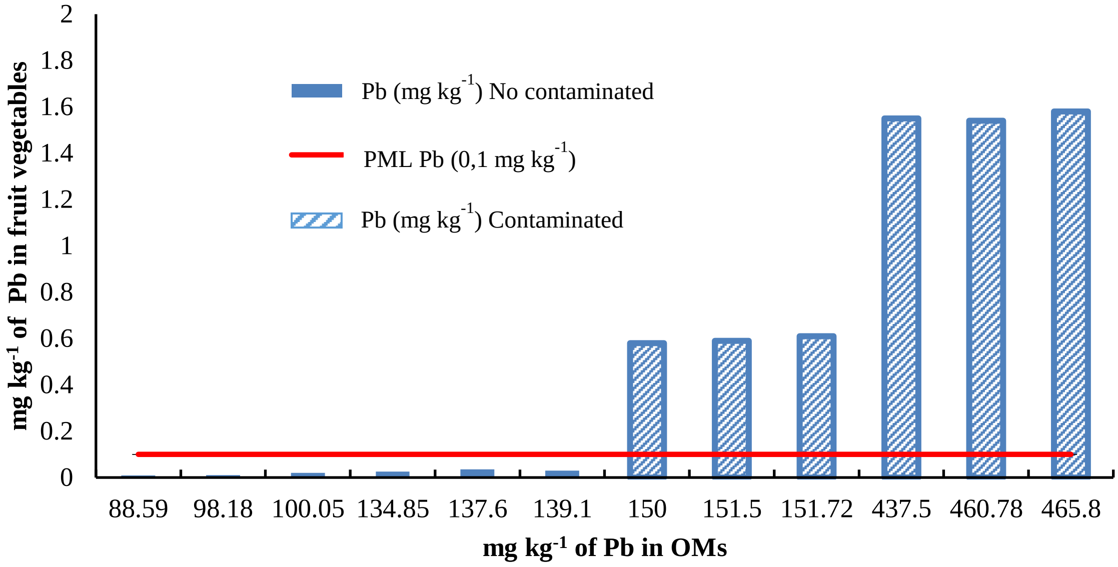


PML Pb: limit value for leafy vegetables [13]

Figure 3. Relationship between Pb contents in leafy vegetables and their content in the OMs

Cultivos Tropicales, 2022, vol. 43, no. 1, e01
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

When the Pb content in fruit vegetables is analyzed in relation to the Pb content in the organic fertilizer used for their production (Figure 4), a behavior similar to that found in leaf vegetables is observed, i.e., OMs with values below 140 mg kg^{-1} can be used to produce vegetables with low risk to human health; whereas, a concentration equal to or higher than 150 mg kg^{-1} can contaminate vegetables consumed by humans and cause serious damage to their health [22].



PML Pb limit value for fleshy fruit and root vegetables [13]

Figure 4. Relationship between Pb contents in fleshy fruit and root vegetables and their content in the OMs

Corresponding to the above, the values 2-3 mg kg^{-1} for Cd and 140-150 mg kg^{-1} for Pb are established as maximum permissible limit ranges for these metals for OMs used in food production, especially vegetables. This proposal coincides with what is referred to in the Spanish regulation RD 824/2005 for class B and class C *compost*, with the Ecolabel Decision 2001/688 and the resolution 2nd Draft B.T/2001 for second category *compost* of the European Community and with the Brazilian Normative Instruction for organic manures [15,23]. It is necessary to deepen these studies in order to obtain a final proposal of these maximum permissible limits of Cd and Pb.

CONCLUSIONS

- The permissible ranges 2-3 mg kg^{-1} Cd and 140-150 mg kg^{-1} Pb in organic manures guarantee the production of food, especially vegetables, free of these contaminants.
- Organic manures with Cd and Pb concentrations above the maximum permissible limits cannot be used to prepare substrates for food production because they constitute contamination risks for plants and animals, as well as for human health.

