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Microorganisms and Plants as Tools for Phytoremediation of Soil Polluted with Different Forms of Arsenic

N. Asatiani[a], E. Bakradze[b], T. Butkhuzi[c], K. Didebulidze[c], A. Gujabidze[c], T. Kartvelishvili[a], G. Khatisashvili[c], S. Khmiadashvili[d], M. Kurashvili[c]*, M. Pruidze[c], D. Razmadze[c], N. Sapojnikova[a], T. Varazi[c]

[a] Andronikashvili Institute of Physics, I. Javakhishvili Tbilisi State University, 6 Tamarashvili Str., 0162, Tbilisi, Georgia
[b] LEPL Environmental Pollution Monitoring Department, The National Environmental Agency, David Aghmashenebeli Ave. 150, Tbilisi, 0112, Georgia
[c]Agricultural University of Georgia; 240, David Aghmashenebeli Alley, Tbilisi, 0159, Georgia
[d] LEPL National Environmental Agency, Ambient Air, Water and Soil Laboratory, Marshal Gelovani Ave. 6,

Tbilisi, 0159, Georgia

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A B S T R A C T

The presented work concern to establish the basis of cleaning technology for arsenic-contaminated soils in Georgia. To achieve this aim, the selected microorganisms and plants for phytoremediation of soil polluted with different forms of arsenic (As^{+3} - and As^{+5}) have been tested.

Model experiments were carried out to test the suitability of plants - fern and sunflower for phytoremediation of artificially contaminated soils with arsenite or arsenate. Thus, among the plants tested in the experiments, the most effective was sunflower, which can decrease arsenic content in soil at 200 ppm contamination with As^{+3} by about 35% and in case of contamination with As^{+5} - by almost 50%. It is important that the degree of purification of soil contaminated with arsenic increased by plant if the soil is enriched with bacterial strains that have the oxidizing-reducing ability of arsenic containing compounds.

Keywords: Phytoremediation, soil pollution, Arsenic, arsenate, arsenite.

*Corresponding author: Maritsa Kurashvili, E-mail Address: m.kurashvili@agruni.edu.ge

Introduction

The study deals with chemical pollution of the environment, in particular, arsenic contamination of soil and water, which is a highly pressing problem for both Georgia and the world. The solution is to develop innovative remedial technology based on the ability of plants and microorganisms to absorb a wide range of chemical pollutants from the environment [1].

Arsenic is the most dangerous pollutants because practically all of its compounds have high toxicity, and they can cause various pathologies, including cancer diseases [2, 3].

On the territory of Georgia during Soviet Union period, intensive work was carried out for the mining and production of arsenic, which today has led to a high level of pollution with dangerous wastes [4].

Preventing of natural waters and soils from pollution in potentially contaminated regions, evaluation of pollution and health risks, to provide ecosystem enhancement and population safety, is extremely important for the reality of Georgia.

In modern ecological biotechnologies, which means cleaning the environment polluted by chemicals, the most effective is phytoremediation, from economically and ecologically point of view, which means to develop selected plants in polluted regions [1]. It is necessary to choose plant for phytoremediation according to the type of chemical contaminant, and characteristics of polluted environment. It is also necessary to study the level of pollution, chemical and physical characteristics of soil, and condition of soil microbiota. This factor is important due to the fact, that microorganisms have already established consortium, which on the one hand is adapted to exist in polluted environment and on the other hand to determine conditions for development and growth of plants. In some cases, they cause transformations of contaminants, which increases ability of plants to assimilate pollutants.

The aim of the presented work is to establish the basis of cleaning technology for arsenic-contaminated soils in Georgia. To achieve this aim, the selected microorganisms and plants for phytoremediation of soil polluted with arsenic have been tested.

Materials and methods

The model experiments were carried out to test the phytoremediation method for clean-up of artificially contaminated soils with arsenic. For testing the following plants - fern *(Pteris vittata)* and sunflower (*Helianthus annuus*) have been used.

The soil has been artificially contaminated by the following way: carbonate-type soil was sieved into a 2 mm sieve and then dried in the air. Then arsenate or arsenite containing solutions were added to the soil. The initial contamination was 100 or 200 ppm. 100 g of each soil sample was placed in a 100 ml plastic cup in which the plant was sown.

