# Non-nutrient Heavy Metals in Tomato Plants Cultivated in Soil Amended with Biosolid and Sugar-Cane Bagasse Compost[1]

A.A.D. Cintra, M.D. Revoredo and W.J. Melo
Departament of Tecnologia
Faculdade de Ciências Agrárias e Veterinárias
UNESP/Jaboticabal, SP, CEP 14884-900
Brazil

L.T. Braz
Departament of Produção Vegetal

**Keywords:** *Lycopersicon esculentum*, Cd, Cr, Ni, Pb, compost, waste

## Abstract

**In this study, non-nutrient heavy metal concentrations (Cd, Cr, Ni and Pb) were measured in composts during the composting process, in compost/Red-yellow Latosol mixtures, and in tomato plants. Composts were produced using sugar-cane bagasse, biosolids and cattle manure in the proportions 75-0-25, 75-12.5-12.5, 75-25-0, 50-50-0 or 0-100-0 (composts with 0, 12.5, 25, 50 and 100% biosolids). The composts were applied to the soil, in 6 treatments and a control (mineral fertilization). Control and the 0% biosolids treatments received inorganic nitrogen and all the treatments received the same amount of N, P and K. Tomato plants were cultivated in 24-L pots, in a green house in Jaboticabal, SP, Brazil. The experiment had a split plot design, in randomized blocks. Cadmium, Cr, Ni and Pb concentrations were determined during the composting process (7, 27, 57, 97 and 127 days after compost mounting), in soil (0 and 164 days after mixing) and plants. The samples were subjected to digestion with $HNO_3$, $H_2O_2$ and HCl and the metals were determined by AAS. Negative correlations were observed between Cd, Cr and Pb in the compost and Cd, Cr and Pb plant uptake, as well as Ni in the compost and Ni concentration in the plants. The concentrations of Cd, Cr, Ni and Pb increased during composting. Only Cd levels increased when compost was applied to the soil. The roots accumulated Cr, Ni and Pb, the stems and leaves, Cd and Ni and the fruits did not accumulate any of the metals studied. The composts with biosolids did not increase Cd, Cr, Ni and Pb uptake by plants.**

## INTRODUCTION

Recently, there has been an increase in the use of organic residues as raw material for composting (Costa et al., 1997; Melo et al., 2000). Among organic materials, there is the possibility of using biosolids, which are rich in plant nutrients, in agricultural soils, and thereby solving two major problems: an adequate destination for the residue (Melo and Marques, 2000) savings on the use of mineral fertilizers (Ribeiro et al., 2000). However, in addition to organic matter and plant nutrients, biosolids also contain agents harmful to the environment, such as pathogenic organisms and heavy metals (Aggelides and Londra, 2000). The management of residues has thus changed from a disposal problem into a research challenge for reuse without creating adverse effects on the environment. Consequently, detailed studies are required to monitor areas that receive biosolids, so that the risks to plants and animals and humans can be evaluated (Sims, 1996). According to Ozores-Hampton (1994), the greatest possibility of using biosolids in agriculture is as a compost, and the use of this residue on horticultural crops has been studied extensively.

However, in some European countries, research has placed restrictions on the use of urban residues in agriculture, especially for food crops. Such restrictions are due to the relatively high levels of heavy metals, such as Cu and Cd in biosolids. These can lead to the contamination of the food chain, since there is an increase in the level of these elements in the soil (He et al., 1992).

[1] Presented by the first author. Part of his MS thesis in the Program Vegetable Production at the FCAV/UNESP.

Proc. XXVI IHC – Sustainability of Horticultural Systems
Eds. L. Bertschinger and J.D. Anderson
Acta Hort. 638, ISHS 2004
Publication supported by Can. Int. Dev. Agency (CIDA)

This study quantified the levels of Cd, Cr, Ni and Pb in composts prepared with biosolids, and their effects on the metal concentrations in the soil and their absorption by tomato 'Carmen' (*Lycopersicon esculentum* Mill.).

## MATERIALS AND METHODS

The study was carried out in a green house at FCAV/UNESP, located in the county of Jaboticabal, State of São Paulo, Brazil.

