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GEOCHEMISTRY

Ecological–Geochemical Patterns of Northern European Russia

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The arrangement and activity of plants in northern Russia that use atomic energy for the solution of economic and defense tasks has resulted in the pollution of the environment by technogenic radionuclides in some areas of this region. In order to develop measures for providing radioecological safety of the region and predicting the behavior of artificial radionuclides in case of emergencies at sites with potentially hazardous radiation, it is necessary to define the constraints of the distribution of radionuclides in tundra and northern taiga ecosystems characteristic of the northern part of the country. Therefore, the following radiation–ecological investigations are being carried out near such objects:

(1) elucidation and analysis of real and potential sources of radionuclide pollution;

(2) complex study of interrelated ecological–geochemical systems along with natural and technogenic geochemical barriers; and

(3) analysis of the distribution of radionuclides in different components of geosystems and compilation of different-scale radioecological maps.

The need for reliable information on the spatial distribution of radionuclides in natural ecosystems compelled us to organize works along two directions that reflect different levels of generalization of factual material:

(1) Regional level investigation. Regionalization of northern Russia with respect to conditions of migration and accumulation of artificial radionuclides based on analysis of geological, geomorphologic, and ecological–geochemical features. Compilation of corresponding small-scale maps.

(2) Local level investigation. Elucidation of specific features in the distribution of artificial radionuclides in northern taiga and tundra ecosystems based on ecological–geochemical analysis of regions influenced by the activity of large plants that apply nuclear technologies. Compilation of large-scale maps of radiation pollution. The accomplished field studies and measured levels of concentrations of artificial radionuclides in tundra and northern taiga ecosystems demonstrated relatively variegated patterns of their distribution, although no anomalously high concentrations of radioactive pollutants in the surface ecosystems have been revealed. The concentrations of cesium 137 in soils of the study region usually do not exceed 5–10 Bq/kg. Only near some specific objects do its concentrations amount to 100 Bq/kg and, in some cases, reach 150–160 Bq/kg, which are, nonetheless, substantially below an ecologically dangerous level.

The technique for regional studies developed for the Murmansk region is characterized by a quite variegated distribution of ecosystems with different geochemical characteristics due to the complicated geotectonic structure of the Kola Peninsula; different degrees of morphological differentiation in its western and eastern parts; and diversity of hydrographic, hydrologic, and landscape features. In this connection, we compiled a series of maps that reflect the influence of the abovementioned factors on the redistribution of artificial radionuclides accumulated at the surface, their migration, and their concentration in ecosystems [1]. These data made it possible to define regions with different conditions of radionuclide redistribution.

The ecological–geochemical patterns is based on the concept of geochemical arenas (i.e., areas of river and lake drainage systems governing the distribution of pollutants that migrate in surface waters inside a arena) and possibility of the removal (accumulation) of pollutants beyond (inside) the arena. The distribution pattern of basins in the region combined with its geologic–geomorphologic and biologic–climatic factors imparts specific features to local geochemical ecosystems that determine the transfer and accumulation of matter and

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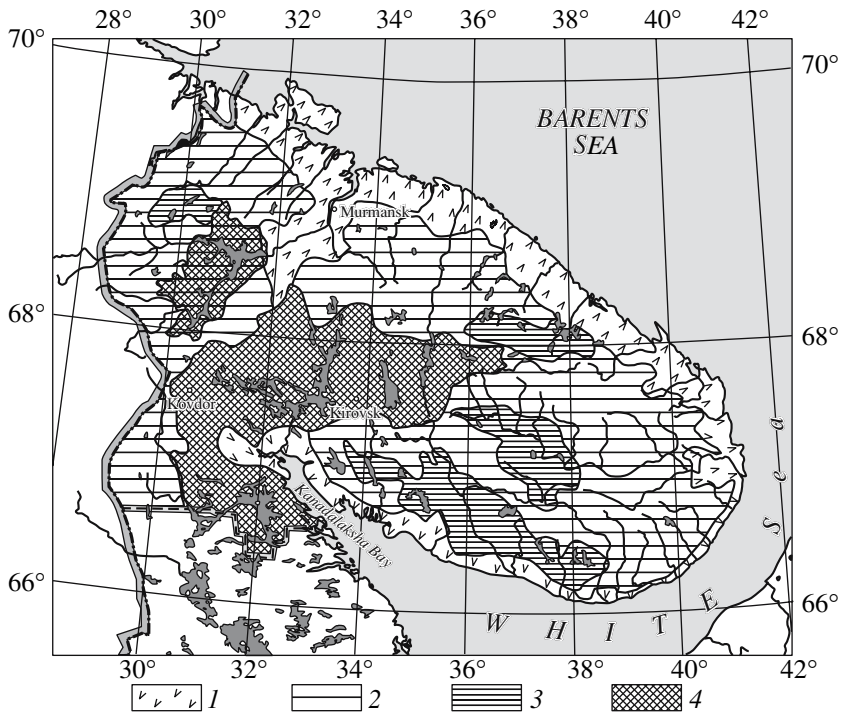

Ecological–geochemical patterns of the Kola Peninsula. Ecogeochemical regions: (*1*) active migration, (*2*) moderate migration, (*3*) moderate accumulation; (*4*) intense accumulation.

energy, as well as redistribution of artificial radionuclides, in watersheds.

