THE BEHAVIOUR OF RADIONUCLIDES AND CHEMICAL CONTAMINANTS IN TERRESTRIAL AND WATER ECOSYSTEMS OF URALS REGION

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1. Introduction

One of the regions of Russia, with extreme ecological conditions is the Ural. On the territory of region some large industrial complexesare located, which structure includes enterprises of nuclear fuel cycling, non-ferrous and ferrous metallurgy, chemical industry mining, and fuel industry all having an impacton the ecological situation. In this connection ecologists of such a diverse structure studies are developed to investigate the condition of the environment, disclosing any regularities in the evolution of the ecological conditions in the region, with a forecasting goal.

Some results of researches conducted by two scientific collectives of Institute of Ecology of plants and Animals of the Urals division of RAS are represented one of which attends to problems of radioecology, and the other study of the influence on terrestrial ecosystems of chemical contaminants.

The purpose of the work is:

1) to show features of radionuclides contamination of bog-river ecosystems near the NPP and to evaluate its function as a biogeochemical barrier to migration of radionuclides towards underlying links of a river system;

2) to present a system of practical and theoretical approaches to be used for the installation of limits of stability of natural ecosystems against the action of pollutants.

2. The content and the behaviour of radionuclides in the bog-river ecosystem in the vicinity of the Nuclear Power Plant (NPP).

The Olkhovka bog is situated 5 km southeast of the Beloyarskaya NPP. It extends from the southwest to the northeast for about 3 km. The south-western part of the bog receives weekly radioactive wastewater from the NPP and municipal sewage from the city of Zarechnyi. The Olkhovka river flows out of the northeastern end of the bog. The eastern and southeastern parts of the bog are occupied by a birch canopy. In addition, there are willow groves (*Salix cinnerea L.* and *S. pentandra L.*) of different size and individual pine trees (*Pinus sylvestris L.*)

The Olkhovka bog-river ecosystem consists of the Olkhovka bog and Olkhovka river, implications from another bog and running into the Pyshma river, which is included into structure of the Ob-Irtysh rivers system. The Olkhovka bog-river ecosystem represents the half-natural formation which has arisen during the work on

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the first two reactors of Beloyarskaya NPP. (Beginning of the workson the first reactor was of 1964, second of 1967. These reactors were brought into operation accordingly in 1981 and 1989. In 1980 a third fast neutron reactor is brought into operation . The Olkhovka bog was derived asa result of the dumping on a wood swampy plot of unbalanced and domestic waters from NPP, and also of sewer waters of the city of Zarechny, where the workers of the NPP live.

In general the main radioactive contamination of the bog-river ecosystem has taken place during the operation of the first two reactors (table 1-3). The researches of the last years have shown, that the long-term dumping of unbalanced waters of Beloyarskaya NPP in the Olkhovka bog has also lead to plutonium accumulation . The greatest concentration of ^{239,240}Pu (39-114 Bq/kg) are marked in the base suspension of a beginning of a bog. In region of a source of Olkhovka river in stratums of base adjournment 0-5 ñì and 5-10 ñì the concentration ^{239,240}Pu is equalled accordingly 12,0 and 0,9 Bq/kg. However main contaminants are ^{137}Cs, ^{60}Co and ^{90}Sr. The concentration ^{137}Cs make tens, and ^{60}Co and ^{90}Sr - accordingly units and tenth shares of kBq/kg (tab. 1, 2) [1-5].

Table 1. Concentration of radionuclides in the sediments of bog-river ecosystems for 1978-1986, kBq/kg [1]

Location	Sediments	^{60}Co	^{90}Sr	^{137}Cs
Discharge cannel	Sand	4.0 (1.6-6.0)*	0.07 (0.02-0.10)	16.0 (7.0-25.0)
	Silt	5.0 (3.0-46.0)	0.20 (0.06-0.27)	22.0 (18.0-28.0)
Swamp: beginning	Sand	34.0 (1.0-60.00)	1.80 (0.48-3.80)	58.0 (9.0-112.0)
centre	Silt	3.0 (1.0-7.0)	1.20 (0.07-3.40)	27.0 (7.2-65.0)
Olkhovka river: source	Sand	0.12 (0.10-0.15)	0.03 ((0.02-0.15)	20.0 (10.0-30.0)
	Silt	1.40 (0.77-2.30)	0.19 (0.06-0.87)	30.0 (8.0-51.0)
mouth	Sand	0.30 (0.14-0.50)	0.06 (0.01-0.17)	16.0 (3.0-26.0)
	Silt	0.90 (0.15-2.10)	0.14 (0.01-0.24)	34.0 (7.0-86.0)

