^{90}Sr spread in hydroecosystem and factors controlling this process

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The main task of radioecology is to study radionuclides spreading in the environment, to evaluate its radioactive contamination and to determine the factors controlling these processes.

A major problem with trying to limit an ecosystem is that all ecosystems depend on the physical (nonliving) factors and biotic (living) things.

Key words: biotic, abiotic hydroecosystem's components

INTRODUCTION

The main task of radioecology is to study radionuclides spreading in the environment, to evaluate its radioactive contamination and to determine the factors controlling these processes.

A major problem with trying to limit an ecosystem is that all ecosystems depend on the physical (nonliving) factors and biotic (living) things.

The bulk of ^{90}Sr after the Chernobyl NPP accident fell out in a 30 km zone and its activity did not exceed 3–5 Ci/km^2, however, the accident's consequences are actual to Lithuania. Among the radioactive contaminants, ^{90}Sr is very important, because: 1) it spreads in the environment in a mobile chemical form; 2) ^{90}Sr is a chemical and biological analogue of calcium – one of the most important elements of alive nature; 3) ^{90}Sr easily joins the metabolic processes and accumulates in critical man's organs where it forms local ionization zones; 4) ^{90}Sr has a long half-period and a long survival in the organism (from 500 days to some years).

Environmental contamination with ^{90}Sr is possible from two sources: by global fallouts and by the nuclear power plants (NPP).

The main task of this paper was to establish ^{90}Sr migration in hydroecosystems with the aim to determine common peculiarities stimulating the ^{90}Sr accumulation level in hydrophytes and to evaluate the factors controlling this processes.

MATERIALS AND METHODS

Seventeen species of hydrophytes popular in the water and bottom sediments of ten Lithuanian lakes (7 of them are unflowing water basins, 1 – flowing, and 2 are water basins – coolers of the Ignalina NPP and the Lithuanian State Heat and Power Plant) were investigated with the aim to determine ^{90}Sr spreading in a hydroecosystem and to evaluate the role of the objects studied in ^{90}Sr accumulation.

Hydrophytes, molluscs and bottom sediment samples were dried and incinerated at 400 °C. The concentration of ^{90}Sr in plant, water and bottom sediments ware estimated by the clasical oxalate method [1, 2]. ^{90}Sr was measured according to its daughter product ^{90}Y, which reaches a balance after 14 days. The concentration of ^{90}Sr in hydrophytes, molluscs and bottom sediments was expressed in the dry weight (d.w.) of the samples. The calcium concentration was determined using the titration method [3].

Accumulation coefficient (AC) of ^{90}Sr in hydrophytes and bottom sediments was calculated as a ratio of ^{90}Sr concentration in plants and in water. A correlation coefficient (r) was determined.

RESULTS AND DISSCUSION

It was established that ^{90}Sr after entering a hydroecosystem is diluted and distributed among biotic and abiotic hydroecosystem's components (Fig. 1). The bulk of ^{90}Sr (61.2%) is found in the biotic components: in macrophytes – 10.6%, molluscs – 30.1%, algae – 20.5%, while in abiotic components only 38.8% was determined: in water 33.4% and bottom sediments 5.4%. Hydrophytes obtain ^{90}Sr from water, where 95% of ^{90}Sr is in water-soluble form. In spite of a low ^{90}Sr concentration in the water of (0.016–0.086 Bq/l) the in lakes studied, hydrophytes

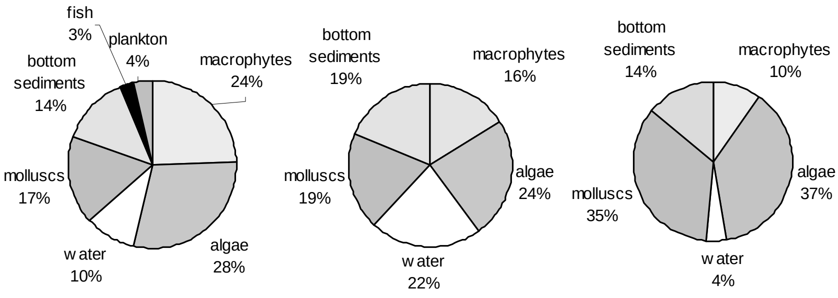

Fig. 1. Percentage of ^{90}Sr distribution in Curonian Lagoon (1), Lake Dusia (2) and Lake Galstas (3) ecosystems