The organic composts were produced by the standard procedure of stacking the materials in alternate layers, with periodic turning and irrigation (Kiehl, 1998), in the proportions of 25:0:75; 12.5:12.5:75; 0:25:75; 0:50:50 and 0:100:0 cattle manure, biosolid and sugar-cane bagasse, respectively, denominated 0%; 12.5%; 25%; 50% and 100%, according to the amount of biosolid that each compost received. The chemical characterization of the materials used for composting is presented in Table 1.

After 137 days of composting, 300, 501, 430, 367 and 330 g organic compost of the treatments 0%, 12.5%, 25%, 50% and 100% respectively, were incorporated in a Red-Yellow distrophic latosol, A moderate, medium texture, in 24-L pots (25.34 kg air dried soil, 2 mm sieved). The compost doses varied in such a way to provide 8.33g N, 5.80g P and 8.11g K per pot (IAC, 1996) for the treatments 12.5%, 25%, 50% and 100%. Treatment 0% received 4.61 g N in an organic form (dose equivalent to 10 Mg $ha^{-1}$) and 3.72 g N in an inorganic form. Therefore, all treatments received the same amount of N, P and K. Applications of urea, simple superphosphate and potassium chloride were made if needed. Tomato 'Carmen', presenting determinate growth and long life type, was cultivated in the pots for 155 days, and was trained vertically, until the $4^{th}$ raceme appeared.

The concentrations of Cd, Cr, Ni and Pb were determined in the composts, in the soil and in the plants, by digesting them with $HNO_3$+$H_2O_2$+HCl (U.S. EPA, 1996), and then analyzing them by atomic absorption spectrophotometry. Samples were collected from the organic compost at 7, 27, 57, 97 and 137 d.a.m. (days after making the piles) and from the soil at 0 and 155 d.a.i. (days after incorporation of the compost). The correlations between the values of Cd, Cr, Ni and Pb in the compost, in the soil and in the plant were calculated.

A completely randomized block design was used in a 5x5 factorial scheme (five composts vs. five sampling dates) for the statistical analysis on the composts and a 6x2 factorial scheme for the soil (five organic fertilizations + mineral fertilization vs. two sampling dates). The averages were compared by the Tukey test ($p>0.05$).

## RESULTS AND DISCUSSION

There was an increase in metal concentration as the composting process advanced (Table 2), due to the loss of carbon, in the form of $CO_2$, as a result of microbial activity. This increase in concentration was more evident for Cd and there were exceptions in the 12.5% and 100% treatments. These variations in metal behavior could be explained by understanding that composts are a mixture of materials, and that the12.5% treatment received cattle manure, biosolid and sugar-cane bagasse, which made it harder to sample. In addition, biosolids are essentially mixtures, with great variation in their components.

As the amount of biosolids increased in the composts, there was an increase in the concentration of metals (Table 1). It was observed that beyond 99 d.a.i. there was no further increase in the concentration of the metals studied, indicating that the composting process was already stabilized.

The application of biosolids compost to the soil increased the level of Cd (Table 3) but did not change the levels of Cr, Ni and Pb. Growing tomato in the amended soil, increased the levels of Cd and Ni in the soil, while the level of Cr was stable and the level of Pb decreased (Table 3). Among the metals analyzed, Ni, Cd and Cr were most readily absorbed by tomato plants (Fig. 1). It is known that the incorporation of organic materials in the soil promotes the liberation of organic acids that can increase the availability of metals adsorbed on the chelates and clays. This effect could have increased the availability of Cd and Ni, allowing the plants to absorb more of them. Illera et al. (2000) analyzed the distribution of heavy metals in organic materials to determine their bioavailability and found differences in the speciation of heavy metals in organic residues: Cr and Ni were more abundant in the residual and organic fractions of the soil. According to Melo et al. (2000), the heavy metals tend to be complexed with the organic matter, decreasing their mobility, and making the distribution in the soil profile follow that of soil organic matter. These authors also state that, in some cases, however, the formation of low molecular weight complexes with the soluble fraction of the organic matter can make these metals soluble.

