



Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants

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Abstract

The level of pollution has reached the dimensions that threaten human health, with the rapid urbanization and the increase of energy consumption especially in developing countries. Every year in the world, millions of people lose their lives because of air pollution. Heavy metals have a separate precaution in pollutants, especially in terms of human health, because they can remain intact in nature for long periods of time, they tend to bioaccumulate and some are toxic or carcinogenic even at low concentrations. Therefore, monitoring of heavy metal pollution and determination of risky areas is very important. Biomonitoring are the most commonly used methods for monitoring heavy metal pollution. However, determining which plants and organs are more suitable for monitoring the metal is essential in order to ensure that the monitoring is reliable. In this study, it was aimed to determine the variations of the concentration of Ni, Pb, and Cd elements depending on the traffic density in leaves, seeds, and branches of *Ailanthus altissima*, *Biota orientalis*, *Platanus orientalis*, and *Pyracantha coccinea* which are grown in areas with heavy, low dense, and non-traffic areas. As a result of the study, it was determined that concentrations of Ni, Pb, and Cd increased depending on traffic density. According to the results obtained, it was determined that seeds and branches of *Biota orientalis* were the most suitable species and organs to determine Ni pollution. The leaves of *Ailanthus altissima* are very suitable for monitoring the pollution of Pb and Cd.

Keywords Heavy metal accumulation · Heavy metal pollution · *Ailanthus altissima* · *Biota orientalis* · *Platanus orientalis* · *Pyracantha coccinea*

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Introduction

Monitoring heavy metal pollution and determining risky areas to protect human health and the environment are important tasks. Bioindicators are most useful in determining variation in heavy metal pollution. Plants take up heavy metals from soil and air and accumulate them in their tissues; it is possible to measure heavy metal pollution in the atmosphere or soil by determining the accumulation levels (Shahid et al. 2017; Turkyilmaz et al. 2018a).

Studies on the uptake and accumulation of heavy metals by plants have mostly examined metal accumulation via the root system (Niazi and Burton 2016). This is because majority of the heavy metals build up in the soil system and are absorbed by plants mainly via the root system. In addition to plant roots, the aerial organs of plants such as leaves, fruits, and flowers can also absorb heavy metals (Bondada et al. 2004). Therefore the leaves of tall plants (Monaci et al. 2000; Gratani et al.

2008; Anicic et al. 2011), stem barks (Fujiwara et al. 2011; Sawidis et al. 2011), wood (Gao et al. 2015), lichens (Conti and Cecchetti 2001), and moss (Čeburnis and Steinnes 2000) are also employed as biomonitors (Ugolini et al. 2013).

However, different heavy metals can accumulate at different levels on different species of plants and organelles. Because of this, determining which heavy metal accumulates in which plant organelle at which level and then using those plants as biomonitors is important for better results. In this study, heavy metal accumulation differences in some of the plants used in landscape gardening in the Ankara city center were determined based on the plant species, plant organelle, and traffic density.

Materials and methods

The study was performed on materials collected from the Ankara city center. The population of the capital of Turkey is 5,346,518 according to the 2016 census (URL-1 2018). Ankara is one of the most populated cities of the country. Samples collected from the city center Ulus-Kızılay were used for the study. The area where the samples were collected from is shown in the map in Fig. 1.

Samples were collected from areas with heavy, low, and no traffic. Heavy-traffic areas included the Kızılay–Ulus route, through which an eight-lane, two-way highway passes. In this area, samples were mostly gathered from the central refuge. Low-traffic areas included main roads with two lanes. In low-traffic areas, traffic becomes heavier during morning and evening rush hours, but traffic density is low during the daytime. No-traffic areas are those where vehicles may not come closer than 50 m. These areas are the internal parts of large parks in Ulus-Kızılay area.

Samples were collected from *Ailanthus altissima*, *Biota orientalis*, *Platanus orientalis*, and *Pyracantha coccinea*, which are plants that are often used in landscape gardening. Samples collected at the end of the 2017 vegetation season were bagged, tagged, brought into the laboratory, and coded as Aa for *A. altissima*, Bo for *B. orientalis*, Po for *P. orientalis*, and Pc for *P. coccinea*. These codes were used for the rest of the study.

