31st International Seminar on Interaction of Neutrons with Nuclei: «Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics»

RISKS ASSESSMENT OF GOLD NANOPARTICLES EXPOSURE FOR THE SOIL-PLANT-CONSUMER SYSTEM

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Nanoparticles Release into the Environment from Different Sources

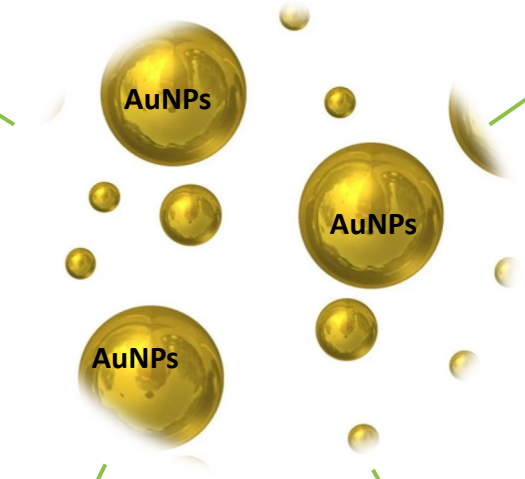
Natural origin

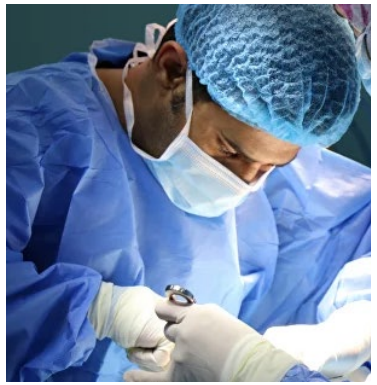
Anthropogenic activity

According to the Nanotechnology Consumer Product Inventory (CPI), consumers can obtain information on more than 1600 nanotechnology-based products

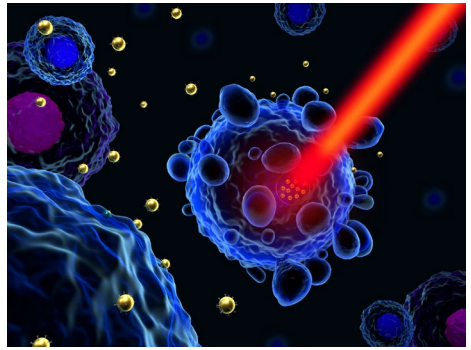
Application of Gold Nanoparticles

- lotions
- antiperspirants
- anti-aging face creams





- AuNPs plays an important role in medicine, where they act as carriers of drugs, amplifiers and optical signal converters, and are used in the diagnosis and treatment of cancer tumors.



- In the agricultural sector gold NPs can be used as nanofertilizers and nanopesticides

The Application of Nanoparticles in Industry, Medicine and Commercial Products Leads to Their Release into the Environment

- The use of wastewater for crop irrigation is practiced by many countries around the world
- Thus, the use of wastewater, containing NPs for irrigation may results in the accumulation of nanosized particles into soil which in its turn can affect soil microbiota and plants
- It was found that the plants *Erigeron canadensis* and *Boehmeria nivea* collected in the Guangdong Province of China contained AuNPs of various shapes with a diameter of 5–50 nm
- The AuNPs with the size 16 nm and concentration $1.38 \cdot 10^9$ particles/kg were determined in sewage sludge

Mentha Spicata L.

The aerial parts of spearmint, which have antioxidant, anticancer, and antimicrobial effects, are used to obtain essential oil and flavor cosmetics and food products. Leaves, stems and flowers are traditionally used for brewing tea and infusions used as a tonic for fatigue, headaches, toothaches, diabetes, as a diuretic, and in case of intestinal problems.

The main goal of the research was (1) to identify the ability of spearmint plants to accumulate NPs when applied two ways of treatment, (2) to evaluate health risk associated with the consumption tea, prepared from contaminated leaves and (3) to identify the AuNPs effect on soil microbiota.