* Annual variation

Table 2. Radionuclide content in the soil-vegetative cover of the Olkhovskoye bog region (1) and control lot (2), kBq/m^2. (Layer of soil 0-10 cm.)

Location	^{90}Sr		^{137}Cs	
	1	2	1	2
Watershed	1.85	1.29	9.09	6.84
Slope	1.20	1.23	4.20	4.74
Bank of the bog	1.85	1.24	47.80	5.31

Table 3. Concentration of radionuclides in the water of the Olkhovskoye bog-river ecosystem, Bq/l [5]

Location	^{60}Co		^{90}Sr		^{137}Cs	
	1976-1986	1989-1991	1976-1986	1989-1991	1976-1986	1989-1991
Discharge cannel	2,6 (2,2-6,4)*	BDL**	0,6 (0,1-1,2)	0,7 (0,3-1,2)	10.0 (2.8-28.3)	9.0 (2.4-15.6)
Bog: beginning	3,3 (2,6-7,6)	BDL	0,8 (0,1-1,6)	1,3 (1,0-1,6)	16.6 (2.3-49.2)	8.4±1.8
centre	2,8 (1,5-10,1)	BDL	0,9 (0,1-1,7)	1,2 (0,7-1,2)	20.7 (4.1-43.4)	17.0 (9.9-24.1)
Olkhovka river: source	2.8 (1.2-7.6)	0.3±0.03	0.8 (0.2-2.5)	1.0 (0.8-1.1)	16.0 (9.7-35.0)	11.6 (4.7-20.2)
mouth	1.3 (1.1-2.6)	0.3±0.02	0.4 (0.2-1.0)	0.5 (0.2-1.0)	10.0 (2.4-16.0)	7.9 (4.1-17.9)

* Annual variation

** Below detection limit

The increased content of radionuclides is established in the soil-vegetative cover of the coastal zone of the bog. Especially high concentrations of ^{137}Cs, exceeding about 3-4 order of magnitudes compared to the background , are detected in wood plants (birch and willows), that grow on the bog and on periodically flooded plots adjacent to land [6,7]. Birch and willow from the territory of the bog cannot be used for economic purposes because of a high ^{137}Cs content.

From 1978 to 1986 onwards., when the Olkhovka bog-river ecosystem was subjected to periodic input from three NPP reactors, the concentration of radionuclides in the water on a section of the discharge channel-mouth of the Olkhovka river was changed a tenfold over the years (table 3). In this period though, on the average, the concentration was below the sanitarian norms for potable water. After the closure from operation of the first two NPP reactors of the inputof ^{60}Co with liquid dumping practically was stopped, the contents in water of the Olkhovka bog-river ecosystem ^{90}Sr was not essentially changed and the ^{137}Cs content has decreased.

The stock of radionuclides (^{60}Co, ^{90}Sr, ^{137}Cs) in the swamp was estimated at more than 100 Ci, with ^{137}Cs a the main component [2].

During the last years dumping of city sewer waters in a bog , whose volume was exceeding the natural charge of the Olkhovka bog, was terminated.This has entailed a modification of the hydrological status of the bog and caused a shrinking of the surface size of this constantly flooded territory. The discontinuing of the l dumping in theunbalanced waters of Beloyarskaya NPP in the Olkhovka bog has resulted in a reduction of the widespread content of radionuclides in this ecosystem . A removal of a small amount of radionuclides occurred with water through Olkhovka river in Pyshma river (table 3) and through radioactive disintegration. A variable velocity of migration ^{90}Sr, ^{137}Cs and Pu in the base suspension and in soil, and also their leaching from the top horizonswill in due course change the character of the vertical distribution of radionuclides in these media.