Determining heavy metal concentration

Samples brought to the laboratory were divided into seeds, leaves, and branches and then tagged accordingly. They were dried at room temperature for 15 days. Dried samples were placed in glass containers and then further dried in an incubator for a week.

Dried samples were ground and pulverized in a steel blender. Two grams of pulverized samples were kept in 10 mL concentrated HNO₃ at room temperature inside the fume

cupboard and then boiled at 180 °C for 1 h. Distilled water (20 mL) was added to the prepared solution, and the solution was filtered through a 45- μ m filter paper. The solutions were numbered and prepared for analysis. The filtrates were analyzed for the presence of the heavy metals Ni, Pb, and Cd using GBC Integra XL–SDS-270 ICP-OES. The method used in the study is a prevalent method often used in other studies in this field (Turkyilmaz et al. 2018a, b).

Statistical analysis

Obtained data were arranged in tables using Excel and analyzed using SPSS. Variance analysis was performed, and the samples with a difference of at least 95% confidence level were subjected to Duncan's test to obtain homogenous groups. Acquired data were simplified and tabulated for interpretation. Graphics were created using Excel for easier understanding of the data.

Results

Differences in heavy metal concentrations depending on species and organelle

Differences in Ni concentrations depending on species and organelle in correlation with traffic density

Differences in Ni concentrations from the leaf, seed, and branch samples were examined in correlation with traffic density. The *F* value determined by the variance analysis of the data, significance level, average values obtained, and homogeneous groups obtained with Duncan's test are shown in Table 1.

Table 1 shows that Ni concentration differences in correlation with traffic density were statistically significant with 99.9% confidence level in all organelles except for Aa branches. According to the mean results, the lowest concentration was obtained from Bo branches in no-traffic areas (73 ppb), and the highest concentration was obtained from Aa seeds in heavy-traffic areas (8887 ppb). Duncan's test shows that all values, except for Aa branches, which revealed no statistically significant difference of at least 95% confidence level, can be divided into three homogeneous groups: the first group consisting of values obtained from no-traffic areas, the second group consisting of values obtained from low-traffic areas, and the third group consisting of values obtained from heavy-traffic areas.

The comparison of average Ni concentration in samples collected from no-traffic areas and low-traffic or heavy-traffic areas revealed that the difference in Bo is significant. In Bo seeds, Ni concentration obtained from low-traffic areas was almost 1.44 times the concentration obtained from no-