Experiment

Stage №1

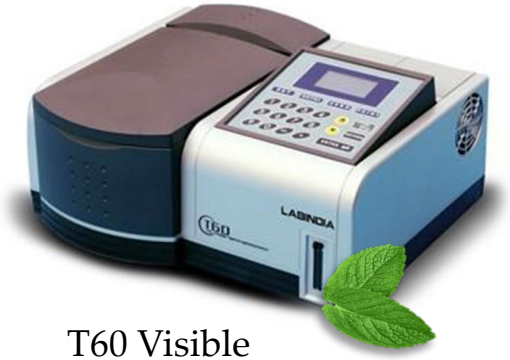
Mentha Spicata L.

On the first stage spearmint plant, were exposed to AuNPs under root irrigation and foliar spraying condition in a concentration range of 1-100 mg/L during 28 days

Stage №2

Dried crushed spearmint leaves were used to prepare herbal infusions

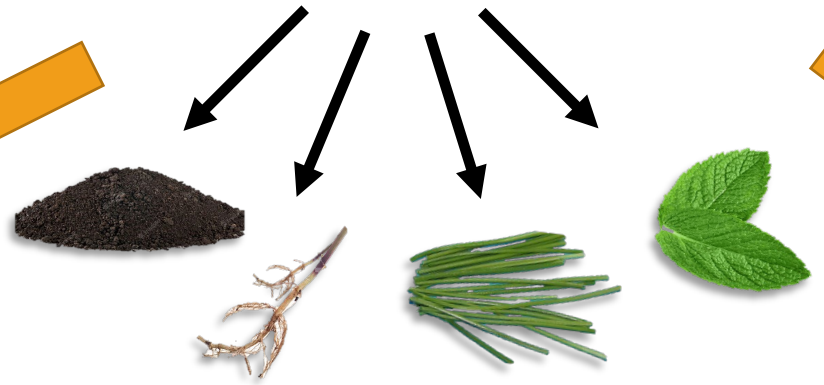
Samples Preparation and Analysis



T60 Visible Spectrophotmeter (UK) was used to determine the biochemical parameters

Mentha Spicata L.

AuNPs 1–100 mg/L, duration of experiment 28 days



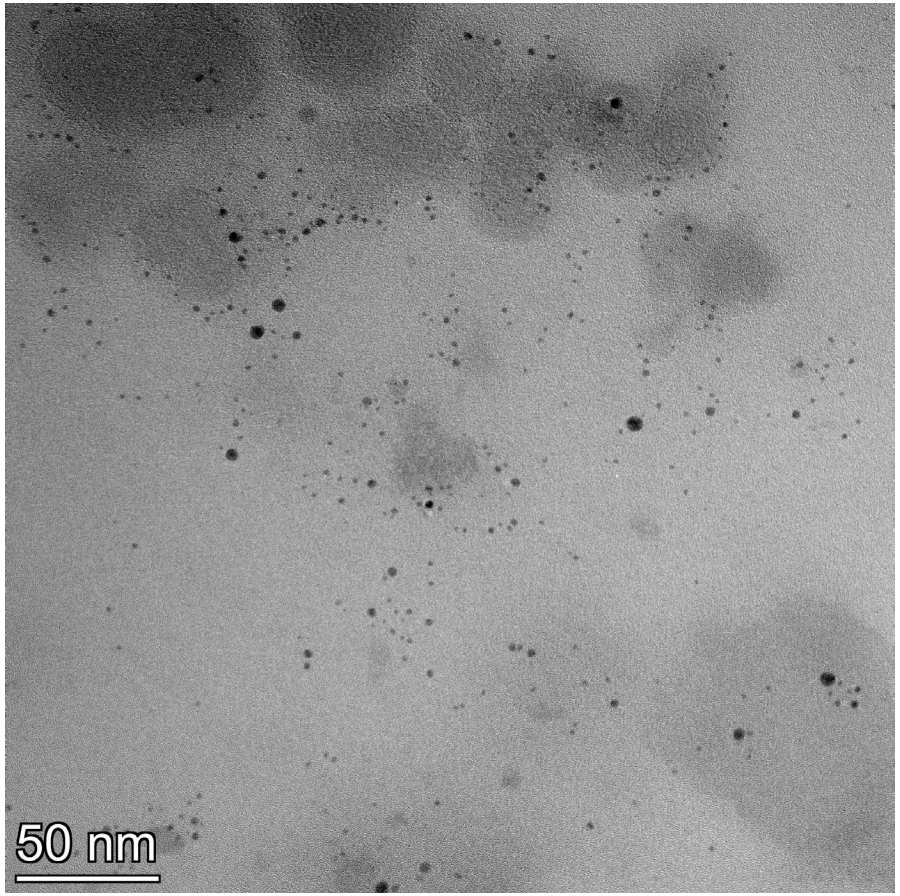
Soil and plant materials were collected for analysis. Plant materials were divided in leaves, stems and roots