The analysis of data on the ecological conditions on territory of the Olkhovka bog-river ecosystem has shown, that the levels of contamination of its components are lower than those limits, that are able to cause its deterioration [13]. Therefore, in the given situation the sanitary-hygienic standards are sufficient for safeguarding of the ecosystem.

3. Influence of chemical contaminants on the terrestrial ecosystems

Despite the presence in the Urals region of extensive territories with radionuclide contamination, it is obvious that aquatic and terrestrial ecosystems have been more effected by chemical releases. In a number of places it has lead to the destruction of ecosystems and even to the origination of industrial deserts. It has become clear, that the observance of the sanitary-hygienic standards does not protect a natural medium from a destructive operation by pollutants. It has resulted in the development of an ecological normalization of the smoke-gas emission and liquid dumping of toxicants .

The original methodical approaches for the creation of the ecological specifications were developed on the basis of researches which are being carried out in the vicinity of copper-melting plant , located near the city of Revda (Sverdlovsk District, Middle Urals).

As a methodological basis of the approach to study the influence of chemical contaminants on the terrestrial ecosystems the construction and an analysis of associations between the received pollutants in principal components of the terrestrial ecosystems and the response of natural ecosystems on a concrete toxic level of the load has been chosen. This approach was set up for the installation of threshold levels of the effect (critical loads) of the delivery of heavy metals, in a complex with SO_2, onto the principal components of wood ecosystem: wood and herb-undershrub layers, wood litter, soil biota, epiphytic lichens communities [8-12]. Researches were conducted in a combined operative range with regard to the production draft-quality copper. To study the degree of effect on a natural medium three zones were chosen: impact , buffer and background. The long-term (since 1940) atmospheric contamination has generated a high gradient of toxic load: the content of heavy metals (Cu, Pb, Cd and Zn) in wood litter near the factory exceeds the background level for one to two orders of magnitude (with a maximum of more than 400 times). Actually, it means, that near the emission source the most contrasting technogenic geochemical anomaly is generated. High significant correlation coefficients between the concentrations of separate metals are shown: for the Cu - Pb pair it is equal to 0.95 a,for Zn - Cd equal to 0.94 – and 0.63-0.81 for the in remaining combinations (in all cases $P << 0.00001$, $N = 221$). Such close direct correlations allow to correctly present multi-dimensional information about the contamination of the territory as a one-dimensional load index of contamination (average of the concentration, normalized to background levels of elements), which is used in case of the need of analysis of “dose-effect” curves (technique of account is indicated in [8]).

In most cases the response of components on natural ecosystem at a toxic load appears to have a sharply expressed non-linear character (the “dose-effect” curve is S-shaped). It indicates the existence of a trigger effect: there are two metastable conditions (plots with slow modifications), and then a very sharp transition in between(plot of a gradient with fast modifications). Such a response threshold allows to rather objectively installing limits in size of release or dumping of pollutants (critical loads).

The emissionsof SO_2 result in a important acidification of wood litter (Figure 1), which brings about a significant contribution in the expressivity of processes of degradation of wood ecosystems (toxicity of heavy metals, as is known, largely depends on the acidity of the soil solution).

As a convenient integrated parameter of activity of a saprotroph complex of soil biota , which can be effectively used in diagnostics of anthropogenic intrusions of a wood ecosystem, the modification of the thickness of forest litter is used. The increase of the thickness of forest litter - one of the most noticeable manifestations of intrusion of the biological circulation in wood ecosystems, is sensitive to chemical contamination. Emissions from a copper-melting plant (heavy metals and SO_2) in the Middle Urals introduces a 2.7 - 3.9 times increase of the thickness of forest litter. For several variants of biotopes, distinguished by its contours (eluvial, transit and accumulative landscapes), non-linear dose - effect regressive dependencies, connecting thickness of litter to Cu, Pb, Cd and Zn contents, are put up. The critical loads and, accordingly, stability soil biota appear to essentially depend on the connection of the litter thickness to its Cu, Pb, Cd and Zn content in it. The critical loads and, accordingly, stability soil biota essentially moreover depend on the ecotopic conditions: In accumulative landscapes the litter thickness starts to increase at essentially smaller levels of contamination compared to transit and eluvial landscapes.