accumulate ^{90}Sr in the amounts that hundred and thousand times exeed its concentration in water. The accumulation coefficient (AC) of ^{90}Sr in algae fluctuates from 88 to 1315 units (average 635 units), while in macrophytes it reaches from 51 to 662 units (average 225 units) depending on their species (Fig. 2). That means that ^{90}Sr concentration in algae is 730 ± 28 and in macrophytes 207 ± 11 times higher than in water.

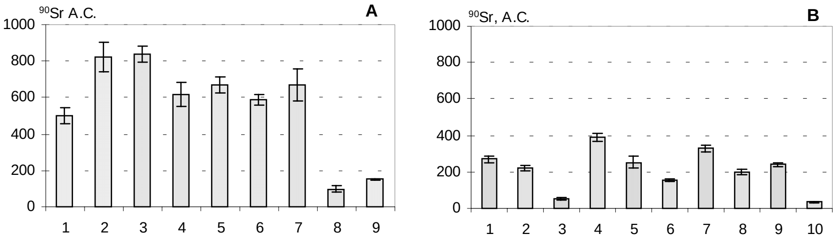

Fig. 2. The coefficient of accumulation im algae (A) and macrophytes (B).
A: 1 – *Nitellopsis obtusa*, 2 – *Chara rudis*, 3 – *Ch. aspera*, 4 – *Ch. tomentosa*, 5 – *Ch. fragilis*, 6 – *Ch. vulgaris*, 7 – *Ch. contraria*, 8 – *Nitella syncarpa*; 9 – *Cladophora glomerata*.
B: 1 – *Myriophyllum spicatum*, 2 – *Stratiotes aloides*, 3 – *Lemna trisulca*, 4 – *Elodea canadensis*, 5 – *Ceratophyllum demersum*, 6 – *Potamogeton natans*, 7 – *P. lucens*, 8 – *P. perfoliatus*, 9 – *P. pectinatus*, 10 – *Utricularia vulgaris*

Charophyta algae an the hydrophytes is distinguished by a high content of Ca which, depending on species, fluctuates from 15 to 25% [7], and carbonates (50% and more from a common content of mineral remnants) [8].

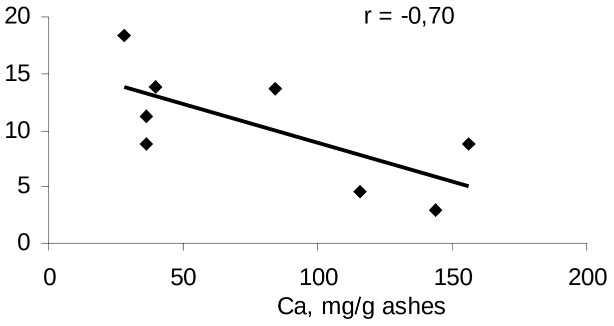

Fig. 3. Indirect correlation between ^{90}Sr and Ca concentration in plants

Ca is a biological and chemical analogue of ^{90}Sr and the relation between them is competitive: hydrophytes begin to accumulate ^{90}Sr only in the case when in the environment there is a lack of Ca [4]. We obsrved a great variation in Ca concentration in the hydrophytes. In the same species growing in various lakes, Ca concentration in *Elodea canadensis* differs 6 and in *Potamogeton lucens* 9.5 times. The determined direct correlation between ^{90}Sr accumulation in the hydrophytes and exchangeable amount of Ca in them explain that dependence (r = = –0.688) (Fig. 3).

That means that a higher level of Ca in algae in comparison with the macrophytes stimulates the metabolism between ^{90}Sr and Ca and ^{90}Sr conversion into an irreversible form of carbonaceous compounds in them.

