ΛΌΓΟΣ

www.logos-science.com

RACCOLTA DI ARTICOLI SCIENTIFICI CON GLI ATTI DELLA

VII CONFERENZA SCIENTIFICA E PRATICA INTERNAZIONALE

«Ricerche scientifiche e metodi della loro realizzazione: esperienza mondiale e realtà domestiche»

Bologna
Repubblica Italiana

6 giugno
2025

In Viaggio Con il Levi: Scienza, Tecnologia e Impresa &
ONG «Piattaforma scientifica europea»

DOI 10.36074/logos-06.06.2025

ISBN (online) 978-88-31277-24-2
ISBN (stampa) 978-617-8440-77-0

ΛΌΓΟΣ

RACCOLTA DI ARTICOLI SCIENTIFICI

CON GLI ATTI DELLA
VII CONFERENZA SCIENTIFICA E PRATICA INTERNAZIONALE

«RICERCHE SCIENTIFICHE E METODI DELLA LORO REALIZZAZIONE: ESPERIENZA MONDIALE E REALTÀ DOMESTICHE»

Bologna,
Repubblica Italiana

6 giugno,
2025

Repubblica Italiana
«Associazione Italiana di Storia Urbana»

Ucraina
«UKRLOGOS Group»

2025

UDC 082:001
R 52

Presidente del Comitato Organizzatore: Goldenblat M.[1]
Vicepresidente del Comitato Organizzatore: Squarchalupi D.[2]

L'organizzazione per conto della quale viene pubblicato il libro:
[1] Piattaforma scientifica europea, Ucraina
[2] In Viaggio con il Levi: Scienza, Tecnologia e Impresa, Repubblica Italiana

Responsabile del layout: Bilous T. *Responsabile del design: Bondarenko I.*

Recommended for publication by the Academic Council of the Institute of Scientific and Technical Integration and Cooperation. Protocol № 22 from June 5th, 2025.

R 52 **Ricerche scientifiche e metodi della loro realizzazione: esperienza mondiale e realtà domestiche**: Raccolta di articoli scientifici «ΛΌГOΣ» con gli atti della VII Conferenza scientifica e pratica internazionale, Bologna, 6 giugno, 2025. Bologna-Vinnytsia: Associazione Italiana di Storia Urbana & UKRLOGOS Group LLC, 2025.

ISBN 978-617-8312-62-6 «UKRLOGOS Group» LLC, Ucraina
ISBN 978-88-31277-24-2 (PDF) «Associazione Italiana di Storia Urbana», Repubblica Italiana
DOI 10.36074/logos-06.06.2025

La raccolta contiene materiali dei partecipanti di VII conferenza scientifica e pratica internazionale multidisciplinare «Ricerche scientifiche e metodi della loro realizzazione: esperienza mondiale e realtà domestiche», che si è tenuta a Bologna il 6 giugno 2025.

The conference is certified by Euro Science Certification Group (**Certificate № 22903 dated April 3, 2025**);

The conference is also included in the catalog of International Scientific Conferences by ResearchBib; and registered by State Scientific Institution «Ukrainian institute of scientific and technical expertise and information» in the database «Scientific and technical events of Ukraine» (**Certificate № 418 dated June 12, 2024**).

La descrizione bibliografica dei materiali della conferenza è indicizzata da Google Scholar, CrossRef, OpenAIRE, OUCI, Scilit, Semantic Scholar, Mendeley, WarldCat e ORCID.

