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Public health and heavy metals in urban and periurban horticulture

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Abstract

The health effects of heavy metals can be complex and severe. Exposure to heavy metals has been linked with developmental retardation, various cancers, kidney damage, and even death in some instances of exposure to very high concentrations. Soils in urban and suburban areas are transformed by human activities, they are characterized by a strong spatial heterogeneity resulting from the various inputs of exogenous materials and the mixing of original soil material, and they often hold pollutants that may be a threat to human health. The objective of this work is to present a study of heavy metals occurrence in 33 urban and periurban soils dedicated to horticulture in Buenos Aires (Argentina). Total heavy metal content in soils (cadmium, chromium, copper, nickel, lead and zinc) was evaluated using Sequential Plasma Emission Spectrometer (ICP-ES). Data were analyzed using multivariate analysis showing a primary separation in two groups: eight sites with high contents of one or more of the analized heavy metals and the second group with lower levels of heavy metals. Maximum values of Cd, Pb, Zn and Cu in horticultural soils resulted problematic with reference to public health.

Key words: Heavy metals, Public health, Urban horticulture

Introduction

Heavy metals are substances that can contaminate our environment and damage our health. The addition of heavy metals to the cultivated soil during the 20th century caused an increase of cadmium content of 30%, and for lead of 15% in soil (Logardt, 2007).

The health effects of heavy metals can be complex and severe. Exposure to heavy metals has been linked with developmental retardation, various cancers, kidney damage, and even death in some instances of exposure to very high concentrations. Exposure to high levels of mercury and lead has also been associated with the development of autoimmunity, in which the immune system starts to attack its own cells, mistaking them for foreign invaders. Autoimmunity can lead to the development of diseases of the joints and kidneys, such as rheumatoid arthritis, or diseases of the circulatory or central nervous systems (WRI, 1999).

Heavy metals pose a major concern in public health from acute and chronic toxicity and the wide variety of sources of exposure. The metals with environmental exposure, primarily through food, are lead (Pb), chromium (Cr), cadmium (Cd), and mercury (Hg). Cr and Cd are considered carcinogenic for World Health Organization, while Pb and Hg are especially concerned by their neurotoxicity (Zubero Oleagoitia et al., 2008).

Current guidelines for toxicity are based on earlier attempts to predict the soil concentrations of heavy metals where a measurable effect can influence human health. Trace elements in soils may or may not enter the root tissues and then move to the xylem. Some are often transported to the leaves (e.g. Zn, Cd, Co, B, Mo) whilst others (e.g. Cr, Pb, Hg and Cu) typically have limited mobility to aerial parts of the plant. It is particularly difficult to identify critical contamination limits for concentrations of heavy metals in soils, due to physico-chemical and biological variables which control bioavailability and potential toxicity (Dickinson et al., 2000).

Soils in urban and suburban areas are transformed by human activities; they are characterized by a strong spatial heterogeneity resulting from the various inputs of exogenous materials and the mixing of original soil material. The evolution of urban soils is controlled by the same factors as natural soils, but the human factor imposes extremely rapid transformation cycles in comparison with those dominant under natural

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conditions. They often hold pollutants that may be a threat to human health (Morel et al., 2005).

The rate of absorption of heavy metals by vegetables seems to be linked with their levels in the soil. Lead is taken up by the plant roots and is then transported to the leaves. Lead from traffic fumes in the air settles on the leaves. It can be washed away by watering the leaves, especially when the leaf surface is waxy (cruciferous plants, Alliums). Cadmium can be taken up by plants through roots and leaves. For these two very poisonous heavy metals with no positive biological functions, their presence in plants is controlled by respecting the soil standards (Tixier and de Bon, 2006).

The objective of this work is to present a study of heavy metals values in 33 urban and periurban soils dedicated to horticulture in Buenos Aires, Argentina.

Materials and methods

Soil Samples

Three soil samples were taken per location, in an acre homogeneous area, geo-referenced with GPS. Each sample was composed of three sub-samples that were taken at a depth of 0-20 cm. The soil samples were extracted with a stainless steel borehole, were air dried for 24 to 48 hours, passed by the mortar and sieved by 2 mm. Sampling situations are presented in Figure 1.