It is obvious that hydrophytes forming a great phytomass in water basins play an active role in water basin purification from various pollutants, including radioactive. We determined that in ^{90}Sr extraction from water the main role belongs to *Myriophyllum spicatum, Potamogeton lucens* and algae *Chara rudis* and *Nitellopsis obtuse,* which form a big phytomass and a big bottom sediment projective cover (Table 1.).

The ^{90}Sr AC predominant among 17 species was indicated in immersed and half-immersed macrophytes (the average AC 128 and 188, respectively) whose habitat is from water over plant surface. In buoyant macrophytes whose habitat is from water and over the roots, the AC of ^{90}Sr was lower and reached on average 110.

Table 1. **The role of hydrophytes in ^{90}Sr extraction**

Species	Biomass, g/m^2	Area, h	^{90}Sr, %
Potamogeton natans	1450	3.1	0.3
Potamogeton perfoliatus	990	1.1	0.04
Potamogeton lucens	1450	26.2	5.8
Myriophyllum spicatum	4600	12.3	6.0
Elodea canadensis	1900	11.4	3.1
Nitellopsis obtusa	5150	16.9	19.4
Chara rudis	5650	36.4	64.7

The ^{90}Sr accumulation level in the hydrophytes depends on water basin type: in hydrophytes growing in flowing water basins, the AC of ^{90}Sr was considerably lower than in plants growing in unflowing water basins (115 and 278, respectively). We determined that the AC of ^{90}Sr in hydrophytes growing in unflowing water basins increased through the whole vegetation season from spring to autumn, while in the macrophytes growing in flowing water basins such peculiarities were not found (Fig. 4).

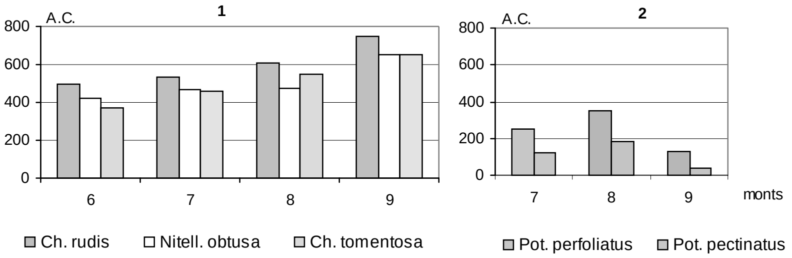

Fig. 4. The coefficient of ^{90}Sr accumulation in macrophytes growing in unflowing (1) and flowing (2) water basins

We determined that between the factors controlling ^{90}Sr level in hydrophytes, high Ca concentration in water and its saltiness stimulate ^{90}Sr lowering in the hydrophytes.

The ^{90}Sr AC in *Potamogeton perfoliatus* and *Potamogeton pectinatus* growing in the north part of the Curonian lagoon reduce the ^{90}Sr AC from 190 (Ca concentration in water 42 mg/l) to 82 (Ca concentration in water 108 mg/l) and show that the effect of salty water displayed by water saturation with Ca and ^{90}Sr discrimination.

At the same time the effect of salty water on the ^{90}Sr AC in phytoplankton was determined. When water saltiness changed from 0.02 to 3.14‰, the AC of ^{90}Sr in phytoplankton decreased 7 times (from 100 to 14 units); when water saltiness changed from 0.02 to 1.5‰, it decreased only 3 times (from 100 to 33 units).

Among the factors influencing ^{90}Sr accumulation in hydrophytes, water temperature his of great importance. Distinct differences in ^{90}Sr accumulation in hydrophytes depending on their growing place were established. In plants growing in heated water outflow zones of Lake Drūkšiai (the Ignalina NPP cooler) the ^{90}Sr AC 1.7 times lower was than in hydrophytes growing in the lake zones distant from the heated water (the AC was 215 and 380, respectively). We determined that the heated water outflow had a negative effect on the physiological state of hydrophytes up to a complete disappearing of individual species.

In warm waters, the processes of hydrophyte destruction are more active than in basins with a natural water temperature. The ^{90}Sr concentration in bottom sediments, mainly in zones rich in macrophytes and marked for a high rate of destruction processes (Lake Drūkšiai at the Ignalina NPP and Lake Elektrėnai Lithuanian State Heat and Power Plant) from May to October in bottom sediments increased 2.4 times – from 13.3 to 32.8 Bq/kg.