Sadonikova & Zyrin (1986) classified the pollution level of a soil by heavy metals as a function of the organic matter level. When the heavy metal level reaches 3-5 times the original level and the organic matter level is around 10-15 g $kg^{-1}$, or when the heavy metal reaches 5-20 times the original level and the organic matter is around 30-40 g $kg^{-1}$, the soil is considered polluted. In this sense, areas that receive fertilizers (organic or inorganic) containing materials that could be harmful should be carefully monitored. A lack of statistical significance for the levels of metals in a soil does not imply that there is no possibility of problems occurring after several years of cultivation. The levels permitted for heavy metals in the soils of São Paulo State (CETESB, 1999) are approximately 10 times greater than those found in this experiment, and the contribution of the organic materials incorporated was minimal (Table 3), since the metals studied were already present in the soil analyzed.

There was no translocation of the heavy metals into the fruits (Figure 1). Poulik (1999) observed Ni translocation to the fruit when increasing doses were applied. The greatest concentrations of Cd were found in the leaves, and those of Cr, Ni and Pb in the roots (Figure 1). The greatest absorption of Cr, Ni and Pb was found in the treatment with 0% biosolids. Poulik (1999), growing tomato and lettuce in soils contaminated with increasing amounts of Ni, found that Ni absorption by the plants was much smaller than the levels present in the soil.

The control and 0% biosolids treatments, that had the greatest dry matter accumulation, promoted greater extraction of heavy metals from the soil. An exception to this was for the leaves from the 100% treatment, that accumulated Cd in levels lower than the control. This greater accumulation of metals in the treatments that did not receive biosolids could be due to the addition of highly soluble inorganic nitrogen, which promoted an increase in dry matter production. However, the100% treatment produced dry matter similarly to the control treatment, and still accumulated less heavy metals. This could have been due to the “organic matter” effect, which promotes a greater retention of metals by the soil, with a subsequent lower availability for the plants. The roots were the major part on the plant accumulating Cd, Cr and Pb and the leaves accumulated more Ni.

The correlation analyses among the attributes studied showed a negative correlation between Cd, Cr and Pb in the composts and Cd, Cr and Pb accumulated by the plants, with 2nd degree polynomials: $Y=0.1829x^2 - 0.82x + 0.9325$; $R^2=0.7693$ $Y=6E - 0.6x^2 - 0.0026x + 0.2701$; $R^2=0.6511$ and $Y=8E -0.6x^2 - 0.0007x + 0.0143$; $R^2=0.4505$ respectively, as well as for Ni in the composts and Ni accumulated by the plant $Y=0.0206x2 - 0.9338x + 16.091$ $R^2=0.4267$. This correlation study shows that with the application of organic fertilizer, the accumulation and concentration of heavy metals decreased. The heavy metals adsorption effect of the organic matter could have contributed for the decreases in their accumulation and concentration in the plant.

**ACKNOWLEDGEMENTS**

The authors are grateful to CAPES (Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior), to CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) and to FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) for the assistantships.

## Literature Cited

Aggelides, S.M. and Londra, P.A. 2000. Effects of compost produced from town wastes and sewage sludge on the physical properties of a loamy and a clay soil. Bio. Technol. 71:253-259.

CETESB. 1999. Aplicação de lodos de sistemas de tratamento biológico em áreas agrícolas. Critérios para projeto e aplicação. São Paulo.

Costa, C.A., da Casali, V.W.D., Lourdes, E.G., Cecon, P.R. and Jordão, C.P. 1997. Teor de zinco, cobre e cádmio em cenoura em função de doses crescentes de composto de lixo urbano. Hort. Bras. 15:10-14.

He, X., Traina, S.J. and Logan, T.J. 1992. Chemical properties of municipal solid waste compost. J. Environ. Qual. 31:318-329.

IAC Instituto agronômico de Campinas. 1996. Recomendações de adubação e calagem para o estado de São Paulo. In: RAIJ, B. Van (ed.), Vol. 2, Instituto Agronômico & Fundação IAC, Campinas.

Illera, V. Walter, I. Souza, P. and Cala, V. 2000. Short-term effects of biosolid and municipal solid waste applications on heavy metal distribution in a degraded soil under a semi-arid environment. Sci. Tot. Environm. 255:29-44.

Imbar, Y. Hadar, Y. and Chen, Y. 1993. Recycling of cattle manure: the composting process and characterization of maturity. J. Environ. Qual. 22:857-863.

Kiehl, E.J. 1998. Manual de Compostagem: Maturação e qualidade do composto. ESALQ, Piracicaba.