Soil samples were irradiated for 10 h and plant samples for 15 h at the rotary rack with a thermal neutron flux of $3.8 \times 10^{12} n \cdot cm^{-2} \cdot s^{-1}$

Gold concentration in herbal infusions was measured by AAS (Thermo Scientific iCE 3000)

Soil microbial activity was estimated by measuring the CO_2 emission rate using Li-850 (LI-COR, USA)

Gold Nanoparticles

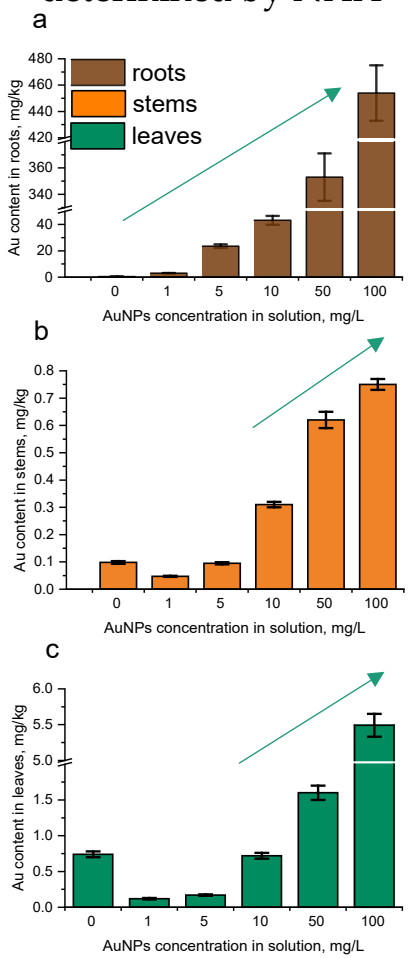


TEM images showed that AuNPs were of spherical form and size of 1-5 nm

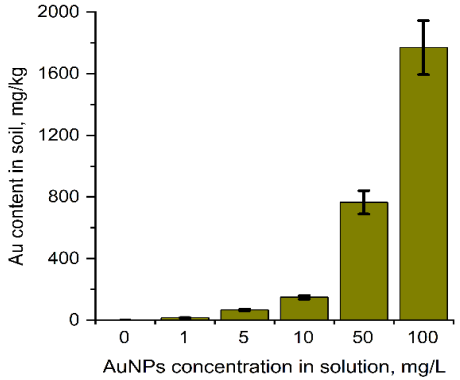
Transmission electron microscopy (Thermo Scientific Talos F200i) was used to determine the size and shape of the gold nanoparticles

Results of root application of AuNPs

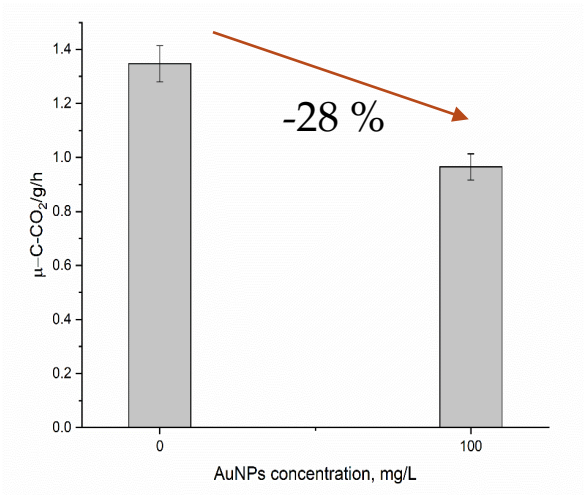
The gold content in spearmint's segments determined by NAA