It was determined that, besides the ionic exchange processes between the hydrophytes and water, an active mechanical sedimentation of ^{90}Sr on the plant surface takes place as a result of a high lake eutrophication level and over the hydroecosystem saturation with Ca [5].

We determined that Ca carbonate inlays appear on the hydrophyte leaves with a distinct trend to increase in autumn from 0.56 to 1.0 Bq/g in which ^{90}Sr joins an insoluble carbonaceous structure. Carbonate inlays actively form on the nuface of *Charophyta algae, Potamogeton perfoliatus, Potamogeton lucens, Potamogeton natans, Myriophyllum spicatum* and *Ceratophyllum demersum*. It is a biogenic decalcination process (Романовский, 1979) which takes place in all lakes exposed to contamination.

The lake shoreline is a specific zone where sandy bottom sediments predominate, so the possibility to accumulate contaminants is very low. Galkus et al. (1995) found that in Lake Drūkšiai canal zones are formed sediments with a high contaminant sorbtion possibility.

Helophytes (*Typha latifolia* and *Phragmites australis*) which are growing in the lake shoreline and canals accumulate ^{90}Sr over the roots. In view of the fact that after vegetation season helophyte roots continue to function and are alive three years (Vestleik, 1968), and about 79% of helophyte biomass is made up by roots [10], the ^{90}Sr AC in helophyte roots is 1.85 times higher than in leaves (2.15 and 1.16 respectively) and depends on their growing place (Table 2). Our data show that the average ^{90}Sr AC in helophyte leaves growing in a lake shoreline is 0.8 and in roots 2.3, while in the zone canal it reaches in leaves 1.14 and in roots 3.2, respectively, *i.e.* ^{90}Sr accumulation in the helophyte leaves and roots in the canal zone is 1.4 times higher than in the lake shoreline. We think that some amounts of ^{90}Sr enter Lake Drūkšiai from industrial sewage and rain canals of the wastewater disposal system and concentrates in the bottom sediments.

The ^{90}Sr AC in helophyte roots, depending on their growing place, fluctuated from 1.3 to 6.0, while in leaves no real difference was found (Fig. 5). ^{90}Sr AC in helophytes root is stipulating by the bottom sediment mechanical composition and ^{90}Sr concentration level in them.

Table 2. **The coefficient of ^{90}Sr accumulation in helophytes depending on their growing place**

Species	Shoreline			Canals		
	Tilžė	Grikiniškės	Vosyliškės	7 st.	4 st.	2a st.
Thypha latifolia						
leaves	0.6	1.1	–	1.3	1.6	0.8
roots	2.0	1.7	1.7	1.9	4.8	2.4
Phragmites australis						
leaves	0.6	1.3	0.4	-	1.2	0,8
roots	3.0	1.9	1.3	1.0	6.0	3.3

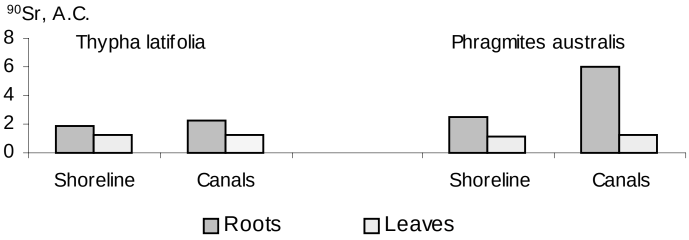

Fig. 5. The coefficient of ^{90}Sr accumulation in helophytes depending on their growing place

The ^{90}Sr concentration level in shoreline bottom sediments varied, depending on their collecting place, from 13.8 to 41.6 Bq/kg (average 22.2 Bq/kg), when in canal bottom sediments it reached from 7.7 to 26.2 Bq/kg (average 12.2 Bq/kg). Our data on the Ca concentration fluctuation in the shoreline and canal bottom sediments show differences in their mechanical composition.