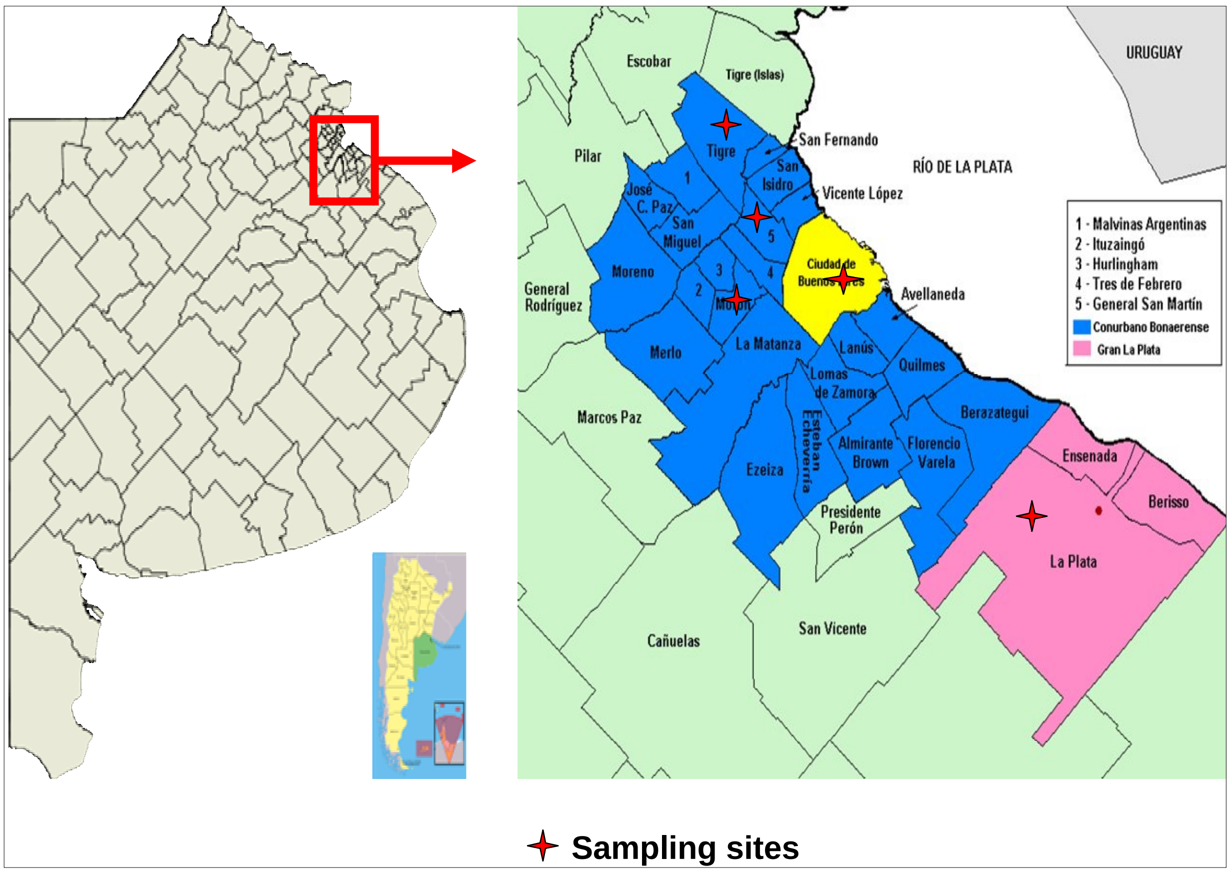

Figure 1. Argentine and Buenos Aires province, periurban samples of La Plata (# 1-22), periurban samples of Buenos Aires (# 23-29) and urban samples of Buenos Aires (# 30-33).

Chemicals

A dried and ground sample (0.5 gram) and 10 ml of aqua regia acid solution (3:1 HCl 37%:HNO_3 70%) were added into a 50 ml teflon digestion vessel. The mixture was heated at 120-130 ºC until nearly dryness and then was treated with 7 ml of 20% HCl (37%) and re-warmed at 80° C for 20 min. After cooling, the solution was hand mixing and filtered through Whatman 40 filter paper into a 10 ml volumetric flask, rinsed and made up to volume with deionised water (McGrath et al. 1994).