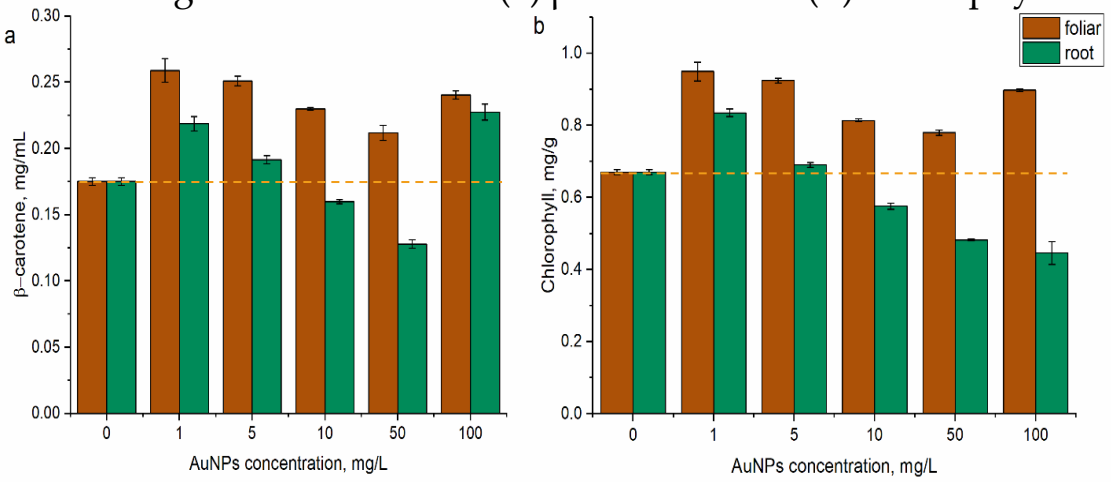
The content of gold in soil



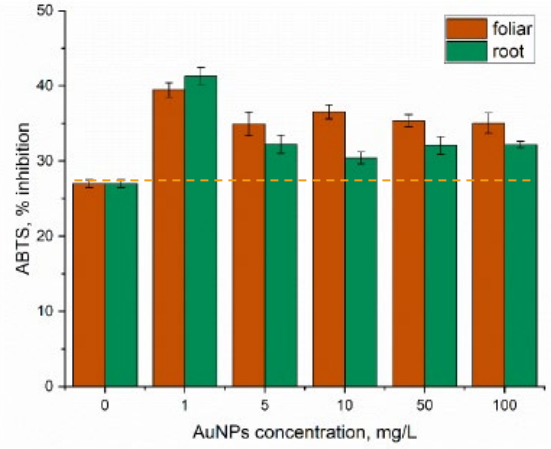
Soil respiration rates



Change in the content of (**a**) β-carotene and (**b**) chlorophyll

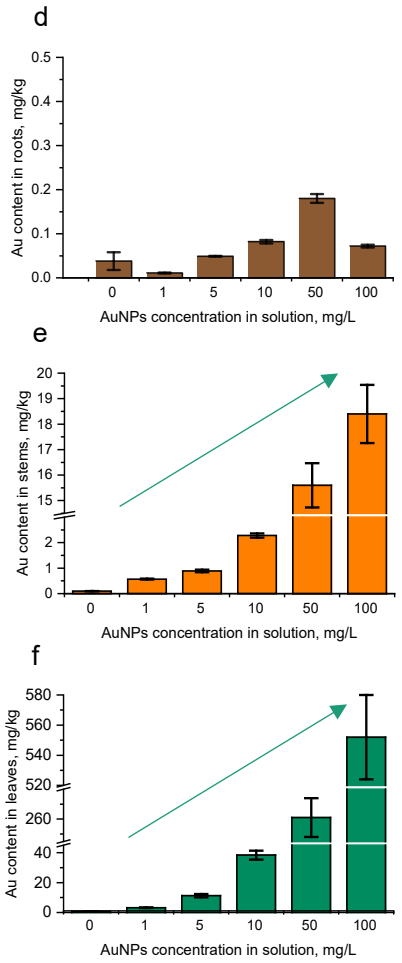


Modification of the antioxidant activity of ethanolic extracts obtained from mint under the action of AuNPs

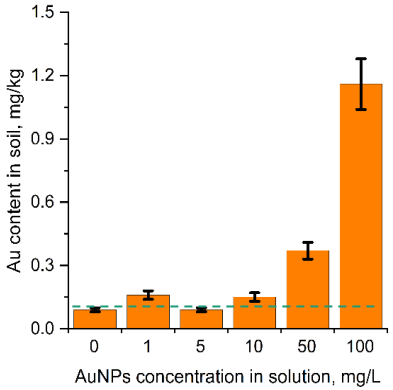