BIBLIOGRAPHY

1. Fernandez M, Williams J, Figueroa G, Graddy-Lovelace G, Machado M, Vazquez L, et al. New opportunities, new challenges: Harnessing Cuba's advances in agroecology and sustainable agriculture in the context of changing relations with the United States. Elementa: Science of the Anthropocene [Internet]. 2018;6. Available from: https://online.ucpress.edu/elementa/article/doi/10.1525/elementa.337/112850/New-opportunities-new-challenges-Harnessing-Cuba-s
2. Sánchez Báscones M, Correa-Guimaraes A, Pérez-Espinosa A, Blanco Covián D, Cabaleiro Núñez F, García-Morales JL, et al. De Residuo a Recurso: El Camino hacia la Sostenibilidad. I Recursos Orgánicos 2. Residuos Ganaderos [Internet]. Mundi-Prensa; 2016. Available from: https://digital.csic.es/handle/10261/196132
3. Alfaro MR, Do Nascimento CWA, Ugarte OM, Álvarez AM, de Aguiar Accioly AM, Martín BC, et al. First national-wide survey of trace elements in Cuban urban agriculture. Agronomy for sustainable development [Internet]. 2017;37(4):1–7. Available from: https://link.springer.com/article/10.1007/s13593-017-0437-7
4. Martínez F, García C, Gómez LA, Aguilar Y, Martínez-Viera R, Castellanos N, et al. Manejo sostenible de suelos en la agricultura cubana. Agroecología [Internet]. 2017;12(1):25–38. Available from: https://revistas.um.es/agroecologia/article/view/330321
5. Wei X, Zhou Y, Jiang Y, Tsang DC, Zhang C, Liu J, et al. Health risks of metal (loid) s in maize (*Zea mays* L.) in an artisanal zinc smelting zone and source fingerprinting by lead isotope. Science of the Total Environment [Internet]. 2020;742:140321. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0048969720338432
6. Hu Z, Li J, Wang H, Ye Z, Wang X, Li Y, et al. Soil contamination with heavy metals and its impact on food security in China. Journal of Geoscience and Environment Protection [Internet]. 2019;7(05):168. Available from: https://www.scirp.org/html/9-2170976_92760.htm?pagespeed=noscript
7. Dieleman H. Urban agriculture in Mexico City; balancing between ecological, economic, social and symbolic value. Journal of Cleaner Production [Internet]. 2017;163:S156–63. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0959652616001311
8. Kabata-Pendias A. Trace Elements in Soils and Plants [Internet]. Routledge & CRC Press. 2010 [cited 13/11/2021]. Available from: https://www.routledge.com/Trace-Elements-in-Soils-and-Plants/Kabata-Pendias/p/book/9781420093681
9. Hernández-Jiménez A, Pérez-Jiménez JM, Bosch-Infante D, Speck NC. La clasificación de suelos de Cuba: énfasis en la versión de 2015. Cultivos Tropicales [Internet]. 2019;40(1). Available

from: http://scielo.sld.cu/scielo.php?pid=S0258-59362019000100015&script=sci_arttext&tlng=pt