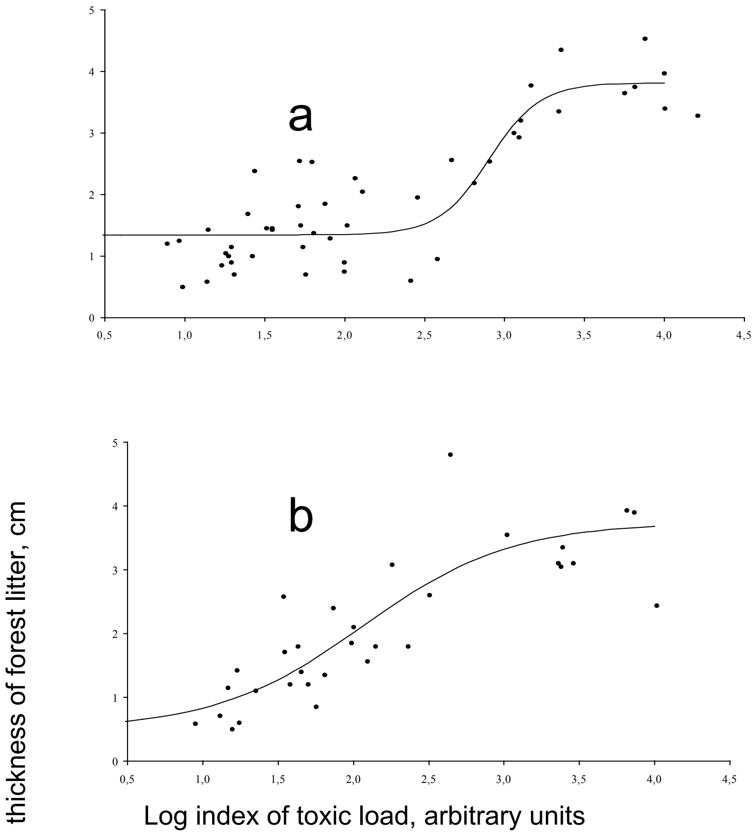

Fig. 1. Dependence a dose - effects on the thickness of forestry litter in eluvial (a) and accumulative (b) relief elements.

The increased space variation of toxicity of soil and litter in a transitional zone can be one of the key mechanisms causing the observable nonlinearity in the response of ecosystems on contamination. It has caused the necessity of an evaluation of levels of space variation (in scales from ten centimetres up to kilometres) in heavy metal content and acidity of wood litter.

In all zones with a contaminant load the space variation of pollution in the accumulating media both for separate elements and for a resulting parameter, the index of contamination is increased because of the transition from the gross content into exchangeable forms together with a magnification of square of test (coefficient of variation will increase from 10-20 of % till 50-80 of In most cases, the following regularity is observed: the space variability is the lowest in the background zone, is maximum in buffer and the impact zone takes an intermediate position. The space variation both for the gross content, and for the exchangeable forms is higher for the soil in comparison to litter (in soil probably considerably more mechanisms, modifying the contents of elements are active). In the context of the discussed problem the particular importance of a trigger effect is shown by an evaluation of the space range of toxic load in different zones of contamination. The range of concentration of metals in buffer and impact zones is extremely large and reaches to 50-90 % for the complete range of the possible variation.

It also established that the acidity range of of soil and litter both in buffer and impact zones makes 0.7-1.4 units pH and maximum reaches almost two units ðÍ, whichsignifies 30-90 % of the complete range of the possible variation. , This condition is probably the key factor that is modifying the space variation of the toxicity of soil and litter for biota.

The suggested approach to standardization is of applied character as there are the following sufficient limits: all reasoning are with assumption that ecosystems in background and transformed condition are obtained for the definite emission structure and after its sufficient changing new standard obtaining is necessary; the research scheme for standard obtaining can be correctly fulfilled only in the region where background environment slightly differs with pre-industrial condition.

Different from the sanitary-hygienic standards, the ecological standards (the extreme allowable ecological loads) should be differentiated on regions (botanical-geographical zones), types of ecosystems, types of productions and nature management regimes.

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