Original paper

URBAN ENVIRONMENT IN PODUNAJSKÉ BISKUPICE (BRATISLAVA) FOCUSED ON BLACK WALNUT (*JUGLANS NIGRA* L.) PARK PLANTING

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Abstract

Based on experimental observations monitored parameters are to solve the mutual relationships within the atmosphere – soil – plant system during the years 2019–2023. The current structure of the interest area represents a strongly anthropogenically modified urban landscape with a high built-up area directly in the site and in the vicinity of the monitored site itself. The focus is on soil cover, considering the quality of urban soil and climatic parameters assessed from the perspective of ongoing climate change. Urban soils develop their specific soil properties under the strong influence of the environmental environment and often depend on their use in the urbanized area, which is diverse. From the analysis of the chemical analysis, the contents of individual parameters in the soils are largely influenced by the exogenous effects of the urban environment. Increased mineralization of organic matter is recorded and reduced supply of soil nutrients (especially phosphorus) due to the absence of macro-nutrient application. The content of carbonates in the range from 14% to 23% is considerably high, which is a consequence of the high proportion of construction and industrial waste (anthroskeleton). It has been shown that the amount of humus in urban soils is a significant factor influencing and largely determining the success of plantings and the ability of tree species to survive in urban environments. The park planting of black walnut is in very good condition, given to the soil and climatic conditions and due to permanent maintenance. During the years under review, black walnut showed good drought and high calcium content tolerance, which is primarily due to good rooting. The results of soil analyses confirm that black walnut can adapt to deteriorating climatic conditions, provided that the soil conditions are of sufficient quality.

Keywords: black walnut, urban soil, climate conditions, urban environment, Bratislava

INTRODUCTION

In the current period, when significant manifestations of climate change are occurring on a global scale, degradation of large areas and recorded loss of biodiversity, soil is becoming one of the most vulnerable natural resources in the world (FAO 2015, Burghardt 1994). Land use in cities is characterized by high population density, intensive development and concentration of various societal demands for the use of urbanized areas (Strategy of the Environmental Policy of the Slovak Republic 2020). Land use is reflected in changed soil properties and their functions (Genske 2003). Given the fact that most soils in urbanized areas are artificially created soils, unlike natural soils, these soils are highly susceptible to contamination, acidification, salinization, reduction and pseudogleying processes, erosion and excessive occurrence of pathogenic organisms (Sobocká *et al.* 2007). With the growth of the world population and its increasing concentration in many areas of the world, the picture of the urbanized landscape is changing intensively. This phenomenon can currently be considered a key component of the urban ecosystem (Hazelton & Murphy 2011, Marquard *et al.* 2020, Hrnčiarová *et al.* 2006, Burghardt, Morel, Zhang 2015). Fundamentally the question becomes one of health, the health of the urban environment, its interconnectedness

with the health of all its inhabitants (human and more-than), and how to manage for increased health of both. Smith (2024) seeks to begin answering these questions by examining the interrelatedness of black walnut tree health and socioeconomic wellbeing. In general, when assessing soils in cities (urban and anthropogenic soils), there is an increasing demand to take into account and prefer a criterion aspect other than the "productive capacity of soils". It is related to a different understanding of the functions of soils in urban areas (Sobocká *et al.* 2007). Urban soils are, for example, characterized by the presence of alien (anthropogenically displaced) mineral material covered with composted organic matter: in this case, we are talking about a change in soil taxonomy.

For example, if soils are classified as anthrozems urbic (Jambor *et al.* 2011), we order them into the group of anthropogenic or technogenic soils according to the content of the anthroskeleton. applying the Morphogenetic Classification System of Soils of Slovakia (Societas pedologica slovaca & VÚPOP 2014). In addition, a significant element is the built-up area (soil sealing), which is often a problem when mapping soils in urban areas (Sobocká & Saksa 2020, Sobocká *et al.* 2020, Saksa *et al.* 2021).