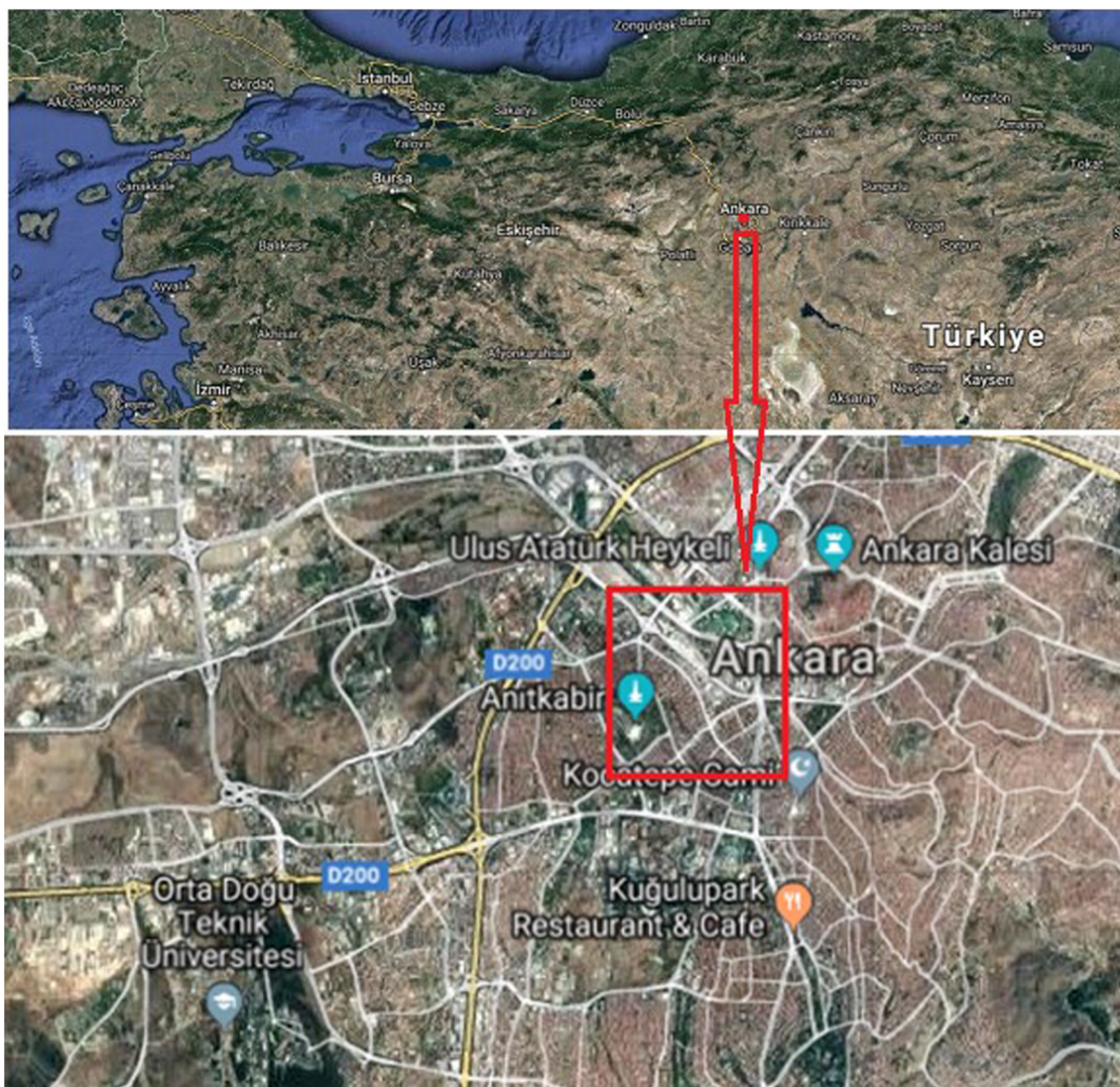


Fig. 1 Areas of sample collection

traffic areas, and Ni concentration determined in heavy-traffic areas was calculated to be almost 19.36 times the concentration obtained from no-traffic areas. In Bo leaves, Ni concentration obtained from low-traffic areas was calculated to be almost 5.06 times the concentration obtained from no-traffic areas and the concentration obtained from heavy-traffic areas was determined to be almost 13.14 times the concentration obtained from no-traffic areas. Based on these results, it can be concluded that Bo is the most favorable species to determine Ni pollution, and the most suitable organelles for the same purpose are Bo seeds and branches.

Differences in Pb concentrations depending on species and organelle in correlation with traffic density

Variance analysis was used to determine whether differences in Pb concentrations in correlation with traffic density were

statistically significant with at least 95% confidence level. The *F* value and significance level obtained from variance analysis is shown in Table 2. Duncan’s test was used when all organelles showed statistically significant differences of at least 95% confidence level. The mean values and homogenous groups based on Duncan’s test are given in Table 2.

$$f(x) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right)$$

Table 2 shows that in all organelles of all species, Pb concentration differences in correlation with traffic density were statistically significant with at least 95% confidence level. Differences in Pb concentration in correlation with traffic density and differences in Pc seeds and Po leaves and seeds were statistically significant with 99% confidence level, and differences in other organelles were statistically significant with 99.9% confidence level.