Melo, W.J., Marques, M.O., Melo, V.P. and Cintra, A.A.D. 2000. Uso de resíduos na agricultura e impacto ambiental. Hort. Bras. 18:67-82.

Melo, W.J. and Marques, M.O. 2000. Potencial do biossólido como fonte de nutrientes para as plantas. In: Betiol, W. and Camargo, O.A. (eds.) Impacto ambiental do uso agrícola do biossólido. EMBRAPA Meio Ambiente, Jaguariúna-SP.

Ozores-Hampton, M. 1994. Nutrient concentrations, growth and yield of tomato and squash in municipal solid waste amended soil. Hort Science 29:785-788.

Poulik, Z. 1999. Influence of nickel contaminated soils on lettuce and tomatoes. Sci. Hortic. 81:243-250.

Ribeiro, H.M., Vasconcelos, E. and Santos, J.Q. dos 2000. Fertilization of potted geranium with a municipal solid waste compost. Biores. Tec. 73:247-249.

Sadonikova, L.K. and Zyrin, N.G. 1986. Indices of soil pollution by heavy metals used for soil monitoring. Soviet Soil Science 17:58-63.

Sims, R.E.H. 1996. Utilization of waste organic matter. Agric. Ecosyst. Environ. 58:91-95.

U.S. EPA 1996. Standards for the use and disposal of sewage sludge. Washington. (Code of Federal Regulations 40 CRF Part 503).

**Tables**

Table 1. Characterization of the raw materials used for composting.

| Materials | C | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|---|
| | g kg$^{-1}$ | | | | | | |
| Biosolid | 366.6 | 39.08 | 9.04 | 0.90 | 22.08 | 2.56 | 0.24 |
| Cattle manure | 337.1 | 26.15 | 3.27 | 2.25 | 25.34 | 8.08 | 0.04 |
| Sugar-cane bagasse | 453.8 | 3.26 | 0.47 | 0.15 | 1.25 | 0.35 | 0.08 |
| | **Fe** | **Zn** | **Mn** | **Cu** | **Cr** | **Ni** | **Cd** | **Pb** |
| | mg kg$^{-1}$ | | | | | | | |
| Biosolid | 20.481 | 1099.6 | 178.1 | 159.4 | 309 | 30.83 | 2.95 | 72.3 |
| Cattle manure | 3.365 | 135.6 | 186.0 | 28.7 | 8.6 | 2.58 | 0.35 | nd[¥] |
| Sugar-cane bagasse | 1.162 | 10.8 | 14.5 | 0.6 | 4.4 | 0.50 | 0.04 | nd |

Table 2. Concentration of total Cd, Cr, Ni and Pb in the composts (mg kg$^{-1}$ compost, dry weight) at 7, 27, 57, 97 and 137 days after mounting the compost piles (d. a. m.).