UDC 082:001

ISBN 978-617-8312-62-6
ISBN 978-88-31277-24-2 (PDF)

DOI 10.36074/logos-06.06.2025.051

SORPTION PROPERTIES OF TERRESTRIAL PLANTS FOR CERTAIN RADIONUCLIDES

Nadiia Haiuk[1], Oleksiy Mykhaylenko[2]

1. Candidate of Chemical Sciences, Associate Professor
Department of Organic and Biological Chemistry
Bila Tserkva National Agrarian University, UKRAINE
ORCID ID: 0000-0002-5466-7084

2. Candidate of Chemical Sciences, Associate Professor
Department of Supramolecular Chemistry
Taras Shevchenko National University of Kyiv, UKRAINE
ORCID ID: 0009-0006-5529-9726

Abstract: *Experimental studies have shown a high degree of purification of aquatic environments contaminated with soluble forms of radionuclides, making the development of aquaphytodecontamination technologies based on this approach highly promising.*

Relevance of the problem of decontamination of natural and man-made water is due to the fact that in most cases they have a very high level of pollution with toxic compounds and radionuclides, which requires the development of fundamentally new technologies for cleaning soils and water bodies from contaminants [1, 2, 3].

It is known that there are plants capable of concentrating and accumulating certain elements in increased amounts. Their use for cleaning water bodies has led to the emergence of phytoremediation technology. Two aspects of this technology can be distinguished: 1) phytosorption – the use of plants that sorb various toxic substances and radionuclides from soils; 2) rhizofiltration – the use of plant roots to remove toxic substances and radionuclides from water bodies.

When discussing the purification of water bodies, it should be noted that not only aquatic plants are characterized by high accumulation coefficients, but also terrestrial plants grown under aquatic culture conditions have the same ability to accumulate radionuclides. This fact is significant because the possibility of obtaining the necessary biomass of terrestrial plants far exceeds that of aquatic plants, which allows significantly increasing the efficiency of water body decontamination.

The high efficiency of using plants as active biosorbents can be based not only on their high accumulation capacity but also on the possibility of significantly enhancing this capacity through factors of physical (gamma irradiation, hyperthermal treatment), chemical (physiologically active substances, stable radionuclide analogs), and biological (planting density, bioengineering effects) nature.

Radionuclides enter plants through roots from any nutrient medium, as well as through other plant organs [4]. The most common indicator for assessing the entry of radionuclides from the nutrient medium (soil, water body) is the accumulation coefficient (AC). The AC is the ratio of the radionuclide content per unit weight of the plant to the corresponding value in the soil [5]. The authors established that all studied organisms (plankton, duckweed), which spend their entire life cycle in water, contain radium at concentrations hundreds of times higher than its concentration in water, thus acting as accumulators of this element.

Tolerance of freshwater plants to the concentrations of radionuclides accumulated in their bodies, dynamics of accumulation, and dependence of accumulation coefficients on radionuclide concentrations were tested.

At radionuclide concentrations in water from 10^{-8} Ci/L to 10^{-5} Ci/L, no noticeable effect on the growth and development of freshwater organisms compared to the control was observed over several months. Thus, it can be concluded that microconcentrations of radionuclides did not affect the physiological state of the experimental plants.

At an increase in radionuclide concentration to 10^{-4} Ci/L, accumulation coefficients increase relatively quickly. When transferred to clean water, the concentration of almost all radioisotopes in freshwater organisms decreases. Only some radioisotopes (sulfur, ruthenium) may be completely excreted; others are released slowly and inconsistently.

Thus, these experiments showed that accumulation coefficients stabilize at a certain level in all living organisms. In most planktonic organisms, the stabilization of accumulation coefficients occurs faster – from several hours to several days.

Aquatic organisms can accumulate large amounts of chemical elements that are present in water at very low concentrations. Moreover, experiments on the effects of low doses of the low radionuclide concentrations on plant organisms almost always resulted in noticeable stimulation of growth and development of organisms [12].

Since after the Chernobyl nuclear accident, the main dose-forming radionuclides are radiostrontium and radiocesium [19], it was important to study the nature of their distribution among the components of the water body in the absence of soil, which forms strong competition for water and biota [19]. In fact, only water and the biotic component remain in the water body, playing a major role in the developed phytoremediation technology for decontaminating water from radionuclides and heavy metals. The absence of the soil component, which can sorb a significant amount of contaminants but is difficult to dispose of, increases the chances for biota to sorb a considerable amount of radionuclides and heavy metals.