The quality of urban soil is based on and depends primarily on its use in the urbanized area. Several types of urbanized area use are distinguished, which are differentiated according to the quality requirements of the urban population. These are similar to soils with a natural soil profile structure but are largely degraded. Among the basic soil functions, they serve as a nutrient medium for vegetation, as a retention medium for water and air, as a retention medium for the absorption of various pollutants, as a universal biological sorbent, as a regulator of the ground atmosphere, etc. Thus, they fulfil barrier, sanitary, retention and other important functions (Sobocká *et al.* 2007, Lal & Stewart 2018). Urban green spaces are associated in scientific works with an average temperature reduction ranging from 2°C to 11°C (Cameron & Hitchmough 2016, Doick & Hutchings 2013), thus ensuring local and thermal comfort for residents living near the park.

The role of urban vegetation on the urbanized landscape and soil is significant (Nicolescu *et al.* 2020). Urban soil can change its properties through the plants, i.e. each organism affects its environment. In an urbanized area, this is primarily by mitigation the impacts of erosion effects, and secondly by the quantity and quality of its litter (leaves, needles, bark, branches, roots). Dead plant tissues from aboveground and underground biomass affect the soil directly and indirectly: directly by the formation of organo-mineral humus substances, indirectly as a source of energy and matter for soil biota, by creating the so-called phytoclimate, microclimate under their crowns.

Specific moisture and temperature conditions are created on the soil surface in the rural landscape, incomparable with moisture and temperature conditions on the hot summer streets of the urban environment. At the current level of knowledge, we can clearly state that the microclimate above the soil surface is fundamentally modified by the vegetation cover: the inseparability of the influence of the abiotic components of the ecosystem from the influence of its biotic components, especially vegetation, is now demonstrable (Salašová 2016). Plants reduce temperature extremes above the soil surface compared to temperature extremes in open spaces in the city. The primary reason for the mitigating ability here is the density of the canopy: the greatest differences are in city parks, in floodplain valleys, located in concave shapes of urbanized terrain (Craul 1999). In many floodplain valleys, the higher density of the canopy layer is primarily determined not only by orography, but also by deeper soils (Rejšek 2016). The planting of trees, tree rows and groups of trees in urban areas is also addressed in works by Supuka, Bihúňová, Štepánková (2005), Hudeková (2018) and Šerá (2013).

In accordance with the legislation, we focused on the analysis of the investigated area with black walnut (*Juglans nigra* L.) planting in terms of soil cover and a systematic approach considering the quality of urban soil and respecting ongoing climate change (Sobocká *et al.* 2022). The aim of the paper is to evaluate the quality of the urban park in terms of soil and climate conditions and to determine planting options for similar urban parks in the future.

MATERIAL AND METHODS

The urban district of Bratislava – Podunajské Biskupice with an area of 42.5 km^2 is one of the largest urban districts of the capital of the Slovak Republic, Bratislava. It is located on the northwestern end of Žitný ostrov and at the same time on the eastern edge of Bratislava. The area of interest of Podunajské Biskupice belongs to a warm and at the same time dry climate area with an average number of summer days per year of 50 or more, with a mild winter. According to the climatic and geographical types (Atlas of the Slovak Republic), the surveyed area and its wider surroundings belong to the type of lowland, warm and dry climate with a mild winter. The air temperature in individual seasons in 2019 – 2023 is shown in Tab. 1.

Table 1

Studied area air temperature in individual seasons in 2019 – 2023

Air temperature in individual seasons Bratislava – airport in 2019 – 2023 (in °C)					
	2019	**2020**	**2021**	**2022**	**2023**
Winter	2.1	3.8	2.2	3.9	2.8
Spring	11.9	11.8	9.9	11.8	10.7
Summer	23.8	2.9	22.2	23.2	22.0
Autumn	12.1	11.8	11.7	11.9	12.9
Source: Yearbook of climate observations SHMÚ 2019 – 2023					

Deviations of average air temperature from the normal values in individual seasons for the years 1991 – 2020 are presented in Tab. 2.

Table 2

Deviations of average air temperature in individual seasons from the normal for the years 1991 – 2020

Deviations of average air temperature from the normal in individual seasons for the years 1991 – 2020 Bratislava – airport (in °C)					
	2019	**2020**	**2021**	**2022**	**2023**
Winter	1.2	2.4	1.4	2.5	2.3
Spring	0.3	0.2	-1.7	0.2	-0.3
Summer	2.2	0.3	1.3	1.7	0.7
Autumn	1.4	0.5	0.3	0.8	2.7
Source: Yearbook of climate observations SHMÚ 2019 – 2023					

In connection with hydrological conditions, the area of interest is part of Žitný Ostrov (inland island), which belongs to one of the most important areas of groundwater accumulation from a European perspective.