In some variants, 10 ml of suspension of relevant bacteria was added to the soil which were extracted from the Georgian soils contaminated with arsenic, based on the results obtained using the biochip [5]. They have the ability to participate in the oxidation-reduction of arsenic compounds, in particular, these are *Shewanella spp.* (SH04) and an unknown strain X02, which could not be identified at this time.

Each model experiment was carried out in 4 variants:

1 - control in which the contaminated soil was placed.

2 - contaminated soil in which the plant was sown.

3 - contaminated soil in which was added bacterial strains.

4 - contaminated soil with bacterial strains in which the plant was sown.

The duration of model experiment was 37 day-night, temperature 20-25$^{\circ}C$; artificial lighting – 14L/10D.

After incubation from soil samples were removed the plant samples, shredded, dried and was determined the arsenic concentration by ICP-AES method ISO 11885: 2007; EPA 200.2 [6].

Results and discussion

Model experiments were carried out to test the suitability of plants for phytoremediation of artificially contaminated soils with different forms of arsenic (As^{+3} and As^{+5}). In the experiments besides to plants were used bacteria of the genus *Shewanella* isolated from soils of Georgia contaminated with arsenic, which during the study showed the ability to participate in the oxidation-reduction of arsenic compounds.

Model experiments on ferns and sunflowers have shown that these plants can grow in soils contaminated with both arsenite and arsenate. It should also be noted that these plants grew better on contaminated soils in which bacteria were present. It seems that under the influence of these strains, arsenic transfer into a less toxic form in the soil, which increases plant tolerance.

Determination of arsenic content in the soil after plant growth showed that fern insignificantly - by about 20% decreased soil contamination in the case of both As^{+3} and As^{+5} (Figs.1 and 2).

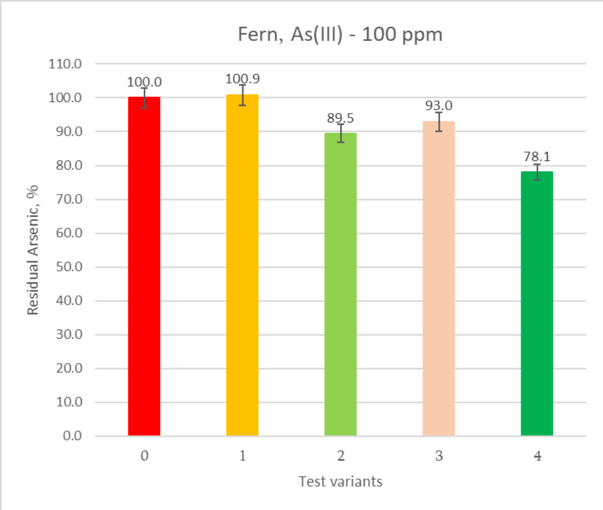

Fig. 1. Model experiment: clean-up of the soil artificially contaminated with arsenic by fern. Initial pollution - 100 ppm (calculated as As^{+3}). Duration - 37 days, temperature 20-25 °C; artificial lighting - 14L/10D.

Test variants:

- Initial contamination
- Control variant (without plant and bacteria)
- Plants without bacteria
- Bacteria without plant
- Plants and Bacteria.

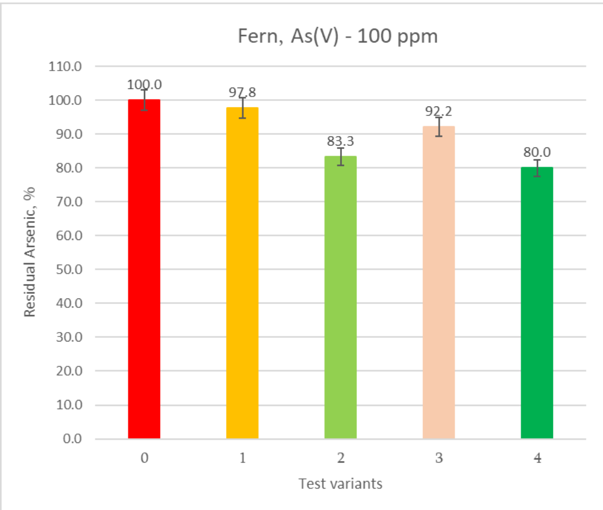

Fig. 2. Model experiment: clean-up of the soil artificially contaminated with arsenate by fern. Initial pollution - 100 ppm (calculated as As^{+5}). Duration - 37 days, temperature 20-25 °C; artificial lighting - 14L/10D.