Apparatus

This solution was analysed by ICP-ES Baird 2070 to evaluate heavy metal content in soils (cadmium, chromium, copper, nickel, lead and zinc). The calibration solution was prepared by diluting Certipur ® ICP multi-element standard solution IV, and in order to monitor the effectiveness of method, reference material NIST 2704 with a recovery of 88 to 91%, was used.

Statistical

Data were processed using the Infostat statistics program (2007). The data were firstly analysed using multivariate analysis (cluster and principal component analysis). The cluster analysis grouped the treatments according to the values of a set of measured soil variables. This analysis is often used as exploratory data method in order to obtain more knowledge about the structure of the observations under study. This technique allows grouping the study units with the maxima similarity under some criterion. To have a better understanding of the cluster separation, a principal component analysis provide a graph where both, treatments and soil variables, can be displayed to study the correlation among the soil variables, and the association between treatments and soil measurements. Then, to compare the soil heavy metals content, the data were firstly checked for normality and then subjected to analysis of variance (ANOVA). The separation of treatments means was carried out by the Tukey test ($P < 0.05$).

Results and discussion

Heavy metals data were analysed using multivariate analysis with cluster analysis, which allows grouping objects described by a set of values of several variables. The grouping of objects is often used as exploratory data method in order to obtain more knowledge about the structure of the observations in the study. This technique brings together units of study with maximal similarity.

Figure 2 shows a primary separation in two groups. The first one includes all the horticulture sites with high contents of one or more of the analysed heavy metals. The second group considers the situation with lower levels of heavy metals.