It is known that ^{90}Sr accumulation in bottom sediments depends on a concentration of cations such as PO_4, SO_4 and CO_3 in sediments. Our data showed maximum ^{90}Sr concentration (42 Bq/kg) in silt type bottom sediments where the Ca concentration reached 72 mg/g ash, and a minimum (14 Bq/kg) in sand type bottom sediments, where the Ca concentration was only 20 mg/g ash. Such a dependence confirms a direct correlation between ^{90}Sr and Ca concentrations in bottom sediments (Fig. 6). On the basis on this correlation we can evaluate bottom sediment contamination with ^{90}Sr depending on bottom sediment type.

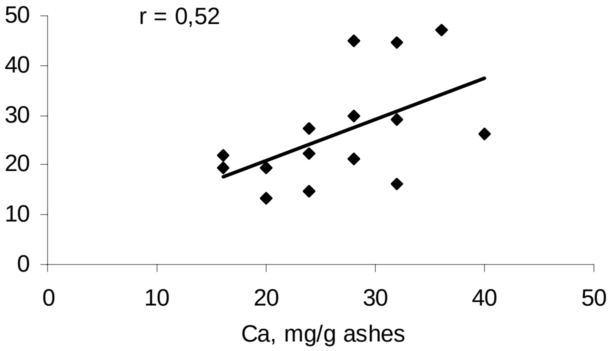

Fig. 6. Direct correlation between ^{90}Sr and Ca concentrations in soil (r = 0.52)

CONCLUSIONS

Biological ^{90}Sr accumulation in hydrophytes depends on natural and anthropogenic factors, while radionuclide accumulation in hydrophytes depends on their participation in biological processes and their intensity.

^{90}Sr distribution among the ecosystem components depends on the ecological situation of a water basin, water chemical composition and hydrophyte nutrition. ^{90}Sr accumulation in hydrophytes growing in the lake zones in which the influence of anthropogenic factors is obvious deteriorates their physiological state and lowers their accumulation possibility.

The highest ^{90}Sr levels were found in plants growing in unflowing type water basins and in immersed and half immersed hydrophytes whose habitat is water over the plant surface in comparison with the ^{90}Sr amount in helophytes whose habitat is bottom sediments.

Ca concentration in water, hydrophytes and bottom sediments is a very important factor controlling the ^{90}Sr accumulation level in hydrophytes. There is a direct correlation between ^{90}Sr accumulation in hydrophytes and exchangeable Ca amount in them: the Ca content in water limits the ^{90}Sr accumulation in hydrophytes.

We determined that water saltiness and temperature are of great importance for ^{90}Sr accumulation in hydrophytes and lowering ^{90}Sr accumulation in hytoplankton.

Helophytes whose type of habitat is connected with the bottom sediments in the best way reflect bottom sediment contamination with ^{90}Sr, while the ^{90}Sr accumulation level in hydrophytes reflect the level of water contamination by ^{90}Sr.

We consider *Charophyta* algae, distinguished by a high ^{90}Sr accumulation ability, to be the best test organism in hydroecosystem. ^{90}Sr concentration in *Charophyta* algae is 730 times and in macrophytes 207 times higher than in water.

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^{90}SR SKLAIDA HIDROEKOSISTEMOJE IR VEIKSNIAI, LEMIANTYS ŠĮ PROCESĄ

Santrauka

Darbe pateikti duomenys apie ^{90}Sr sklaidą hidroekosistemoje rodo, kad biotinis hidroekosistemos komponentas vaidina svarbų vaidmenį ^{90}Sr akumuliacijos procesuose. Jame sukaupta 61% šio radionuklido, o abiotiniame hidroekosistemos komponente – 39%. Tarp hidrofitų, aktyviai kaupiančių šį radionuklidą, išsiskiria menturdumbliai ir pasinėrę hidrofitai. Ištirta keletas veiksnių, pavyzdžiui, vandens baseino hidrologinės ir hidrocheminės savybės, augalų mineralizacija ir jų įtaka ^{90}Sr kaupimuisi hidrofituose. Parodyta, kad pasinėrę hidrofitai yra vandens užterštumo ^{90}Sr rodikliai, o aukštieji helofitai rodo dugno nuosėdų užterštumo ^{90}Sr lygį.