For outlining of geochemical arenas with different potentials for the accumulation or removal of matter, we classified the structure of basins in terms of different-rank drainage areas based on the Horton analysis [6], the well-known Straler–Filosofov system [5], and Simonov's concept of the morphological structure of river basins [3, 4].

The analysis of river and lake drainage areas in the Kola Peninsula made it possible to define three main groups of geochemical arenas: open, semiclosed, and closed (isolated). The *open arenas* (drainage areas of rivers) are characterized by the domination of intense removal of migrating matter beyond their limits. The rivers are characterized by a substantial longitudinal relief gradient, insignificant channel branching, and direct contact with seawater. The *semiclosed basins* include watersheds dominated by slow transit of migrating matter and its partial deposition inside the basins. The relevant rivers are characterized by significant length, branching of channels, and slow currents. Not all of them flow into sea basins. The *closed arenas* incorporate watersheds of rivers and lakes sharply dominated by the precipitation of migrating particles from the surface water and their accumulation inside the arena. These arenas host watersheds of lakes, reservoirs, and inflowing rivers, as well as rivers that have no immediate contact with seas.

The geologic–geomorphologic characteristics of the study region were investigated to define areas with different conditions of potential radionuclide redistribution within large geochemical arenas. The results obtained made it possible to reveal zones with different intensities of radionuclide migration and accumulation with consideration of the types and forms of relief, the degree of differentiation, the specific features of underlying sediments and bedrocks, the complexity of the landscape structure, and the density of bogs and lakes in watersheds.

The study region is divided into three (very active, active, and moderate) zones in terms of migration intensity and three (low, moderate, and intense) zones in terms of accumulation intensity. Based on the comparison of maps demonstrating conditions of matter migration and accumulation with the structures of watersheds of rivers and lakes, we compiled a detailed map of the geochemical arenas. Watersheds representing geochemical arenas of the open, semiclosed, and closed types were differentiated with respect to peculiarities in the potential redistribution of radionuclides into the following areas: (1) areas with dominant accumulation ("accumulative"); (2) areas with moderate accumulation ("accumulative–transit"); (3) areas with moderate migration ("transit–accumulative"); and (4) areas with active migration ("active self-purification").

The geochemical arenas of the open type are characterized by prevalence of transit–accumulative and active self-purification watersheds. The semiclosed are-

nas include accumulative, accumulative–transit, and transit–accumulative basins. The active self-purification basins in the semiclosed arenas occupy small areas. The accumulative watersheds dominate in the closed arenas.

Of great significance for the analysis of radionuclide redistribution is the analysis of soil resistance to human impact, i.e., the capability of soils to restore normal functioning after termination of human influence. According to the notion of pedobioms [2] (i.e., groups of soils similar in ecogeochemical properties and general geochemical resistance to certain technogenic chemical impacts), soil restoration is reflected in the rate of self-purification from technogenic products due to their removal from the soil profile. When analyzing the geochemical resistance of soils to radiation impact, we took the following main factors into consideration: (i) intensity of removal and metabolism of technogenic products; (ii) intensity of fixation of technogenic products at respective geochemical barriers.

Thus, the Kola Peninsula incorporates four ecogeochemical regions with specific features of the migration and concentration of artificial radionuclides (figure).

The region with active migration of matter includes basins of coastal zones of the Barents and White seas characterized by differentiated relief, a dense river network, and intense currents of rivers. This region is dominated by active self-purification watersheds with high potential ability to remove radionuclides and other pollutants.

The geochemical arenas with the transit character of matter migration include moderate migration regions, where basins with potential ability to remove matter dominate, and moderate accumulation regions dominated by basins tending to accumulate matter.

The intense accumulation region includes closed geochemical arenas characterized by the potential ability to accumulate matter. These arenas are characterized by complicated geologic, geomorphologic, and ecological–geochemical features; small-scale contrasting intrazonal redistribution of chemical compounds; and their transportation from elevations to lakes and swampy lowlands. Technogenic pollutants accumulated in these zones are retained for a long period. Restoration of geochemical characteristics in ecosystems located in this zone is hampered because of their very low self-cleaning potential.

The results of this study and proposed maps serve as a basis for the development of a radioecological geoinformation system, which may allow us to monitor the radiation situation in the region, make optimal decisions in case of pollution with artificial radionuclides, and elaborate recommendations for rational placement of new objects of the atomic industry.

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