Results of foliar application of AuNPs

The gold content in spearmint's segments determined by NAA



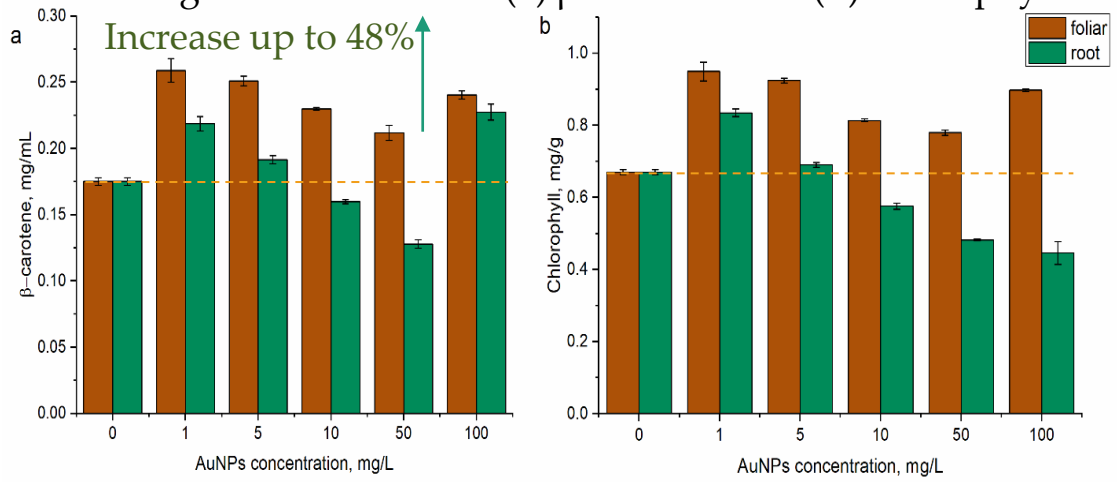
The content of gold in soil samples under root irrigation condition



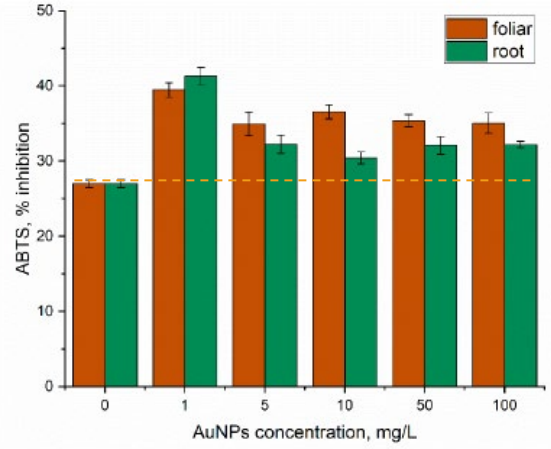
When solutions in concentrations of 50 and 100 mg/L were applied, gold content in the soil was 4- and 13-times higher than in control.

