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Radiation-induced cytogenetic and hematologic effects on aquatic biota within the Chernobyl exclusion zone

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ABSTRACT

During 1998–2014 the rate of chromosomal aberrations in embryo tissues of the pond snail (*Lymnaea stagnalis*) and root meristems of higher aquatic plants, and also hematologic indexes of mantle liquid of the adult snails and peripheral blood of fishes in water bodies within the Chernobyl exclusion zone (EZ) was studied. The absorbed dose rate for hydrobionts from water bodies of the EZ registered in a range from 0.25 to 420 μGy h^{-1} and in the reference ones – up to 0.09 μGy h^{-1}. The level of chromosomal aberrations in the molluscs from the most contaminated water bodies of the EZ was registered within range of 18–27% and for the molluscs from the reference lakes this index was on the average 1.5% with the maximal values 2.3%. The rate of chromosomal aberrations in root meristematic cells of higher aquatic plants from the contaminated lakes of the EZ was in range of 7–17% and in the plants from reference water bodies was not exceed 2.1%. The positive correlation between chromosomal aberration rate and absorbed dose rate in the pond snail's embryos and root meristems of higher aquatic plants in water bodies of the EZ was registered. Analysis of hemolymph structure of snails from the most contaminated water bodies showed a high rate of dead and phagocytic cells as well as decrease of the young amoebocytes quantity. Hematologic research of fish allows to determine on the one hand an insignificant changes of leukogram structure, and from the other hand a high level of red cells with different abnormalities in the peripheral blood of fishes from the water bodies with high levels of radioactive contamination. It is suppose that qualitative indexes of red cells in peripheral blood of fish are more sensitive to long-term radiation impact in comparison with elements of white blood, which can be used for conducting of the hematologic monitoring of radioactive contaminated water bodies.

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1. Introduction

The Chernobyl NPP (ChNPP) accident was the largest scale catastrophe in history of nuclear energy both in terms of the amounts of radioactive materials thrown out into the environment and the area of contaminated territory. The most contaminated lands around the destroyed reactor at the ChNPP were incorporated within the administrative-territorial unit “The Exclusion Zone and the Zone of Absolute Resettlement” (referred further to as EZ) covering an area of approximately 2600 km^2. In a south-eastern direction, the EZ is crossed by the Pripyat River – the main tributary of the Dnieper River. Along with a dense river network, related to this river basin, and also the cooling pond of the ChNPP, with a water-surface area of approximately 22 km^2, there are many flood-plain lakes, dead channels etc. within territory of the EZ, that have been exposed as a result of the accident to intensive radioactive contamination.

In conjunction with natural decontamination processes in aquatic ecosystems, such as physical decay of radionuclides and the water transport of radionuclides from the EZ, there is a change of physical and chemical forms of radioactive substances in soils of catchment areas. This may involve transformation and transition to mobile and bioavailable states (Kashparov, 1998; Ivanov, 2001; Sobotovich et al., 2002), washout to the closed aquatic ecosystems and accumulation by hydrobionts (Gudkov et al., 2005, 2009). This may essentially lead to a deterioration in the radiation

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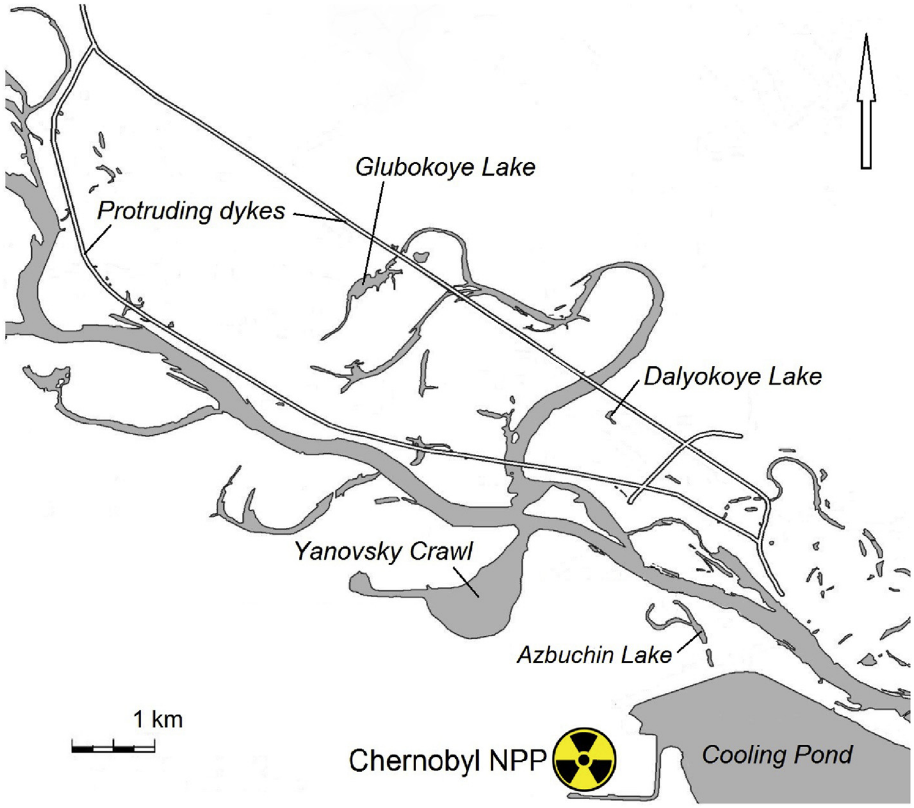