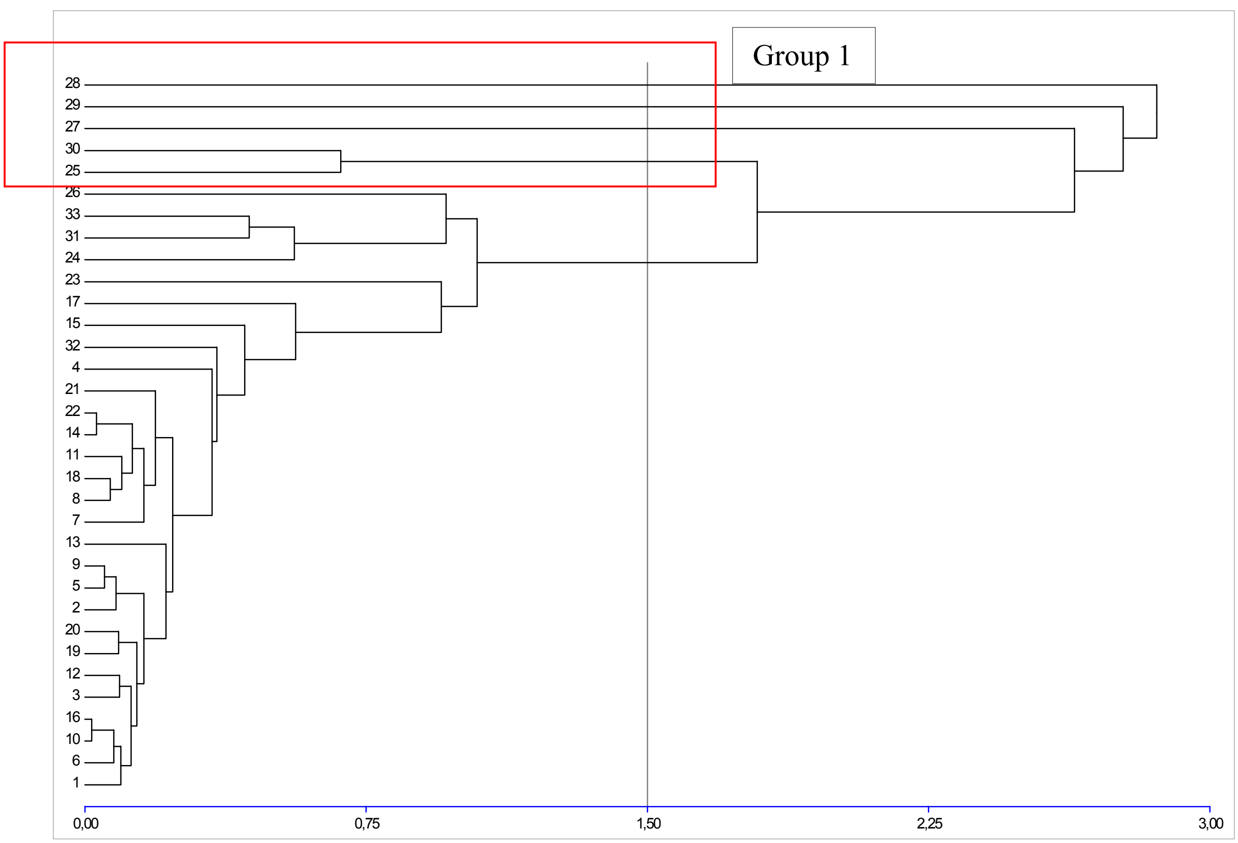

Figure 2. Cluster analysis of the heavy metals for the horticulture sites.

In Figure 3, as a result of the principal component analysis, it can be noticed that one of the studied situations (29) presents the highest level of Cu. The horticultural site number 27 presented the highest value for Pb, while the situation 28 had the maximum value for Cr. Both situations 25 and 30, presented the highest levels for Zn and Ni. The Cd values were maximum in four of the studied situations: 24, 25, 30, and 31, with higher values than 1.90 mg kg^{-1}. All samples with elevated levels of the mentioned heavy metals were from periurban and urban sites of Buenos Aires.

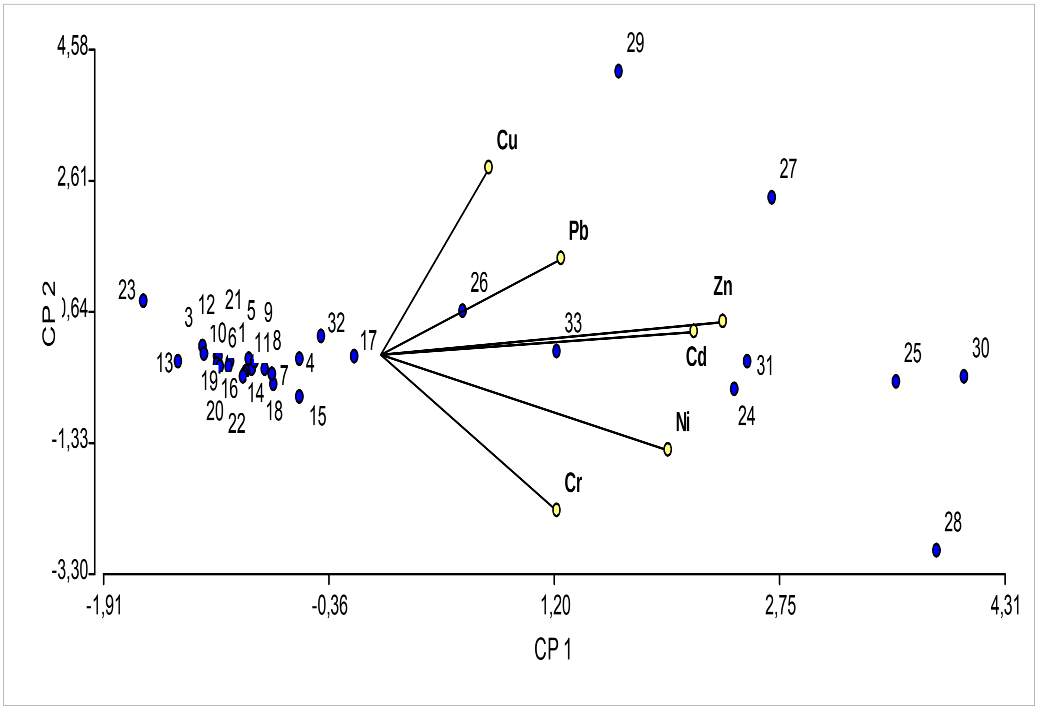

Figure 2. Bi-plot from the principal component analysis considering the heavy metals analyzed for all the horticulture sites.