The **aim and tasks** lie in using intact terrestrial plants and their isolated parts as biosorbents of radionuclides and heavy metals under conditions of partial or complete isolation from the soil component. By incubating cut or mowed leaf-stem mass for a short time (a few days) in a solution containing a known contaminant, thus complementing the rhizosorption of intact plants, a high level of contaminant accumulation can be achieved through the work of active and passive biosorption mechanisms. A series of experiments is devoted to clarifying the ratio of these mechanisms for different types of plant tissues and finding conditions under which their sorption properties manifest to the greatest extent.

Objects, materials, and methods of experiments

In the first series of experiments, 0.5 L glass containers were used, pre-treated for three days with a 0.1 M solution of stable cesium chloride ($^{133}CsCl$) to prevent cesium sorption onto the vessel walls. The aqueous solution of $^{133}CsCl$ had a specific activity of 10^4 Bq/L and a pH = 7. Each container was filled with 400 mL of solution prepared from tap water and immersed with 30 g of freshly cut stems of Tradescantia and tobacco. The vessels with plant samples were placed in a thermostat and incubated at 18°C under continuous lighting.

To determine the potential biosorption capacity of plant tissues, the biosorption abilities of Tradescantia stem tissues were compared under continuous light and darkness. From each container, 1 mL of solution was periodically sampled, diluted with 18 mL of scintillation liquid (PC-103), and the radioactivity was measured using a RACKBETA scintillation counter. The proportion of radioactivity absorbed by plant tissue was calculated by the difference between the initial and current activity.

Results and Discussion

Notably, vessels treated with stable cesium chloride solution did not sorb radioactive cesium, eliminating the need for a control sample without plant tissue. Radioactive strontium was not sorbed onto the inner surface of untreated vessels.

It was found that a sharp increase in sorption occurred within the first four hours of incubation (up to 40% under lighting and up to 25% in darkness), followed by a smoother increase under continuous lighting and a decline (after two days) in darkness. The initial fast phase of accumulation is likely due to inherent sorption capacity retained by intact tissues under adequate oxygenation. Over six days of incubation (at 18°C and continuous lighting), the sorption level reached approximately 70%, suggesting that under optimal incubation conditions, near 100% sorption might be achievable within 1-2 days.

These findings suggest that Tradescantia primarily uses active mechanisms for cesium sorption. Large fluctuations and a significantly lower biosorption level in dark conditions support this. Since more than half of the cesium uptake is due to active mechanisms, Tradescantia tissues likely have a low sorption capacity for radiostrontium. Unlike radiocesium (a potassium analog), strontium-90 (a calcium analog) may only be actively sorbed during tissue growth, participating in cell wall synthesis. Since highly specialized tissues (leaves and stems) under non-growing conditions were used, significant radiostrontium uptake was unlikely. Although lateral roots began forming after a week in tap water, their low biomass could not significantly affect sorption levels.

This hypothesis was confirmed in the next experimental series using 20 g of fresh Tradescantia stems placed in 400 mL of Sr-90 nitrate solution with a specific activity of $4.1 \cdot 10^{-6}$ Ci/L. Sorption was measured similarly, showing a maximum biosorption level not exceeding 8% of the initial radionuclide quantity within 3 days.

High radiostrontium sorption could be expected from plant tissues with higher ion-exchange capacity [17], such as tobacco stems and leaves, which have higher ash content than Tradescantia. To test this, two variants were used: freshly cut and pre-dried (1 hour at 35°C) tobacco stems. As anticipated, dried stems exhibited slightly higher biosorption, likely due to additional sorption sites formed during autolysis. Sorption stabilized at around 30% of the initial radioactivity, suggesting a maximum sorption capacity under given conditions. The difference in sorption levels between fresh and dried tobacco stems indicates that harvested plant material retains sufficient biosorption capacity for subsequent use in phytodecontamination technologies.

