Natural ^{210}Pb migration in the Ignalina NPP water basin

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The main task of radioecology is to study radionuclides spreading in the environment and determine the factors controlling this process. ^{210}Pb is characterized by a high adsorption level. Our study showed that ^{210}Pb is a good tracer of stabile lead migration in hydroecosystems.

Key words: hydroecosystem, ^{210}Pb chemical forms, accumulation, biotic and abiotic factors

INTRODUCTION

Among the radionuclides of natural origin, ^{210}Pb plays an exceptional role because of its high level of toxicity (Morgan et al., 1964). Its stable analogue Pb^{2+} evokes deformations of plant cell membrane albumen, resulting in disturbed membrane conductivity (Morgan et al., 1964; Вахмистров, 1969).

^{210}Pb in the ecosystems exists in microconcentrations. It migrates in the hydrazide form and is characterized by high adsorption (Старик, 1969).

Pollution of water basins with ^{210}Pb takes place from both "wet" and "dry" fallouts and depends on the season: it is higher in dry and lower in wet periods (Перцов, 1964).

^{210}Pb belongs to radionuclides with low migration possibilities. This feature depends on low soluble ^{210}Pb forms dominating in natural waters and its high sorption level on suspended matter when water pH reaches 7.0–7.2 (Бахуров и др., 1965).

This paper deals with: (1) determination of ^{210}Pb distribution in the Lake Drūkšiai ecosystem, determining ^{210}Pb concentration and its accumulation level in biotic (hydrophytes) and abiotic (water, bottom sediments) components of the hydroecosystem of Lake Drūkšiai, the Ignalina NPP cooler; (2) evaluation of the factors controlling ^{210}Pb concentration and accumulation levels in the study objects; (3) evaluation of the role of hydrophytes in bottom sediment contamination with ^{210}Pb.

MATERIALS AND METHODS

Samples of hydrophytes, water and bottom sediments were collected from Lake Drūkšiai. The concentration of ^{210}Pb in the samples was estimated by the ion-exchange method (1) using the anionit EDE-IOP (Cl^- form) resin and measured by its daughter product ^{210}Bi, which strikes a balance with ^{210}Pb after 25 days. The stable lead concentration was determined at the Institute of Geology. The accumulation coefficient (AC) was determined as a ratio of ^{210}Pb concentration in a treated object and in water or bottom sediments.

RESULTS AND DISCUSSION

Our data show that the main source of ^{210}Pb in the Lake Drūkšiai hydroecosystem is "wet" fallouts where ^{210}Pb concentration fluctuates from 1.7 to 17.7 Bq/m^3 depending on sampling time. Maximum minings (10.7–16.6 Bg/m^3) were determined in summer and minimum minings in autumn (1.7–5.5 Bq/m^3).

We found that the bulk of ^{210}Pb in the Lake Drūkšiai hydroecosystem is localised in the abiotic hydroecosystem component – bottom sediments (66%), while in the biotic ecosystem components its content is lower: in algae 17%, macrophytes 12%, molluscs 2%. In water its content reaches only 3% (Fig. 1).

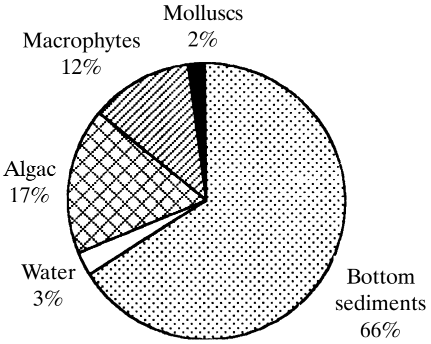

Fig. 1. Distribution of ^{210}Pb in Lake Drūkšiai ecosystem

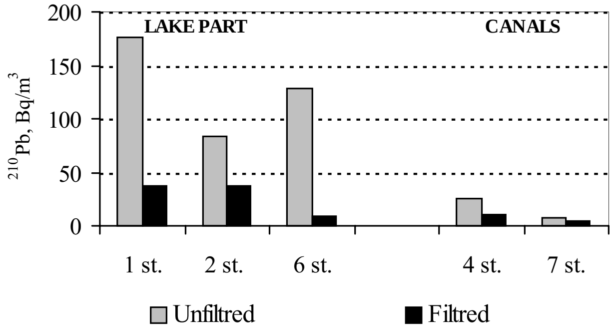

Fig. 2. ^{210}Pb concentration in Lake Drūkšiai water

^{210}Pb in Lake Drūkšiai water is found mainly in insoluble – suspended form. That confirms differences between the ^{210}Pb concentration levels in filtrated and non-filtrated water (Fig. 2).