Fig. 1. Map of the main water bodies of studies within the Chernobyl exclusion zone.

situation in closed aquatic ecosystems.

Because of the geochemical processes that occur in the types of landscapes observed in the EZ related to the migratory flow of matter, aquatic ecosystems can function as a kind of "storage system" for many chemical elements, including radionuclides. Within continental systems, surface radionuclides enter hydrological networks and reservoirs located in closed depressions (mainly lakes) both directly on an aquatic surface with aerosol fallout and atmospheric precipitation, and from the territory of the catchment basin – with surface and ground waters. In lakes, radionuclides may have prolonged residence times, and may migrate and accumulate in the components of the aquatic ecosystem. Thus the potential for intensive radionuclide accumulation by aquatic organisms and/or their habitats in ecological areas with a high density of radioactive contamination can even lead to critical doses of irradiation for biota.

In connection with a slow water cycle, lakes form relatively closed systems allowing, with a minimum uncertainty, the estimation of the general balance of energy and matter in ecosystems and also analysis of the dynamics of biogeochemical processes and their influence on radionuclide distribution and migration under conditions of changing biotic and abiotic factors. Currently the radioecological situation in the EZ is characterized primarily by the long-lived radionuclides ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu and ^{241}Am.

The basic problems of radiation safety of the EZ concern radionuclide wash-off with surface drainage water to the river systems, their export outside of the EZ and impacts upon the water quality in the Dnieper River – the main waterway of Ukraine. Undoubtedly, one of the most important problems is research of long-term impact of ionizing radiation on non-human biota within the EZ. There have been several reviews on biological effects observed following the ChNPP accident and published at the international level (Sokolov et al., 1993; UNSCEAR, 1996; IAEA, 2006; Moller and Mousseau, 2006; Hinton et al., 2007; Geras'kin et al., 2008). Unfortunately, the effects of long-term radiation exposure of aquatic ecosystems on different levels of biological organisation within the EZ are still insufficiently studied.

The main tasks of our research was: (1) radiation dose rate estimation due to external and internal sources of irradiation for different groups and species of hydrobionts and (2) evaluation of dose-dependent cytogenetic and hematologic effects dynamics due to long-term radiation impact on aquatic species within the EZ.

2. Materials and methods

2.1. Water bodies of studies

Our studies were carried out during 1998–2014. The water bodies were the flood plain water bodies of the Pripyat River within a 10-km area around the destroyed unit of the ChNPP – Azbuchin Lake, Yanovsky Crawl, Dalyokoye Lake, Glubokoye Lake as well as cooling pond of the ChNPP and rivers Uzh and Pripyat (Fig. 1). The results of the cytogenetic and haematologic analyses compared to the data collated for hydrobionts from the reference lakes, located in the neighbourhood of the Kiev City: Vyrlitsa, Opechen', Pidbirna, Goloseevo as well as Kiev Storage Reservoir (near vlgs Lyutizh and Strakholesye, Kiev Region) and the Alta River (near the town of Pereiaslav-Khmelnytsky, Kiev Region) with background levels of radioactive contamination. The hydrochemical regime of studied water bodies is typical for natural reservoirs for the region of Kiev Polesye (woodlands) and varied within an insignificant range both for water bodies within the EZ and reference ones.

2.2. Radionuclide measurements and dose rate assessment

The ^{137}Cs concentration was measured by γ-spectrometry

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