Experiments on Biosorption by Sunflower, Corn, and Pea

To explore the potential of using intact plants capable of simultaneously sorbing radiocesium and radiostrontium in aquaphytodecontamination, a series of experiments was conducted with monocot (corn) and dicot (sunflower, pea) species.

Materials and Methods

Seeds of two sunflower varieties (I-DK 3904; II-SF-187), pea (Zelenozernyi), and corn (Dniprovska-286) were soaked in tap water for 8 hours, then placed on filter paper in a moist chamber for germination at 24-25°C. After 4 days, seedlings were transferred to 0.5 L containers with settled tap water. The containers were covered with opaque paper and placed in a growth chamber at 18°C with an 8 h photoperiod.

Cesium-137 chloride ($4.1 \cdot 10^{-6}$ Ci/L) and strontium nitrate ($4.1 \cdot 10^{-5}$ Ci/L) solutions were used. Cesium solutions were prepared in 0.5 L vessels pre-treated with 0.1 M cesium chloride for three days to prevent wall sorption.

After 11 days of incubation, plants were used according to several experimental schemes: (a) classic hydroponics (whole seedlings immersed with roots only), (b) isolated roots immersed (corn, pea), (c) isolated stems immersed (corn, pea). In total, nine experimental variants were tested, including control solutions without plant.

Samples of 0.5 mL solution were taken, mixed with 5 mL of scintillation liquid N103, and measured using a RACKBETA counter. The absorbed activity was calculated by the difference between initial and final values.

Results and Discussion

Dicotyledonous species (sunflowers and pea) reached near-maximal cesium sorption within two days. Corn seedlings reached peak biosorption only after seven days, possibly due to declining viability and loss of active uptake, leading to desorption exceeding sorption and solution activity rising back to initial levels.

Conclusions

Laboratory experiments confirm the high efficiency of terrestrial plants in purifying aqueous environments contaminated with soluble radionuclides. This makes the development of aquaphytodecontamination technologies promising. Special attention should be given to the possibility of sowing plants directly on floating substrates, which would reduce the cost of rhizofiltration-based decontamination. If the resulting phytomass has low radioactivity, it could be used as raw material for biogas production, plant-derived compounds, secondary metabolites, or cellulose. The feasibility of applying this technology will depend on the specific radionuclide contamination levels and landscape conditions, requiring adaptation for each site.

REFERENCES:

[1] Yan L., Le Q.V., Yang H., Gu H., Ma N.L., Lam, S.S., & Sonne, C. (2021). Phytoremediation of radionuclides in soil, sediments, and water. *Journal of Hazardous Materials, 407*, 124771. https://doi.org/10.1016/j.jhazmat.2020.124771

[2] Singh G., Bhadange S., Bhawna F., Shewale P., Dahiya R., Aggarwal A., Manju F., & Arya S.K. (2023). Phytotoxicity of radionuclides: A review of sources, impacts, and remediation strategies. *International Journal of Phytoremediation, 25*(1), 1-8. https://doi.org/10.1080/15226514.2022.2043239

[3] Kondo M., Maeda H., Goto A., Nakano H., Kiho N., Makino T., Sato M., Fujimura S., Eguchi T., Hachinohe M. (2014). Exchangeable Cs/K ratio in soil is an index to estimate accumulation of radioactive and stable Cs in rice plant. *Soil Sci. and Plant Nutr., 61*, 133-143. https://doi.org/10.1080/00380768.2014.890150

[4] Nagakawa Y., Uemoto M., Kurosawa T., Shutoh K., Hasegawa H., Sakurai N., Harada E., & Fukuda S. (2018). Comparison of radioactive and stable cesium uptake in aquatic macrophytes affected by the Fukushima Daiichi Nuclear Power Plant accident. *Journal of Radioanalytical and Nuclear Chemistry, 319*, 185-196. https://doi.org/10.1007/s10967-018-5863-6

[5] Fukuda S., Iwamoto K., Atsumi M., Yokoyama A., Nakayama T., Ishida K., Inouye I., Shiraiwa Y. (2014). Global searches for microalgae and aquatic plants that can eliminate