Test variants:

- Initial contamination
- Control variant (without plant and bacteria)
- Plants without bacteria
- Bacteria without plant
- Plants and Bacteria.

As for sunflower, in these conditions it performs the role of phytoremediator much better: it decreases arsenic content in soil treated with bacteria at 200 ppm contamination with As^{+3} by about 35% (without bacteria by 20%) (Fig. 3) and in case of contamination with As^{+5} - by almost 50% (without bacteria by 40%) (Fig. 4).

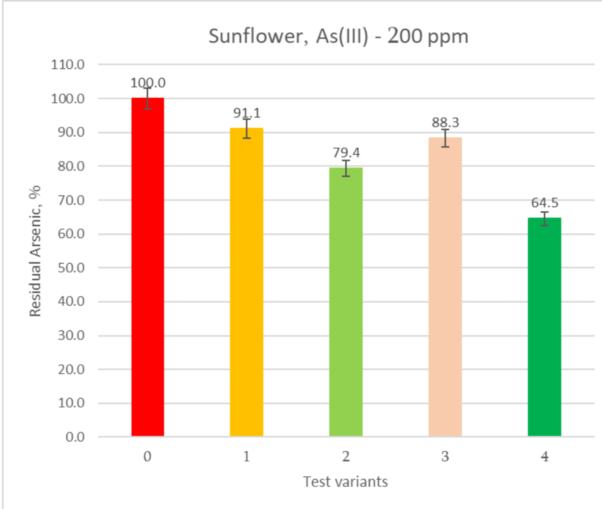

Fig. 3. Model experiment: clean-up of the soil artificially contaminated with arsenite by sunflower. Initial pollution - 200 ppm (calculated as As^{+3}). Duration - 30 days, temperature 20-25 °C; artificial lighting - 14L/10D.

Test variants:

- Initial contamination
- Control variant (without plant and bacteria)
- Plants without bacteria
- Bacteria without plant
- Plants and Bacteria.

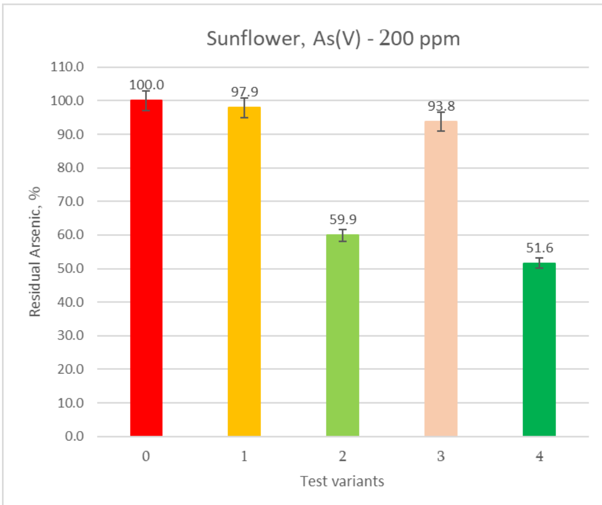

Fig. 4. Model experiment: clean-up of the soil artificially contaminated with arsenate by sunflower. Initial pollution - 200 ppm (calculated as As^{+5}). Duration - 30 days, temperature 20-25 °C; artificial lighting - 14L/10D.

Test variants:
- Initial contamination
- Control variant (without plant and bacteria)
- Plants without bacteria
- Bacteria without plant
- Plants and Bacteria.

Thus, among the plants tested in the experiments, the most effective was sunflower, which can effectively uptake both As^{+3} and As^{+5} forms of arsenic from contaminated soil. Sunflower increased the degree of purification of soil contaminated with arsenic if the soil is enriched with bacterial strains that have the oxidizing-reducing ability of arsenic containing compounds.

Model experiments have shown that these microorganisms promote the uptake of arsenic by ferns and sunflowers while growing on contaminated soil, which allowing the development of phytoremediation technology.

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