| Dates | Treatments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0% | | 12.5% | | 25% | | 50% | | 100% | |
| | ---Cd--- | | | | | | | | | |
| 7 d.a.m. | 0.41 | BCd | 1.07 | CDc | 1.00 | B c | 1.41 | C b | 2.17 | C a |
| 27 d.a.m. | 0.63 | B d | 0.90 | Dc | 1.15 | B c | 1.69 | B b | 2.45 | B a |
| 57 d.a.m. | 0.34 | C d | 1.30 | BC c | 1.14 | B c | 1.74 | B b | 2.22 | BC a |
| 97 d.a.m. | 0.98 | A d | 1.58 | A c | 1.83 | A c | 2.42 | A b | 2.84 | A a |
| 137 d.a.m. | 1.00 | A d | 1.54 | AB c | 1.70 | A c | 2.44 | A b | 2.95 | A a |
| C.V. treat. (%)= 7.22 | | | | | | C.V. dates (%)= 8.76 | | | | |
| | ---Cr--- | | | | | | | | | |
| 7 d.a.m. | 5.86 | A e | 108.00 | ABC d | 156.70 | A c | 238.39 | B b | 446.90 | A a |
| 27 d.a.m. | 7.02 | A e | 71.45 | C d | 149.03 | A c | 250.46 | AB b | 398.49 | B a |
| 57 d.a.m. | 8.99 | A d | 142.60 | A c | 175.76 | A c | 385.61 | A b | 358.03 | BC a |
| 97 d.a.m. | 11.51 | A e | 120.32 | AB d | 173.76 | A c | 251.70 | AB b | 317.72 | CDa |
| 137 d.a.m. | 17.98 | A e | 83.32 | BCd | 177.00 | A c | 258.31 | AB b | 308.98 | Da |
| C.V. treat. (%)= 8.91 | | | | | | | C.V. dates (%)= 13.10 | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ---------------------------Ni------------------------------- | | | | | | | | | |
| 7 d.a.m. | 2.24 | A d | 11.51 | A c | 11.92 | C c | 18.33 | C b | 29.79 | A a |
| 27 d.a.m. | 2.78 | A e | 7.61 | B d | 13.92 | BC c | 20.29 | BC b | 30.72 | A a |
| 57 d.a.m. | 2.77 | A d | 12.37 | A c | 15.30 | AB c | 22.93 | AB b | 29.05 | A a |
| 97 d.a.m. | 3.42 | A e | 12.72 | A d | 17.61 | A c | 25.47 | A b | 32.15 | A a |
| 137 d.a.m. | 4.90 | A e | 12.17 | A d | 16.70 | A c | 25.97 | A b | 30.82 | A a |
| C.V. treat. (%)= 9.56 | | | | | | | C.V. dates (%)= 9.86 | | | |
| | --------------------------Pb------------------------------ | | | | | | | | | |
| 7 d.a.m. | 0.0 | A d | 19.96 | BC c | 27.36 | BC c | 45.84 | C b | 82.74 | A a |
| 27 d.a.m. | 0.0 | A e | 12.81 | C d | 26.65 | C c | 74.01 | BC b | 76.80 | AB a |
| 57 d.a.m. | 0.0 | A d | 27.23 | AB c | 35.68 | AB c | 58.71 | A b | 74.13 | B a |
| 97 d.a.m. | 0.8 | A d | 28.42 | A c | 36.36 | A c | 55.63 | A b | 72.01 | B a |
| 137 d.a.m. | 0.0 | A e | 12.45 | C d | 29.88 | ABC c | 55.23 | AB b | 72.33 | B a |
| C.V. treat. (%)= 14.65 | | | | | | | C.V. dates (%)= 11.78 | | | |

* Averages followed by the same capital letter in the vertical, and the same lower cap in the lines do not differ statistically by the Tukey test ($p< 0.05$).

Table 3. Concentration of total Cd, Cr, Ni and Pb (mg $kg^{-1}$) in soil amended with biosolid composts, and cultivated with tomato.

| Treatments | Cd | | Cr | | Ni | | Pb | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1st Date | | | | |
| Control | 0.45 | C b | 37.77 | A a | 5.56 | A b | 4.74 | A a |
| 0% Biosolid | 0.47 | C b | 37.93 | A a | 5.30 | A b | 4.15 | A a |
| 12.5% Biosolid | 0.50 | BC b | 38.95 | A a | 5.45 | A b | 4.15 | A a |
| 25% Biosolid | 0.55 | AB b | 44.23 | A a | 5.49 | A b | 4.81 | A a |
| 50% Biosolid | 0.53 | AB b | 37.69 | A a | 5.40 | A b | 4.41 | A a |
| 100% Biosolid | 0.57 | A b | 43.77 | A a | 6.23 | A b | 4.56 | A a |
| | | | | 2nd Date | | | | |
| Control | 0.53 | C a | 43.93 | A a | 5.77 | A a | 4.44 | A b |
| 0% Biosolid | 0.52 | C a | 39.29 | A a | 5.61 | A a | 3.77 | A b |
| 12.5% Biosolid | 0.54 | BC a | 41.25 | A a | 6.20 | A a | 4.04 | A b |
| 25% Biosolid | 0.58 | AB a | 42.44 | A a | 6.08 | A a | 4.18 | A b |
| 50% Biosolid | 0.53 | AB a | 40.75 | A a | 5.91 | A a | 4.12 | A b |
| 100% Biosolid | 0.57 | A a | 44.40 | A a | 6.29 | A a | 4.34 | A b |
| C.V. treat. (%) | 4.71 | | 8.48 | | 10.10 | | 10.11 | |
| C.V. dates (%) | 7.06 | | 10.49 | | 8.73 | | 12.25 | |

* Averages followed by the same capital letter for treatments, and the same lower cap for dates do not differ statistically by the Tukey test ($p< 0.05$).