In terms of phytogeographical division, the area of interest falls entirely within the area of the Pannonian flora (*Pannonicum*), the Eupannonian xerothermal flora (*Eupannonicum*), the geomorphological unit of the Danube Lowland. Thermophilic lowland species predominate in the flora of Podunajské Biskupice. Mainly species of the urban environment, park areas, grassy roadsides, unused areas around administrative and economic buildings and areas, types of home gardens, etc. are represented here. From the point of view of the assessment of real vegetation, it can be stated that the monitored area is situated in the central part of the urbanized complex Podunajské Biskupice – Vrakuňa and therefore no remains of the original vegetation have been preserved in the monitored area. Park-like lawns of varying quality and species composition dominate here, with varying representation of tree and shrub vegetation. Some elements of non-forest woody vegetation, solitary individuals, various groups of trees and lines of woody plants with

Fig. 1a, 1b, 1c Investigated locality with black walnut, Kazanská/Podzáhradná Street, Bratislava

varying species composition, height and width of lines prevail. Near the monitored area, American ash (*Fraxinus americana*), narrow-leaved ash (*Fraxinus angustifolia*), slender ash (*Fraxinus excelsior*), king walnut (*Juglans regia*), ash-leaf maple (*Negundo aceroides*), cerus oak (*Quercus cerris*), small-leaved linden (*Tilia cordata*) and shrubs mainly *Amorpha fruticosa*, *Forsythia x intermedia*, *Juniperus horizontalis* and others occur. Due to intense urbanization pressure, the original habitats of floodplain forests have not been preserved in the interested area.

The soils of Podunajské Biskupice belong to the fluvial area on carbonate alluvial sediments of the Danube Lowland. Hydromorphic soils are predominantly represented, partly semi-terrestrial, and on old aggradation embankments. Where the influence of groundwater on soil-forming processes has disappeared, soils of terrestrial character have developed. Overall, Fluvisols are dominated as texturally lighter soils, developed on fluvial sediments, typical calcareous and Gleyic Phaeozems, and complexes of Chernozems and Phaeozems (IUSS Working Group WRB 2022) which are among the most fertile soils in the Slovak Republic. In the depressed positions of the Danube floodplain, gleyic subtypes of the above soil types and typical Gleysols are found, which are located near the Danube flow, in the Šúr depression, as well as under forest floodplains (Hrnčiarová *et al.* 2006, Societas pedologica slovaca & VÚPOP 2014).

According to Burghardt *et al.* (2015), urban soils develop their specific soil properties under the strong influence of the environmental. This means that soil in urbanized areas differs from natural and rural landscapes and has a different character of pedogenesis. Their properties often depend on their use in the urbanized area. Urban soils are characterized by a disordered horizontation of the soil profile formed by deposits of various materials, often stratified. They contain a certain amount of anthroskeleton, often an unusual texture and structure. In addition, they may contain hazardous substances of mineral or organic origin, as they are located in a risk environment at of air-boundary or local contamination with hazardous elements. Mapping such soils is complicated by the development of the area with buildings and transport routes (Sobocká *et al.* 2020a, b, c).

The experiment was conducted in the park planting area of interest (Fig. 1a, b, c) in Podunajské Biskupice in accordance with standard soil mapping procedures (Čurlík & Šurina 1998).

Currently, the site of interest consists of a flat, artificially levelled grassy area with a predominant black walnut plantation, on which soil temperature was measured at depths of 50 mm, 100 mm and 200 mm in 10-day decades in 2019–2023. In 2020–2023, soil samples were also taken at a depth of 100 to 200 mm at the black walnut site Determination of the active soil reaction (pH/KCl): it is given by the mutual ratio of the activities of hydrogen (H^+ or H_3O^+) and hydroxyl (OH^-) ions in the soil solution. It was determined potentiometrically in an aqueous suspension (soil to water ratio 1:5). The content and quality of humus in the soil were analyzed by the wet method according to Walkey-Black. The volumetric soil quality method was used to determine the carbonate content. Accessible soil phosphorus, potassium and magnesium were fixed using atomic absorption spectrophotometry. The measurement itself was performed in an acetylene-air oxidation flame with a slit burner located in the optical axis of the instrument.