Table 1 Differences in Ni concentration depending on species and organelle in correlation with traffic density

Species	Organelle	Traffic density			F value
		None	Low	High	
Aa	Leaf	165 a	612 b	1878 c	9753,324***
	Seed	1287 a	2512 b	8887 c	5203,430***
	Branch	139	165	238	1248 ns
Bo	Leaf	145 a	734 b	1906 c	882,357***
	Seed	159 a	229 b	3079 c	31,223,581***
	Branch	73 a	193 b	270 c	27,494***
Po	Leaf	982 a	1458 b	1686 c	533,950***
	Seed	1061 a	1533 b	2264 c	1524,475***
	Branch	278 a	797 b	2175 c	2377,505***
Pc	Leaf	959 a	1348 b	2347 c	773,236***
	Seed	796 a	1073 b	4693 c	18,315,193***
	Branch	309 a	730 b	1363 c	35,192***

Aa, *Ailanthus altissima*; Bo, *Biota orientalis*; Po, *Platanus orientalis*; Pc, *Pyracantha coccinea*

Duncan's test showed that all organelles except Bo branches form three homogenous groups in correlation with traffic density; the first group consists of values obtained from no-traffic areas, the second group consists of values obtained from low-traffic areas, and the third group consists of values obtained from heavy-traffic areas. In Bo branches, two homogenous groups were formed; the first group consists of

values obtained from no-traffic areas and the second group consists of values obtained from heavy-traffic areas.

According to the mean results, the lowest concentration was obtained from Aa branches in no-traffic areas (32 ppb) and the highest concentration was obtained from Aa leaves in heavy-traffic areas (8181 ppb). The highest relative values were again obtained from Aa leaves. Pb concentrations in Aa leaf samples collected from low-traffic areas were found to be nearly 3.79 times the concentration in samples obtained from no-traffic areas, and Pb concentration obtained from heavy-traffic areas was found to be nearly 25.49 times the concentration obtained from no-traffic areas. In Aa branches, Pb concentration determined in low-traffic areas was found to be nearly 6.87 times the concentration from no-traffic areas, and Pb concentration obtained from heavy-traffic areas was nearly 21.87 times the concentration obtained from no-traffic areas.

Differences in Cd concentrations depending on species and organelle in correlation with traffic density

Variance analysis was used to determine whether differences in Cd concentrations in organelles of plants in correlation with traffic density were statistically significant (with at least 95% confidence level). The F value, significance level, mean values, and homogenous groups based on Duncan's test are given in Table 3.

Table 2 Differences in Pb concentrations depending on the species and organelle in correlation with traffic density

Species	Organelle	Traffic density			F value
		None	Low	High	
Aa	Leaf	321 a	1217 b	8181 c	2488,784***
	Seed	666 a	944 b	1248 c	159,771***
	Branch	32 a	220 b	700 c	56,300***
Bo	Leaf	505 a	1290 b	3635 c	275,089***
	Seed	117 a	207 b	443 c	103,863***
	Branch	343 a	447 a	661 b	5966***
Po	Leaf	465 a	512 b	559 c	13,757**
	Seed	187 a	293 b	357 c	24,516**
	Branch	170 a	447 b	991 c	40,534***
Pc	Leaf	827 a	898 b	2034 c	1990,010***
	Seed	115 a	201 b	248 c	29,006**
	Branch	405 a	944 b	2332 c	289,575***

*significant at 0.05 level; **significant at 0.01 level; ***significant at 0.001 level

The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Table 3 Differences in Cd concentrations depending on species and organelle in correlation with traffic density

Species	Organelle	Traffic density			F value
		None	Low	High	
Aa	Leaf	9.60 a	30.06 b	58.40 c	1174,074***
	Seed	19.93 a	53.66 b	65.66 c	167,335***
	Branch	1.50 a	2.96 b	27.66 c	150,263***
Bo	Leaf	86.33 a	91.40 a	145.33 b	256,232***
	Seed	30.93 a	42.17 b	46.47 c	64,831***
	Branch	57.10 a	81.33 b	97.67 c	78,877***
Po	Leaf	20.03 a	37.46 b	39.63 b	241,666***
	Seed	13.96 a	17.33 ab	20.80 b	9511*
	Branch	23.67	39.77	55.37	4182 ns
Pc	Leaf	57.23 a	75.46 b	192.66 c	319,988***
	Seed	19.53 a	27.37 b	47.47 c	118,257***
	Branch	61.00 a	95.67 b	149.67 c	191,843***

*significant at 0.05 level; **significant at 0.01 level; ***significant at 0.001 level

The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Variance analysis showed that differences in Cd concentration in correlation with traffic density were statistically non-significant with at least 95% confidence level in only Po branches. Cd concentration differences in correlation with traffic density were statistically significant in Po seeds with 95% confidence level and in other organelles with 99.9% confidence level.

