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Biogeochemical cycles of Chernobyl-born radionuclides in the contaminated forest ecosystems: long-term dynamics of the migration processes

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Biogeochemical migration is a dominant factor of the radionuclide transport through the biosphere. In the early XX century, V.I. Vernadskii, a Russian scientist known, noted about a special role living things play in transport and accumulation of natural radionuclide in various environments. The role of biogeochemical processes in migration and redistribution of technogenic radionuclides is not less important. In Russia, V. M. Klechkovskii and N.V. Timofeev-Ressovskii showed some important biogeochemical aspects of radionuclide migration by the example of global fallout and Kyshtym accident. Their followers, R.M. Alexakhin, M.A. Naryshkin, N.V. Kulikov, F.A. Tikhomirov, E.B. Tyuryukanova, and others also contributed a lot to biogeochemistry of radionuclides. In the post-Chernobyl period, this area of knowledge received a lot of data that allowed building the radioactive element balance and flux estimation in various biogeochemical cycles [Shcheglov et al., 1999]. Regrettably, many of recent radioecological studies are only focused on specific radionuclide fluxes or pursue some applied tasks, missing the holistic approach. Most of the studies consider biogeochemical fluxes of radioactive isotopes in terms of either dose estimation or radionuclide migration rates in various food chains. However, to get a comprehensive picture and develop a reliable forecast of environmental, ecological, and social consequences of radioactive pollution in a vast contaminated area, it is necessary to investigate all the radionuclide fluxes associated with the biogeochemical cycles in affected ecosystems. We believe such an integrated approach would be useful to study long-term environmental consequences of the Fukushima accident as well.
In our long-term research, we tried to characterize the flux dynamics of the Chernobyl-born radionuclides in the contaminated forest ecosystems and landscapes as a part of the integrated biogeochemical process. Our field studies were started in June of 1986 (less than two months after the accident) and have been continued up to now, focused on the most common forest ecosystems scattered over the contaminated areas of Russian Federation and Ukraine.
A comprehensive analysis of the 137Cs and 90Sr biogeochemical fluxes shows that downward radionuclide fluxes (those directed from tree crowns to the soil) dominated over the upward fluxes (from the soil to forest vegetation) in the first years after the accident. Currently, the biological cycle in the contaminated ecosystems is a main factor impeding further vertical migration of long-lived radionuclides from upper soil layers to the ground water. The role of biota as a retardation factor depends on landscape type as well. In accumulative landscapes (with positive material balance), biota plays leading role in radionuclide retardation, while in eluvial landscapes (with the negative balance) soil absorbing complex serves as the dominant barrier for radionuclides leaching down the soil profile. The manifestation of both soil- and biota-driven factors depends on the radionuclide chemical speciation in the initial fallout. The latter factor is most important for 137Cs, yet less manifested for 90Sr. Among the biota components, fungi and forest vegetation are of particular importance for 137Cs and 90Sr accumulation, respectively.
In summary, biogeochemical cycles of 137Cs and 90Sr in the investigated forest ecosystems serve as main factors impeding the radionuclide migration from the fallout to ground water. Larger-scale landscape factors determine the radionuclide flux intensity in the biogeochemical cycles and affect the radionuclide spatial variability in the contaminated biota components.