Radioadaptation of small mammals in the East Urals radioactive trace (Kyshtym accident): 50 years on

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INTRODUCTION

The East Urals Radioactive Trace (EURT) zone has appeared in the result of Kyshtym Accident (1957), which took place in the Urals, Russia. This event is usually considered as one of the most huge catastrophes in the world nuclear industry practice. Large-scale radioecological researches (after Kyshtym and Chernobyl accidents) lead to revealing the phenomenon of radioadaptation (Cherezhanova and Alexakhin, 1971; Shevchenko and Pomerantseva, 1985; Pozolotina, 2003; Geras'kin et al., 2007). However, the most part of these works was done on plants; the data on animals’ radioadaptation are still quite scarce and fragmental. Nowadays, the territory of EURT might be considered as a unique plot where comprehensive studies of long-term biological consequences of low-dose irradiation during the sequence of generations could be carried out, at least for small mammals inhabiting the zone of local radioactive contamination. In the present work we aimed to show the results of investigations of radioresistance of small rodents both in acute trials (in laboratory) and under chronic irradiation (dwellers of the EURT zone). Besides, we compared the species of different ecological specialization, trying to evaluate its importance for radioadaptation.

MATERIAL AND METHODS

The objects of the study were several widespread rodents species, substantially different in their ecological and physiological traits. The studied specimens were captured at the plots with different densities by $^{90}$Sr contamination Table 1. Among these species common mole-voles (Ellobius talpinus Pallas, 1770) are subterranean borrowing animals with quite low migratory activity, which characterized by winter hibernation caused by both low ambient temperatures and lack of food. Mean life span of these rodents is up to 6 years. Wood mice (Apodemus (Sylvaemus) uralensis Pallas, 1811) and field mice (Apodemus agrarius Pallas, 1771) both are terrestrial rodents with high migratory activity, which is exhibited all the year round; their life span ranges from 3-4 months to 1.5 years in dependence of the type of ontogenesis (Olenev, 2002). Radioresistance and biological effects of chronic irradiation (e. g. haematological and immunological indices and frequencies of micronuclei occurrence in the bone marrow cells) were studied in animals inhabiting both the EURT zone and undisturbed territories of the Urals. Radioresistance, which was considered as a characteristic determined by a species genotype (Lyubashevsky and Grigorkina, 1995), was assessed experimentally after acute irradiation ($^{137}$Cs) of animals by different doses. The work was conducted on the base of functional approach (Olenev, 2002). This approach supposes to divide natural population into groups of individuals with the same functional status, i. e. with the uniform patterns of growth and/or maturation rate as well as whether they participate in reproduction. In our previous works we have shown (Olenev and Grigorkina, 1998) that individuals of different functional status manifest significantly diverse radioresistance. Such a diversity is based on the differences in metabolic intensity of animals.
RESULTS AND DISCUSSION

For quite a representative series of tests of rodents (51 samples from which 25 are original data) we have established that mole-voles were the most radiosensitive specie Table 1 (Grigorkina, 2002). Radioresistance of wood mice was 1.4 times higher, whereas field mice were 2 times more radioresistant than mole-voles. High sensitivity of mole-voles to the acute irradiation was at great extent linked with their ecological and physiological traits as well as with their habits. Development of preadaptation to the acute irradiation is apparently prevented in mole-voles by their relatively big body mass, inhabiting of borrows with quite constant micro-climatic conditions and the absence of natural insolation. Previously we showed (Grigorkina, 2004) that body mass, food habits, and biotopic inhabitance are significantly related to LD$_{50/30}$, being those biological factors, which determines radioresistance of small rodents for ca. 40 per cent. It is essential to note that radioresistance in both mice and mole-voles inhabiting the EURT zone were practically very close from that in reference populations.

Table 1. Radioresistance (acute irradiation), absorbed doses (per life and up to reproductive age) in rodents and soil pollution density of plots by $^{90}$Sr from the EURT zone (chronic irradiation)

<table>
<thead>
<tr>
<th>Species</th>
<th>LD$_{50/30}$, Gy</th>
<th>Soil pollution density by $^{90}$Sr, Ci/km$^2$</th>
<th>Life span, years</th>
<th>Absorbed dose for life, Rem</th>
<th>Reproductive age</th>
<th>Absorbed dose in animals of reproductive age, Rem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood mice</td>
<td>7.0±0.4</td>
<td>182-451</td>
<td>up to 1.5</td>
<td>0.07-1.5</td>
<td>1.5 months</td>
<td>0.36</td>
</tr>
<tr>
<td>Field mice</td>
<td>10.0±0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mole-voles</td>
<td>5.0±0.7</td>
<td>1000</td>
<td>up to 6</td>
<td>0.33 – 29.63</td>
<td>2 years</td>
<td>11.40</td>
</tr>
</tbody>
</table>