The lowest Cd concentration was obtained from Aa branches in no-traffic areas (1.5 ppb) and the highest concentration was obtained from Pc leaves in heavy-traffic areas. The mean lowest value was obtained from Aa branches (10.71 ppb) and the highest value was obtained from Pc leaves (108.45 ppb).

When differences in Cd concentrations in correlation with traffic density values were examined, the highest increase was found in Aa branches. Cd concentration, which was 1.5 ppb in Aa branches in no-traffic areas, increased to 2.96 ppb in low-traffic areas and 27.66 ppb in heavy-traffic areas. Therefore, Cd concentration obtained from Aa branches from low-traffic areas was found to be nearly 1.97 times the concentration from no-traffic areas, and Cd concentration obtained from heavy-traffic areas was nearly 18.44 times the concentration obtained from no-traffic areas. Since Cd concentration in no-traffic areas was so low, these ratios may not be reliable.

Cd concentration, which was 9.6 ppb in Aa leaves collected from no-traffic areas, was 30.06 ppb in low-traffic areas and increased to 58.4 ppb in heavy-traffic areas. Cd concentration determined in Aa leaves from low-traffic areas was nearly 3.13 times the concentration obtained from no-traffic areas, and Cd concentration obtained from heavy-traffic areas was almost 6.08 times the concentration obtained from no-traffic areas. Based on these results, it can be concluded that the most suitable species and organelle to determine changes in Cd concentrations are Aa leaves.

Discussion

In this study, the lowest Ni concentration was found in branches, and the lowest Pb and Cd concentrations were found in seeds; on the other hand, the highest Ni concentration was found in seeds, and for Pb and Cd, it was leaves. In addition, heavy metal concentrations can differ based on the organelles of different plants. For example, in the heavy-traffic areas, Pb concentration was the lowest in Bo seeds and the highest in branches, whereas the lowest Aa concentration was in branches and the highest was in seeds. This result is compatible with the literature in general. Studies have reported that heavy metal accumulation can significantly vary depending on plant organelle (Emamverdian et al. 2015; Dimitrijević et al. 2016; Tošić et al. 2016; Shahid 2017).

According to the results, Ni, Pb, and Cd concentrations increased in correlation with traffic density. Industry and

traffic density are reported to be the main sources of heavy metal pollution (Uzu et al. 2011; Martley et al. 2004). In addition, heavy metal concentration in plants significantly varies in correlation with traffic density (Assirey et al. 2015; Lei et al. 2015; Galal and Shehata, 2015).

Ni, Pb, Cd, and Cu are harmful to human health. Pb is a toxic heavy metal element that spreads in the atmosphere in the metal or compound form (Perišić et al. 2017; Ghosh et al. 2017; Allajbeu et al. 2017). Pb is one of the main pollutants of the ecological system (Okçu et al., 2009). Therefore, many studies have been conducted on changes in Pb concentration in correlation with traffic density (Lei et al. 2015; Galal and Shehata, 2015; Assirey et al. 2015).

Ni is a potential carcinogenic element for mammals and other animals (Okçu et al. 2009; Shahid et al. 2015). Although plants need Cu for sustenance in different amounts, it is a very toxic metal. Some symptoms of Cu toxicity are tissue damage, degeneration of roots, and darkened plant color. Other symptoms are ion loss in stem cells due to the deterioration of membrane permeability and failure in photosynthesis owing to DNA damage (Okçu et al. 2009).