10. Oficina Nacional de Normalización O. Norma Cubana NC 36: 2009. Calidad del Suelo. Método para la determinación de la erosión potencial hídrica. Ed. 2. 12 p. Oficina Nacional de Normalización; 2009.
11. Oficina Nacional de Normalización O. Norma Cubana NC ISO 11464: 1999. Calidad de Suelos. Pretratamiento de las muestras para los análisis fisicoquímicos [Internet]. Oficina Nacional de Normalización; 1999. Available from: http://ftp.isdi.co.cu/Biblioteca/BIBLIOTECA%20UNIVERSITARIA%20DEL%20ISDI/COLECCION%20DIGITAL%20DE%20NORMAS%20CUBANAS/1999/NC-ISO%2011464.PDF
12. United States Environmental Protection Agency U. Method 3051A. Microwave assisted acid digestion of sediments, sludges, soils, and oils [Internet]. 2017. Available from: https://www.epa.gov/sites/default/files/2015-12/documents/3051a.pdf
13. Codex Stan 193-1995. Norma General del CODEX para los contaminantes y las toxinas presentes en los alimentos [Internet]. 2018 p. 48. Available from: https://www.fao.org/fileadmin/user_upload/livestockgov/documents/CXS_193s.pdf
14. Conselho Nacional do Meio Ambiente C. Resolução no 420, de 28 de dezembro de 2009 [Internet]. Ministerio Do Meio Ambiente; 2009. Available from: https://cetesb.sp.gov.br/areas-contaminadas/wp-content/uploads/sites/17/2017/09/resolucao-conama-420-2009-gerenciamento-de-acs.pdf
15. IN SDA 27. Instrução Normativa SDA nº 27 de 05/06/2006 - Federal - LegisWeb [Internet]. Ministério da Agricultura, Pecuária e Abastecimento. [cited 19/10/2021]. Available from: https://www.legisweb.com.br/legislacao/?id=76854
16. Trierweiler JF, Lindsay WL. EDTA-ammonium carbonate soil test for zinc. Soil Science Society of America Journal [Internet]. 1969;33(1):49–54. Available from: https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj1969.03615995003300010017x
17. García-Ramos C, Arozarena-Daza NJ, Martínez-Rodríguez F, Hernández-Guillén M, Pascual-Amaro JÁ, Santana-Gato D. Obtención de compost mediante la biotransformación de residuos de mercados agropecuarios. Cultivos Tropicales [Internet]. 2019;40(2). Available from: http://scielo.sld.cu/scielo.php?pid=S0258-59362019000200002&script=sci_arttext&tlng=pt
18. Da Silva FBV, do Nascimento CWA, Araújo PRM, da Silva FL, Lima LHV. Soil contamination by metals with high ecological risk in urban and rural areas. International Journal of Environmental Science and Technology [Internet]. 2017;14(3):553–62. Available from: https://link.springer.com/article/10.1007%2Fs13762-016-1170-5
19. Reyes Y, Vergara I, Torres O, Lagos MD, Jimenez EEG. Contaminación por metales pesados: Implicaciones en salud, ambiente y seguridad alimentaria. Ingeniería Investigación y Desarrollo:

I2+ D [Internet]. 2016;16(2):66–77. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=6096110

20. Alloway BJ. Heavy metals in soils: trace metals and metalloids in soils and their bioavailability [Internet]. Vol. 22. Springer Science & Business Media; 2012. Available from: https://link.springer.com/book/10.1007%2F978-94-007-4470-7
21. Cai L-M, Wang Q-S, Luo J, Chen L-G, Zhu R-L, Wang S, et al. Heavy metal contamination and health risk assessment for children near a large Cu-smelter in central China. Science of the Total Environment [Internet]. 2019;650:725–33. Available from: https://www.researchgate.net/profile/Limei-Cai-2/publication/327503351_Heavy_metal_contamination_and_health_risk_assessment_for_children_near_a_large_Cu-smelter_in_central_China/links/5fb5db8092851c933f3d5166/Heavy-metal-contamination-and-health-risk-assessment-for-children-near-a-large-Cu-smelter-in-central-China.pdf
22. Dala-Paula BM, Custódio FB, Knupp EA, Palmieri HE, Silva JBB, Glória MBA. Cadmium, copper and lead levels in different cultivars of lettuce and soil from urban agriculture. Environmental pollution [Internet]. 2018;242:383–9. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0269749118308753
23. Rosal A, Pérez JP, Arcos MA, Dios M. La incidencia de metales pesados en compost de residuos sólidos urbanos y en su uso agronómico en España. Información tecnológica [Internet]. 2007;18(6):75–82. Available from: https://scielo.conicyt.cl/scielo.php?pid=S0718-07642007000600010&script=sci_arttext&tlng=en