An experimental treatment showed that the average 78.3% of ^{210}Pb in Lake Drūkšiai water is in insoluble and 21.7% in soluble form. We determined that ^{210}Pb concentration level in Lake Drūkšiai water depended on the depth. It can be connected with the higher ^{210}Pb dilution degree in deaper waters. An indirect correlation was found between ^{210}Pb concentration in water and lake depth (Fig. 3).

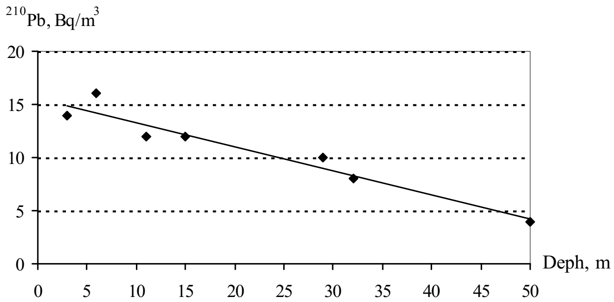

Fig. 3. ^{210}Pb concentration in water depending on the depth

The ^{210}Pb level in hydrophytes is determined by the absorption and adsorption processes. In spite of the low soluble ^{210}Pb level in treated water, hydrophytes accumulate ^{210}Pb in the amounts that on average 650 times exceed its concentration in water.

Among the 13 treated species, *Charophyta* algae was distinguished by the highest ^{210}Pb AC, which 700–1500 times exceeded ^{210}Pb concentration in water (Fig. 4). It depended on the *Charophyta* algae cell wall ability to accumulate chemical elements and a big amount of incoherent calcium which participates in exchange processes between water and plants.

It was determined that ^{210}Pb extraction by hydrophytes depended on their species, biomass and place of growing (Fig. 5).

Charophyta algae form a big biomass (from 4500 to 6850 g/m^2) which 4.6 times exceeds the biomass of macrophytes (from 600 to 1900 g/m^2), occupy

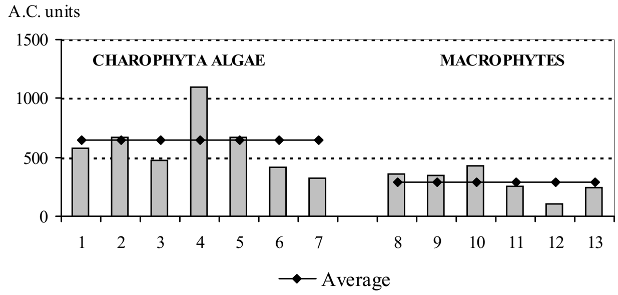

Fig. 4. ^{210}Pb A. C. in Lake Drūkšiai hydrophytes.
1 – Chara rudis; 2 – Nitellopsis obtusa; 3 – Chara aspera; 4 – Chara contraria; 5 – Chara tomentosa; 6 – Chara fragilis; 7 – Chara polyacanta; 8 – Potamogeton perfoliatus; 9 – Potamogeton natans; 10 – Potamogeton lucens, 11 – Myriophyllum spicatum; 12 – Stratiotes aloides; 13 – Batrachium aquatile