Treatment of mint with AuNPs through spraying and watering resulted in the increase in antioxidant activity up to 53%.

Change in the content of (**a**) β-carotene and (**b**) chlorophyll



Modification of the antioxidant activity of ethanolic extracts obtained from mint under the action of AuNPs



Stage №2. Herbal Infusion

1. 0.5 g of crushed dried plant mass was poured with 10 mL of deionized water were used for preparation of herbal infusions

2. Infusion was brewed at a temperature of 80 ºC for 5 minutes

3. Herbal tea was filtered and measurements were carried out using AAS

Risks for human health

Table 1.

Concentration of AuNPs in Solution	Gold Content in Infusion, μg/L		Gold Content in Leaves mg/kg		Extraction, %	
	Root Exposure	Foliar Spraying Condition	Root Exposure	Foliar Spraying Condition	Root Exposure	Foliar Spraying Condition
0	0.66	0.66	0.74	0.74	2	2
1	0.12	35	0.12	3.2	2	22
5	3.8	148	0.17	11.6	45	26
10	7.3	625	0.72	38.4	20	33
50	16.3	11760	1.6	261	20	**90**
100	81	18726	5.4	552	30	**68**

Table 2.

Concentration of AuNPs in Solution	EDI		HQ	
	Root Exposure	Foliar Spraying Condition	Root Exposure	Foliar Spraying Condition
0	1.18×10^{-5}	1.18×10^{-5}	8.93×10^{-6}	8.93×10^{-6}
1	2.14×10^{-6}	6.25×10^{-4}	1.62×10^{-6}	4.73×10^{-4}
5	6.79×10^{-5}	2.64×10^{-3}	5.14×10^{-5}	2.00×10^{-3}
10	1.30×10^{-4}	1.12×10^{-2}	9.88×10^{-5}	8.46×10^{-3}
50	2.91×10^{-4}	2.10×10^{-1}	2.21×10^{-4}	1.59×10^{-1}
100	1.45×10^{-3}	3.34×10^{-1}	1.10×10^{-3}	2.53×10^{-1}

The estimated daily intake (EDI) of gold was calculated according to Equation:

$$EDI = \frac{C_i * IR * EF * ED}{AT * BW}$$

C_i is gold concertation in infusion, mg/L;
IR is the tea ingestion rate, 1250 mL person day;
EF is the exposure frequency, 365 days/year;
ED is the exposure duration, 70 years;
AT is the average exposure time, ***EF*ED***;
BW is the average body weight, 70 kg

The hazard quotient (HQ) of gold in tea infusion was calculated to qualitatively assess the non-carcinogenic effects of metal on humans through tea consumption

$$HQ = \frac{EDI}{RfD}$$

RfD is daily oral reference dose. EDI and HQ values, calculated based on a daily intake of E175 of 1.32 μg/kg

HQ<1 indicates no health risk

CONCLUSION

- Active accumulation of Au in soils and suppression of soil microbiota activity in case of root application have a potential risks of nanoparticle accumulation in the environment.
- High extraction of gold from plants into infusions (up to 90%) indicates an increased risk of element trophic transfer.
- In case of foliar treatment pigment content and antioxidant activity increased, which makes it possible to consider nano-gold for agricultural purposes.
- EDI and HQ values, calculated based on a daily intake of E175 of 1.32 ug/kg, indicate that there is no risk of adverse health effects

More information about this research can be found in:
Peshkova, A.; Zinicovscaia, I.; Cepoi, L.; Rudi, L.; Chiriac, T.; Yushin, N.; Anh, T.T.; Manh Dung, H.; Corcimaru, S. Effects of Gold Nanoparticles on Mentha spicata L., Soil Microbiota, and Human Health Risks: Impact of Exposure Routes. Nanomaterials 2024, 14, 955. https:// doi.org/10.3390/nano14110955

Thank you for your attention!

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