## Figures

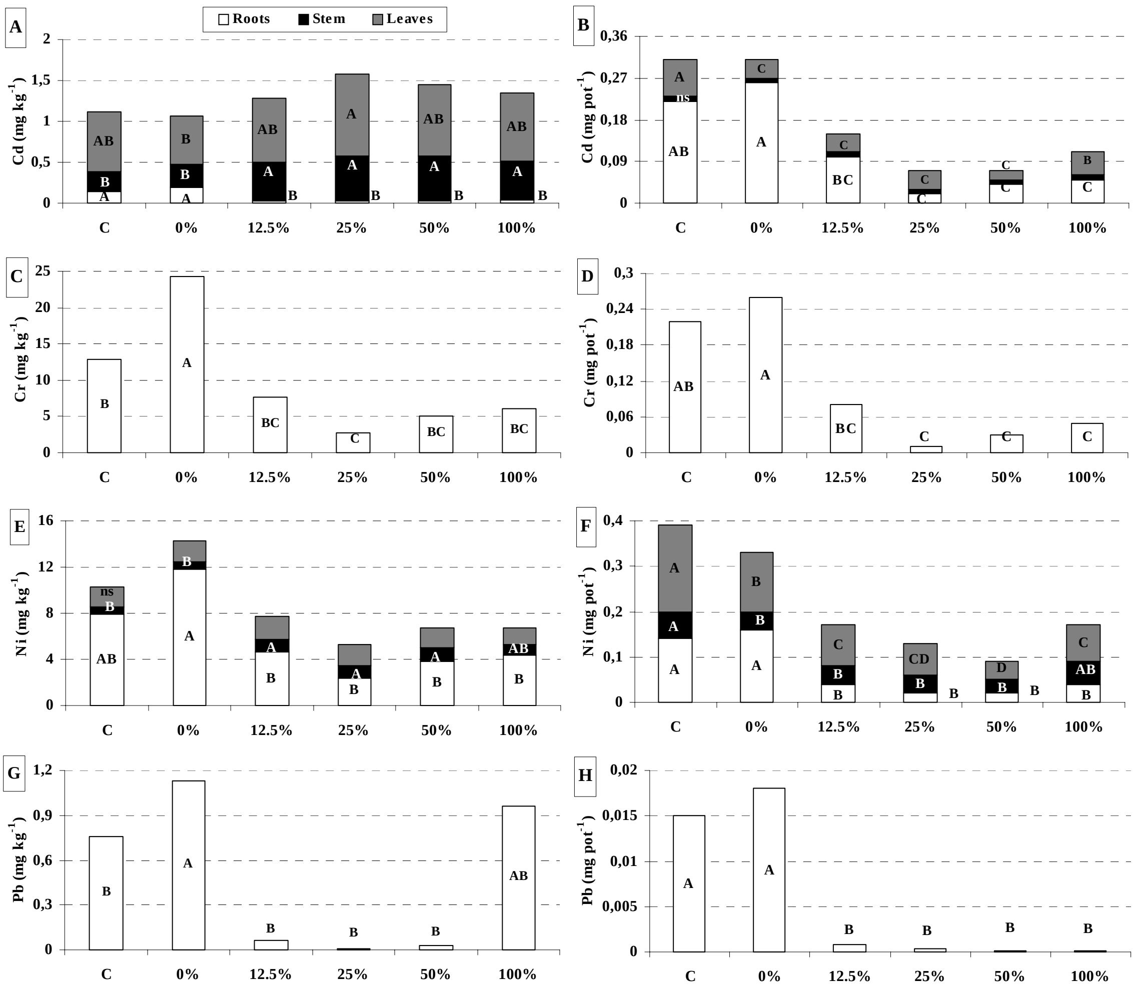


Fig. 1. Cd, Cr, Ni and Pb concentration (A, C, E and G) and uptaking (B, D, F and H) by tomato cultivated in a Latosol amended with sugar-cane bagasse biosolid and cattle manure composts.