Cd is an element that is toxic to humans, animals, and plants (Asri and Sönmez 2006; Boğa 2007). It alters nitrogen and carbohydrate metabolisms in plants and causes many physiological changes. It inactivates enzymes in plants, obstructs photosynthesis, and causes stomas to close up, blocking water loss by transpiration, and deteriorating chlorophyll biosynthesis (Asri and Sönmez 2006). It is therefore important to monitor atmosphere concentrations of Ni, Pb, and Cd and determine risk areas. To monitor these concentrations, it is important to determine which metal tends to accumulate in which plant organelle. Heavy metals do not disperse homogeneously in plant tissues. Metal content in seeds and grains is usually lower than that in vegetative parts. Distribution in various vegetative tissues is reported to be a characteristic of xylem transportation, and the final concentration of an element is correlated with water loss by transpiration in an original tissue (except for stems) and the period needed for this process (Aydın 2017).

This study focused on *A. altissima*, *B. orientalis*, *P. orientalis*, and *P. coccinea* plant species. A plant needs to meet certain criteria so that it can be used as a biomonitor to determine heavy metal pollution. According to these criteria, plants must be abundant in the area, it must be widely distributed over a large geographic area, sampling of plants must be easy, and no identity problem must be encountered (Çavuşoğlu et al. 2016). Species included in the study were preferred because they are easy to collect, abundant in the sampling areas, and used for landscape gardening in many regions in Turkey.

Many plant species have been used in monitoring heavy metal pollution until now, and a great number of studies have focused on lichens and mosses. However, tall plants can be

more effective in decreasing heavy metal pollution than mosses and lichens. Tall plants take up more space than mosses and lichens and decrease air pollution as well as heavy metal pollution in the area where they grow (Cetin et al. 2018). In addition, they have many other ecological, economic, and social functions such as lowering noise, having positive effect on human psychology, presenting economic resources, promoting soil conversation, decreasing wind speed, and providing feed and shelter to wild animals (Cetin and Sevik 2016; Sevik et al. 2016). Therefore, different tall plants are grown in different areas, and the studies to be performed on these plants provide valuable data with regard to monitoring and preventing heavy metal pollution.

Concentration of heavy metal accumulation in plants may vary depending on concentration, plant species, plant organ-elle, and traffic density. For example, Pb concentration in plants tends to increase in autumn and winter. Some of the reasons for this are loss of nutritional materials in winter, old leaves having the tendency to uptake Pb aerosol more readily than young leaves, decreased wind speed which favors aerosol accumulation, and seasonal changes in the amount and severity of rainfall. Heavy metal concentrations in soil have an effect on differences in heavy metal accumulation in plants. As all heavy metal concentrations in soil increase, the concentrations in plants also increase (Fergusson 1990).

Suggestions

Study results show that Ni, Pb, and Cd tend to increase in correlation with traffic density. Ni, Pb, and Cd are very hazardous to the human health; risky areas must therefore be identified by monitoring changes in the concentrations of these elements. The study showed that Bo seeds and branches are the most suitable to determine Ni pollution, whereas Aa leaves and branches and Aa leaves are the most suitable to determine Pb and Cd pollution, respectively.

Plants can significantly reduce air pollution. However, different species have different effects on pollutants. According to our results, species with the highest level of heavy metal accumulation are more effective in removing heavy metals from the air than others. Therefore, the use of these plant species in industrial areas and in heavy-traffic areas can help in removing heavy metals from the air.

This study focuses on four plant species. Although numerous species have been used in similar studies, we do not have sufficient data on the heavy metal accumulation potential of these plants. However, studies have indicated that there are great differences among heavy metal accumulation potentials in different plant species. Therefore, it is necessary to focus on species that have not been studied and identify the plants that are more effective in monitoring and decreasing heavy metal

pollution. Studies on this subject have mainly focused on lichens, mosses, and woody taxa, and there is a limited number of studies on plants such as bushy species, trailing plants, and seasonally flowering plants. Therefore, similar studies should be conducted and diversified.

Author contributions Mehmet and Hakan conceived and designed the experiments. Halil, Tamer, and Handan performed the experiments. Hakan, Handan, and Halil analyzed the data. Tamer, Halil, Mehmet, and Hakan contributed reagents/materials/analysis tools. Tamer, Handan, Halil, Hakan, and Mehmet wrote the paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Abbreviations Aa, *Ailanthus altissima*; Bo, *Biota orientalis*; Po, *Platanus orientalis*; Pc, *Pyracantha coccinea*

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