The protection of tree species in Slovakia is part of Act No. 543/2002 Coll. on the Protection of Nature and Landscape, as amended. Pursuant to Decree No. 170/2021 Coll. of the Ministry of the Environment of the Slovak Republic of 19 April 2021 (Annex No. 36), which implements Act No. 543/2002 on the Protection of Nature and Landscape, as amended, black walnut (*Juglans nigra* L.) is a certified non-native tree species, as is the king walnut (*Juglans regia* L.), which is a more widespread and better known species in our country. Pursuant to the decree, black walnut is classified as a medium-age tree reaching the age of 100 to 200 years.

RESULTS AND DISCUSSION

The result of this anthropic influence in the urbanized environment is the emergence of artificial elements to which belongs a park with black walnut.

Description of the investigated site

The assessed area lies in an intensively used part of Bratislava with important communication corridors. This fact indicates that the biota of the area of interest is to a large extent influenced and determined by human interventions from the past and present. The original vegetation is largely changed.

Locality: Kazanská street/Podzáhradná street, Bratislava II (Figs. 1a, 1b, 1c)

Geographical coordinates: 48°8´0´´N, 17°12´16´´E

Origin of the park: the area is part of the public areas that were created in the years 1973 – 1981

Soil type: Antrozem initial, calcareous (ANä^{c}, MSCS 2014)
Soil texture: loamy, medium heavy
Parent material: construction waste material (at1 MSCS 2014)
Geomorphological unit: Danubian plain, floodplain of the Little Danube
Altitude: 134 m above sea level
Park area: 1.2 ha
Number of black walnut trees: 18, distance between trees 10 m
Trunk diameter: 126 cm, (range from 124 – 165 cm)
The following landscape elements were identified in the monitored environment:

- Urban complex including residential and service elements, multi-storey residential built-up area, low-rise residential areas, individual residential areas, school facilities, commercial facilities, industrial, transport and storage areas;
- Communication and product pipeline complex represents linear transport elements such as roads, sidewalks, parking lots and concrete areas, product pipelines such as gas pipelines, power lines, sewage collector;
- The complex of the used area includes gardens, permanent grasslands of various nature and species composition in the wider surroundings.
- Vegetation in the built-up area is represented by park trees, predominantly with black walnut and accompanying vegetation of non-forest tree and shrub vegetation. Park urban vegetation is supplemented by planted lawns, which are mowed as needed during the growing season.

The surface of the investigated site is artificially levelled by anthropogenic fills with slight differences in height. The terrain elevation is approximately 133 m above sea level. The relief of plains and floodplains is dominating in the area. Directly on the site with black walnut, the anthropogenic soil type Antrozem (AN) (Societas pedologica slovaca & VÚPOP 2014) or Anthrosol (IUSS Working Group WRB 2022) has been identified which represents man-made soil on by human transported and altered substrates. The classified soils are formed on artificial substrates, e.g. fills from reclaimed areas of urban settlements, road embankments and built-up areas with the presence of artifacts less than 10%. By classification

Obr. 2a, 2b Soil profiles in investigated locality

these are soils with a diagnostic anthropogenic surface initial horizon created in a cumulative thickness of more than 60 cm with the sequence of horizons Ad-D (Societas pedologica slovaca & VÚPOP 2014, Figs. 2a, 2b).

Soil temperature measurements were carried out at the black walnut site in 10-day decades at depths of 50 mm, 100 mm and 200 mm in 2019 – 2023. The measurement results show that no negative soil temperature values were recorded in the depth range from 50 mm to 200 mm during the monitored years (Tab. 3).

Table 3
Average soil temperature in individual seasons of 2019 – 2023 in °C

Soil depth	Season	2019	2020	2021	2022	2023
50 mm	winter	1	2	2	1	4
	spring	6	7	5	7	8
	summer	26	25	27	26	23
	autumn	12	10	8	12	15
100 mm	winter	3	1	8	1	3
	spring	8	7	4	6	7
	summer	25	24	27	22	23
	autumn	13	12	10	12	13
200 mm	winter	4	2	3	2	3
	spring	7	8	5	6	8
	summer	23	23	23	23	24
	autumn	12	13	13	11	15

In 2020 – 2023, soil samples were taken at a depth of 100 to 200 mm at the black walnut site, which were analyzed based on the assessment criteria of Annex No. 5, Decree No. 338/2005 Coll., as amended (Tab. 4).