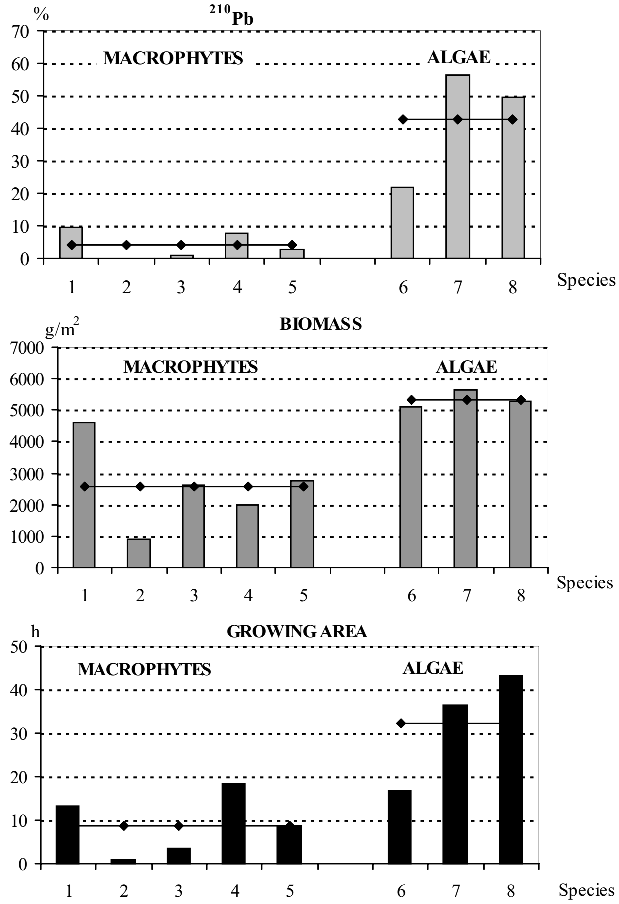

Fig. 5. Percentage of ^{210}Pb accumulation in hydrophytes depending on their biomass and growing area.
1 – Myriophyllum spicatum; 2 – Potamogeton perfoliatus; 3 – Ceratophyllum demersum; 4 – Elodea canadensis; 5 – Stratiotes aloides; 6 – Nitellopsis obtusa; 7 – Chara rudis; 8 – Chara tomentosa

the area which is 2.4 times larger than that of macrophytes (30.7 and 12.8 ha, respectively) and play an important role in ^{210}Pb extraction.

For example, *Nitellopsis obtusa* and *Chara rudis* can extract from 21 to 24% and from 42 to 56% of

^{210}Pb, respectively, while macrophytes such as *Myriophyllum spicatum, Potamogeton lucens* and *Ceratophyllum demersum* only 9.7, 6.3 and 1.5%, respectively.

We found between stable and radioactive lead a direct linear correlation (Fig. 6) which shows that higher contents of stable lead in hydrophytes stimulate a higher ^{210}Pb amount in them. That means that ^{210}Pb is a good tracer for determination of hydroecosystem's contamination with stable Pb.

As a result of thermal and chemical Lake Drūkšiai pollution, beside ionic exchange in hydrophytes an active mechanical sedimentation takes place as a result of high eutrophication level of the lake and the hydroecosystem's saturation with calcium (28 times) (Вахмистров, 1969). Under these conditions plants begin their vegetation season early and early finish it and precipitate on the bottom, forming a secondary long-term bottom sediment contamination source. Bottom sediments are a conservative system, hardly able to clean itself.

^{210}Pb concentration in bottom sediments fluctuated from 5.2 to 100.6 Bq/kg depending on their mechanical composition: in clay and silt samples it was 100.6 and 40.7 Bq/kg, while in sand 5.2 to 9.0 Bq/kg, respectively.

We determined the small dispersed parts of clay and silt type bottom sediments to be the main ^{210}Pb accumulators. In the deep part of the lake we observed the highest ^{210}Pb concentration in bottom sediments (Fig. 7). That means that the deep hollows of the lake are traps of heavy metals and their radionuclides.

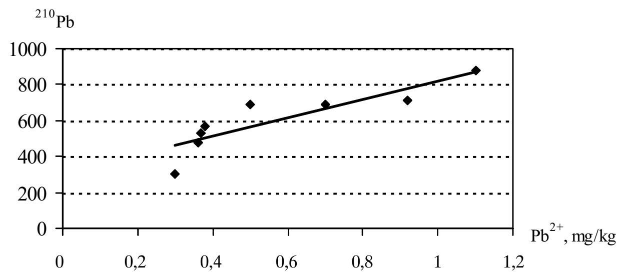

Fig. 6. Linear correlation between ^{210}Pb and stable lead concentrations in hydrophytes