We revealed that mole-voles from the EURT zone did not display any signs of damage of their most radiosensitive systems (haemapoiesis and immunity) while inhabiting the more radioactively contaminated plot than mice did Table 2 (Grigorkina and Pashnina, 2007). They also did not show any morphological anomalies of blood cells as well as any differences by the frequency of chromosomal aberrations (Gileva, 2002). Some signs of activation of the immune system of animals were recorded: increase of the ratio of small lympholeucocytes, higher values of stimulation indices (per cent of phagocyting neutrophyles, phagocytes number, specific activity of peroxidase of the blood) in comparison with a control group. Vaccination of animals showed the absence of differences between mole-voles from the impact and the background plots in titers of antibody to viruses of polyvalent dry vaccine “Trivac”. At the same time, mice from the EURT zone displayed lesser antibody titer than animals from the control territory. Consequently, the reserved abilities and the functional activity of immune systems in mole-voles from the epicenter of EURT were higher than these in animals from the control zone. One might conclude that long-term inhabitance of mole-voles in the epicenter of EURT (ca. 50 generations from the moment of accident) lead to compelled adaptation to the conditions of radiocontaminated bioocoenosis.

On the contrary, mice from the EURT zone (more than 100 generations since 1957) displayed multiple alterations in the haemapoietic system, delays in the maturation of erythropoietic cells in the bone marrow, increase in the frequency of cells with micronuclea and the general lowering of the immune system functional activity Table 2 (Grigorkina, Pashnina, 2007). Besides, the ratio of small lympholeukocytes (the most active immunocompetent cells) in mice was lowered, the number of structural anomalies of leukocytes increased, and some signs of violation of mitosis as well as some indications of haemopoietic process being more tensions were detected. Such structural violations of cells of the lymphopoietic group would
inevitably change their functional activity and reserved possibilities. Lowering in the index of stimulation of phagocyte numbers as well as lowered relative activity of peroxidase might serve as an evidence of this. Significant increase in circulating of immune complexes was also revealed in mice. The results of phenogenetic analysis indicated an increase in the ratio and variability of minor morphogenetic aberrations and deformations in the skull texture as well as an increase in the level of fluctuating asymmetry in the wood mice from the EURT zone (Vasyl’eva et al., 2003).

### Table 2. Different indices of rodents from the EURT zone and undisturbed territories (a comparison)

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency of cells with micronuclei</th>
<th>Haematological indices</th>
<th>Immunological indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood mice</td>
<td>+*</td>
<td>+*</td>
<td>+*</td>
</tr>
<tr>
<td>Field mice</td>
<td>+*</td>
<td>+*</td>
<td>+*</td>
</tr>
<tr>
<td>Mole-voles</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Note: * significant differences, p<0.05

The most important role in the pathology of small mammals from the radiocontaminated territories originates from inherited effects (Lyubashevsky et al., 1995). It was also established that in the EURT zone absorbed doses, which have been accumulated in mole-voles in the course of pre-reproductive period of life as well as for the whole life span were significantly higher (up to 30 times) than in mice Table 1. This apparently is connected with the differences in ages of reproduction and in the mean life span as well as with more resident way of living of mole-voles. Besides, it might be caused also by that the isolated population of mole-voles inhabited in the zone of higher level of $^{90}$Sr contamination than mice did.

It is clear, that the necessary condition for the development of radioadaptation would be low migratory activity of the impact spatial group. It is known that mice are active all the year round doing seasonal migrations and the mean length of their daily displacements are ca. 1.6 km. So, mice are able to pass through significant distances that are comparable with the cross-section size of contaminated zone. This lead to forming of a flowing population (Grigorkina and Olenev, 2004), i.e. a population with constantly changing set of individuals due to immigration from adjacent unpolluted territories and emigration from the contaminated zone. Such a feature is favored by the EURT zone configuration that looks like a prolonged and narrow territory having rapidly decreasing gradient of contamination. Therefore, mice slip off the prolonged influence of a damaging factor, this circumstance preventing the development of radioadaptation. On the other side, the mole-voles are subterranean borrowing-dwellers with a low ability for dispersal. Besides, territorial insulation of their population in the EURT zone for a half-century history of the Kyshtym Accident promoted the development of radioadaptation in this specie. Hence, for the first time some convincing evidence of genetic radioadaptation of animals inhabiting the radiocontaminated zone during a long period and in the course of changing generations was obtained at the example of mole-voles (radiosensitive specie). The leading role in the development of radioadaptation is played by ecological and physiological traits as well as by the main habits of a species. Besides, the configuration of contaminated zone is maybe not less important ecological factor.
ACKNOWLEDGEMENTS

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REFERENCES