Table 4
Soil analysis results in years 2020 – 2023
Year 2020

Analyzed soil characteristics	Value	Unit	Content evaluation criterion	**Methodology**
pH/KCl	8.16	–	strongly alkaline	STN ISO 10390
Cox	1.62	%	medium	ISO 10694
Humus	2.80	%	medium humic	Cox × 1.724%
$N_{inorg.}$	4.22	mg/kg	very low	ISO 14256 – 1 – Soil quality
N_{tot}	0.25	%	high	ISO 13878:1998 Elementary analysis
Carbonates	16.0	%	calcareous	ISO 10693:1995 – Soil quality
P (Phosphorus)	27.1	mg/kg	low	Mehlich III
K (Calcium)	151	mg/kg	good	Mehlich III
Mg (Magnesium)	331	mg/kg	very high	Mehlich III

Year 2021

Analyzed soil characteristics	Value	Unit	Content evaluation criterion	Methodology
pH/KCl	7.50	–	strongly alkaline	STN ISO 10390
Cox	2.37	%	medium	ISO 10694
Humus	3.80	%	medium humic	Cox × 1.724%
$N_{inorg.}$	5.26	mg/kg	very low	ISO 14256 – 1 – Soil quality
N_{tot}	0.29	%	high	ISO 13878:1998 Elementary analysis
Carbonates	14.0	%	calcareous	ISO 10693:1995 – Soil quality
P (Phosphorus)	46.2	mg/kg	satisfactory	Mehlich III
K (Calcium)	153	mg/kg	good	Mehlich III
Mg (Magnesium)	374	mg/kg	very high	Mehlich III

Year 2022

Analyzed soil characteristics	Value	Unit	Content evaluation criterion	Methodology
pH/KCl	7.91	–	strongly alkaline	STN ISO 10390
Cox	4.74	%	very high	ISO 10694
Humus	8.17	%	very high humic	Cox × 1.724%
$N_{inorg.}$	18.8	mg/kg	medium	ISO 14256 – 1 – Soil quality
N_{tot}	0.49	%	very hugh	ISO 13878:1998 Elementary analysis
Carbonates	18.0	%	calcareous	ISO 10693:1995 – Soil quality
P (Phosphorus)	62.6	mg/kg	satisfactory	Mehlich III
K (Calcium)	226	mg/kg	high	Mehlich III
Mg (Magnesium)	313	mg/kg	very high	Mehlich III

Year 2023

Analyzed soil characteristics	Value	Unit	Content evaluation criterion	Methodology
pH/KCl	7.92	–	strongly alkaline	STN ISO 10390
Cox	2.11	%	high	ISO 10694
Humus	3.64	%	strongly humic	Cox × 1.724%
$N_{inorg.}$	8.43	mg/kg	low	ISO 14256 – 1 – Soil quality
N_{tot}	0.277	%	high	ISO 13878:1998 Elementary analysis
Carbonates	23.0	%	strongly calcareous	ISO 10693:1995 – Soil quality
P (Phosphorus)	21.2	mg/kg	low	Mehlich III
K (Calcium)	103	mg/kg	low	Mehlich III
Mg (Magnesium)	275	mg/kg	high	Mehlich III
Note: test results are converted to dry matter.				

Relating to chemical composition, the contents of individual elements are largely influenced by weather conditions or external influences, resulting in increased mineralization of organic matter. Macronutrients are not applied at the site in question, which reduces their supply (especially phosphorus). It is

important to maintain a good ratio of potassium: magnesium. The carbonate content in the range from 14% to 23% is considerably high at the monitored site (calcareous to strongly calcareous soil), which is a consequence of the high proportion of construction and industrial waste (Tab. 4). High values of humus substances can be attributed to regular mowing and partial mulching as annual maintenance measures.

It was confirmed that black walnut has been shown to be adaptable to soil pH, ranging from 5.3 (slightly acidic soils) to 8.20 (alkaline soils). However, it requires deep, permeable soils with high moisture retention capacity. If planted in deep soils with high water retention capacity, their deep-rooted roots can withstand prolonged drought without damage.