Toxic metals, including "heavy metals," are individual metals and metal compounds that negatively affect people's health. Cadmium is an extremely toxic metal commonly found in industrial workplaces, particularly where any ore is being processed or smelted. Cadmium hazards may be present in a number of seemingly unrelated operations and materials, as phosphate fertilizers. Due to its low permissible exposure limit, overexposures may occur even in situations where trace quantities of cadmium are found (OSHA, 2009).

Soil samples presented low values of Cd, sometimes non detectable, for that reason are included in Group 2, but as it presents a low permissible exposure level, overexposures may occur with trace quantities. Maximum values, in a range of 1.90-2.16 mg kg^{-1}, are lower than the guideline soil value of 3 mg kg^{-1} presented by the Hazardous Waste argentine law (Ley 24051, 1992). These cadmium levels, although lower than those supported by law, could indicate anthropogenic contributions according to the limit of 0.8 mg kg^{-1} proposed by Vegter (1995), so these samples should be considered in terms of abnormal concentration and subsequent risk. Cadmium concentrations in soils not contaminated by anthropogenic sources range from 0.06 to 1.1 mg/kg, with a minimum of 0.01 mg/kg and a maximum of 2.7 mg/kg as established by Alloway and Steinnes (1999).

According to Zubero Oleagoitia et al. (2008), higher levels of Cd and Pb were found in resident population of urban areas indicating that vegetable consumption of local products and soil contamination could be associated with this increase in heavy metals.

Lead adversely affects numerous body systems and causes forms of health impairment and disease that arise after periods of exposure as short as days (acute exposure) or as long as several years (chronic exposure). Long term (chronic) overexposure to lead may result in severe damage to the blood-forming, nervous, urinary, and reproductive systems. In general populations, lead may be present in hazardous concentrations in food, water, and air (OSHA, 2009).

Studies have shown that lead does not readily accumulate in the fruiting parts of vegetable and fruit crops (e.g., corn, beans, squash, tomatoes, strawberries, and apples). Higher concentrations are more likely to be found in leafy vegetables (e.g., lettuce) and on the surface of root crops (e.g., carrots). At high concentrations, lead is a potentially toxic element to humans and most other forms of life. For this reason, there is a need to be concerned about elevated lead levels in the environment, particularly in metropolitan areas. The Minnesota State Legislature has established a soil standard of 100 mg kg^{-1}, currently lower than the levels used by the United States Environmental Protection Agency and most other States (Rosen, 2010).

Figure 4 presents lead content of the studied soils. It was found a maximum value of Pb of 676 mg kg^{-1}, high for quality soil guide of Argentina, and considered an excessive level as Angelone and Bini (1992). They are also worring, as stated above, four soil samples in the range of 100-137 mg kg^{-1} Pb.

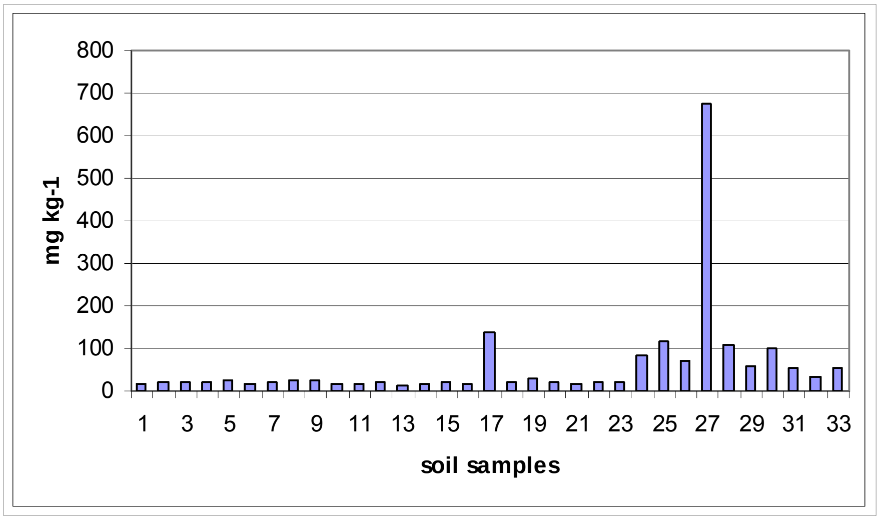

Figure 4. Lead content in horticultural soils.