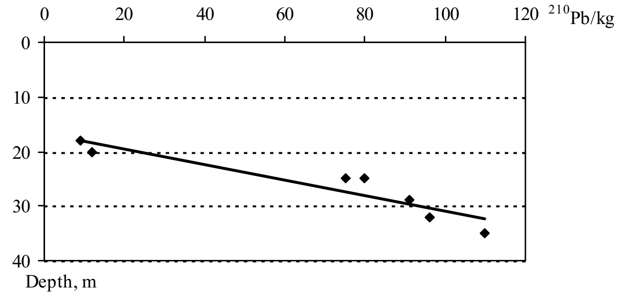

Fig. 7. ^{210}Pb concentration in bottom sediments depending on lake depth

Our data showed that ^{210}Pb accumulation in bottom sediments was bound with the organic sediment fraction, where its concentration in a 0–2 cm layer was 3.6 times higher than in mineral sediment fraction (3050 and 850 Bq/kg, respectively). It is a result of active Lake Drūkšiai eutrophication upon the thermal and chemical hydroecosystem contamination (Dušauskienė-Duž, 1997).

The obtained data indicate that the ^{210}Pb composition of the chemical forms in Lake Drūkšiai bottom sediments differs from those in other lakes (Dušauskienė-Duž, 1999).

In Lake Drūkšiai bottom sediments we found a big amount of exchangeable (46.2%) and acid-soluble (21%) forms of ^{210}Pb, which can take part in biological metabolism processes in the hydroecosystems (Table). It may be connected with water pH changes after washing the power plant blocs when to the lake are discharged great amounts of diluted acids and alkaline solutions (Бахуров и др., 1965) which can change ^{210}Pb chemical forms and make them more accessible to the hydrophytes.

Table. **^{210}Pb chemical forms in Lake Drūkšiai bottom sediments**

Fraction	Reagent	%
Water-soluble	Distilled water	0.8–8.2 3.7
Exchangeable	1 M $MgCl_2$	30–62.5 46.2
Carbonate	1M $NH_4C_2H_3O_2$	4.0–22.7 10.9
Hydroxide-bound	0.04 M NH_2OH HCl/ 25% CH_3COOH	8.3–13.5 8.8
Acid-soluble	7 M HNO_3	17.9–49.9 21.0
Organically bound	30% H_2O_2	10.7–13.5 9.4
Rest	HNO_3	5.5–27.7 11.6

CONCLUSIONS

Our data have shown that ^{210}Pb distribution in the Lake Drūkšiai hydroecosystem is conditioned by the chemical nature of ^{210}Pb.

The ^{210}Pb concentration in Lake Drūkšiai depends on "wet" fallouts and is higher in shallow parts of the lake. ^{210}Pb in Lake Drūkšiai water is found mostly in the insoluble suspended form.

^{210}Pb accumulation in hydrophytes depends on their species, growth area and biomass. The main role in ^{210}Pb extraction – water purification from ^{210}Pb belongs to *Charophyta* algae, which occupy a large area and have a big biomass: *Carophytae* algae can accumulate up to 60% of ^{210}Pb, while macrophytes only 8%. There is a direct correlation between ^{210}Pb and stable Pb concentrations in hydrophytes and bottom sediments, which allow to use ^{210}Pb as a tracer in stable Pb migration and distribution in environmental studies.

The chemical composition of bottom sediments shows that in Lake Drūkšiai under the anthropogenic impact (thermal and chemical pollution) ^{210}Pb chemical forms change when ^{210}Pb is involved in the biological metabolism processes of the hydroecosystem.

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GAMTINIO ^{210}Pb MIGRACIJA IGNALINOS AE VANDENS BASEINE-AUŠINTUVE

S a n t r a u k a

Darbe pateikti duomenys apie ^{210}Pb sklaidą Ignalinos AE vandens baseine-aušintuve. Nustatytas biotinių ir abiotinių ekosistemos komponentų vaidmuo kaupiant šį radionuklidą. Išryškintas antropogeninių veiksnių (terminis ir cheminis užteršimas) vaidmuo šio radionuklido migracijai hidroekosistemoje. Nustatytos ^{210}Pb cheminės formos Drūkšių ežero dugno nuosėdose.

Raktažodžiai: hidroekosistema, ^{210}Pb, cheminės formos, akumuliacija, biotiniai ir abiotiniai veiksniai