The content of organic matter in the urbanized environment, or rather its quantity and quality, is important for the life of woody plants, as it directly and indirectly affects their growth. The degree of accumulation of plant litter on the soil surface is significant, which has a positive effect on increasing the biological activity of the soil, reducing the drying out of the soil profile and reducing the growth rate of unwanted plants on the site. Humus, as a product of initially complex carbon compounds and subsequent polycondensations and bacterial neo-syntheses, is one of the most important factors influencing and, to a large extent, directly determining the success of plantings and the ability of woody plants to survive in urban environments, which is also confirmed by Rejšek (2016).

At the analyzed location with black walnut, a lack of moisture was mainly recorded during the years 2019 to 2023, but we also recorded an excess of water, because of hypoxia, or lack of oxygen, the parenchymatous cells of the roots can be damaged. Both extremes, i.e. a lack or excess of water, are symptomatically manifested in the same way by the drying out of the tree crown. In the case of a lack of water, the drying out has a more chronic course (a reversible process), the other extreme is characterized by a sudden course. It has been shown that woody plants react to a dry period of weather with a two – to three-years delay. This finding is in line with the work of Rozsypálek (2016).

It is confirmed that in terms of species diversity, black walnut (*Juglans nigra* L.) with its positive properties is a suitable tree species for the application of plantings in urban environments. It grows in sufficiently deep soil, permeable and medium-heavy, as well as on gravelly and drier sites, but the increments are smaller in poorer soil conditions than predicted by Pekárová & Pástor (2023). The size of the fruits depends on the overall vitality of the tree, the diameter of the fruits during the monitored years reached 3.5 – 5 cm (Figs. 3a, 3b), while the pericarp remains rough and very hard for several years. Black walnut grows relatively quickly, it has been confirmed that it can reach a height of 6 – 12 m within 20 years, 12 – 18 m within 30 years and 16 – 25 m within 40 years and tolerates polluted air well, which was also presented by Hieke (1997). The locations of the Danube floodplain forests thus represent valuable biospheric segments contributing to the overall favourable environmental situation within Bratislava (Sobocká 2020, Sobocká & Saksa 2022).

Obr. 3a, 3b Size and surface structure of black walnut fruits

The results of the measurements show that during the monitored years, no negative soil temperature was recorded in the depth range from 50 mm to 200 mm which supports the thesis of prolonged warming of not only the air but also the soil.

Generally, it can be stated that the black walnut trees in the park are in good condition, which is a positive indicator of a suitable habitat. During the monitored years, the black walnut showed good tolerance to drought, which is mainly due to good rooting. The results of soil analyses confirm that the black walnut is able to adapt to deteriorating climatic conditions, provided that the soil conditions are of sufficient quality when maintaining it. Given its origin from warmer areas, it can tolerate longer periods of high temperatures well.

The black walnut park in Bratislava thus represents a potentially climate-resistant habitat. The health condition of the trees indicates that the species is suitable for an urban environment, provided that at least minimal gardening maintenance is provided. We recommend more intensive mulching around the trees and regular health monitoring. Given the allelopathic effects of black walnut, planting species that are tolerant to juglone may be considered.

CONCLUSION

The share of greenery accessible to the urban population should not decrease – on the contrary, it is necessary to preserve in good condition the largest possible enclaves of parks and forest parks, playgrounds, recreational areas and protected habitats. The ecological thinking of the urban population is very insufficient in this regard. If they want to maintain their standard of living and recreation, they cannot be interested only in living in the apartments themselves but must also take care of their immediate surroundings. This is the only way for the urban population to maintain a certain quality of life and healthy development.

Interest in public spaces in urbanized environments is growing, as parks and urban green areas help mitigate the urban heat island effect thanks to cooling effect related to evapotranspiration, changing albedo characteristics and shading. The ongoing climate change constantly brings new challenges that affect several economic sectors. Planting trees and applying the principles of their distribution within the landscape structure are currently among the priority conditions for success in introducing and spreading land management methods in connection with mitigating the impacts of climate change and adapting to it. Therefore, the main imperative for ensuring a healthy environment of urbanized areas in relation to the soil is the consistent maintenance of green areas during the growing season.

More detailed information and possibility of applying the results in other settlements and cities would be very beneficial for city planners and managers.

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