With regard to heavy metal chromium, trivalent Cr has a low order of toxicity, but hexavalent form is extremely toxic. There is no evidence, however, that Cr normally present in food is a danger to health (Reilly, 2002). The maximum content of Cr found in horticultural soils: 116 mg kg^{-1}, presented a non-alarming value, is acceptable according to argentine law, and is within the normal range considered by Alloway (1995).

Copper is an essential micronutrient involved in a variety of biological processes indispensable to sustain life. At the same time, it can be toxic when present in excess, the most noticeable chronic effect being liver damage (de Romaña et al., 2011). Copper is readily absorbed from the stomach and small intestine. Although copper homeostasis plays an important role in the prevention of copper toxicity, exposure to excessive levels of copper can result in a number of adverse health effects including liver and kidney damage, anemia, immunotoxicity. One of the most commonly reported adverse health effect of copper is gastrointestinal distress (ATSDR, 2008). Maximum value of Cu found in horticultural soil was elevated (688 mg kg^{-1}), indicates contamination for argentine law, and along with another value of 103 mg kg^{-1}, are considered as excessive levels for Angelone and Bini (1992).

Nickel normally occurs at very low levels in the environment, so very sensitive methods are needed to detect nickel in most environmental samples. A lot of nickel released into the environment ends up in soil or sediment where it strongly attaches to particles containing iron or manganese. Under acidic conditions, nickel is more mobile in soil and might seep into groundwater. Food contains nickel and is the major source of nickel exposure for the general population, but the most serious harmful health effects from exposure to nickel, as reduced lung function and cancer , have occurred in people who have breathed dust containing certain nickel compounds while working in nickel refineries or nickel processing plants (ATSDR, 2005 a). In this study, maximum value of Ni: 17 mg kg^{-1} resulted very low for argentine law and in a normal range for Alloway (1995).

Zinc enters the air, water, and soil as a result of both natural processes and human activities. Food is a source of human exposition to zinc compounds. If large doses of zinc are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol (ATSDR, 2005b). Maximum value of 220 mg kg^{-1} found in horticultural soils, is considered low for argentine regulations, but near to excessive as Angelone and Bini (1992).

As a basis to identify and assess soil contamination processes at regional level Micó et al (2010) proposed baseline values for heavy metals in Alicante (Spain), a representative agricultural area of the European Mediterranean region. Taking into consideration the heavy metals considered in this work, the baseline values were : 0.7 mg kg^{-1} for Cd , 36 mg kg^{-1} for Cr, 28 mg kg^{-1} for Cu,31 mg kg^{-1} for Ni, 28 mg kg^{-1} for Pb, and 83 mg kg^{-1} for Zn. These low baseline values for agricultural soils remark the importance to perform this work for different soils in urban and periurban environments.

De Zeeuw and Lock (2000) suggested a number of prevention and control measures that can be applied in urban horticultural systems to help produce safe and healthy products: test soils and irrigation water for heavy metals, establish minimum distances between field and main roads, increase pH to inmobilise heavy metals, wash contaminated crops to reduce metal content.

Urban horticulture has positive social impacts for the inclusion of different urban sub-communities into a social organisation. Horticulture is practised for home-consumption but very often also for the market as high-value cash crops. In developing countries, the consumption of vegetables is generally lower than the FAO recommendation of 205 g/day/capita (Tixier and de Bon, 2006).

As vegetable consumption should be increased and urban and periurban soils are relevant for horticulture production, an interdisciplinary approach must be focused in order to avoid contamination of natural resources soil and water and protect public health limiting the exposition to metals through related food chain.

Conclusions

According to Argentine regulations, maximum values of Pb and Cu in soils are considered excessive. Both corresponded to soil samples in periurban sites of Buenos Aires that have received industrial waste disposal, and are not suitable for orchard production.

There are also other samples referring to Cd, Zn and Pb in urban and periurban sites of Buenos Aires, which could result problematic considering more exigent international guides, regarding to human exposure through food consumption in contaminated soils and potential environmental problems related to migration to groundwater.

In periurban soils of La Plata, total heavy metal content in soil resulted at a low level, the lowest ones corresponding to organic farms.

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