



## The role of mouse-like rodents in the Chernobyl Exclusion Zone in the spread of blood-borne diseases

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**Abstract.** A feature of the conducted research is the study of a topical issue – the influence of external and internal factors on the prevalence of pathogens of blood-parasitic diseases. One of the most important external factors of influence is the exposure dose of  $\gamma$ -radiation, since the catching of mouse-like rodents was carried out at the landfills of the drained bed of the cooling reservoir of the Chernobyl Nuclear Power Plant. Therefore, the aim of the work was to study mouse-like rodents for the presence of causative agents of blood-parasitic diseases in natural populations under the influence of radioecological conditions of man-made transformation of the cooling reservoir of the Chernobyl Nuclear Power Plant. Mouse-like rodents of the genera *Apodemus* and *Myodes* were studied from three different locations of the cooling pond using parasitological methods. Radiological methods were used to determine the level of contamination of the specified three places where mouse-like rodents were caught using the  $\gamma$ - and  $\beta$ -dosimeter Prip'yat RKS 20.3. Examination of blood smears of mouse-like rodents from three experimental polygons of the cooling reservoir of the Chernobyl Nuclear Power Plant revealed the presence of pathogens of blood-parasitic diseases in 93.8% of animals. In particular, such pathogens as *Rickettsia spp.*, *Ehrlichia spp.*, *Bartonella spp.*, *Babesia spp.*, *Hepatozoon spp.*, *Haemobartonella (Mycoplasma) spp.*, were identified. and spirochetes. The prevalence of zoonotic agents among mouse-like rodents of the Chernobyl Zone of radioactive contamination, as well as its dependence on the level of radioecological pollution of the respective landfills, was established. Therefore, according to the results of the conducted research, the presence of causative agents of blood-parasitic diseases among mouse-like rodents, which are both intermediate and their definitive hosts, including those from dangerous zoonoses, which, subject to the application of timely and complex preventive measures, will prevent human infection

**Keywords:** parasitic; radiation level; *Myodes glareolus*; *Apodemus flavicollis*; *Apodemus agrarius*

## Introduction

Since 2014, the Chernobyl Nuclear Power Plant (ChNPP) zone has been undergoing a project to drain the cooling pond (CP). At present, there has been a significant decrease in the water level in the CP with the disappearance of a significant part of the water area, and the transformation of the aquatic ecosystem into a terrestrial ecosystem formed by bottom sediments. According to the literature (Technical and economic feasibility study of the decommissioning of the cooling pond of Chernobyl NPP, 2013), the accidental release resulted in  $11.1 \cdot 10^{15}$  Bq of  $^{137}\text{Cs}$  and  $3.7 \cdot 10^{12}$  Bq of  $^{90}\text{Sr}$  entering the cooling pond, which is approximately 0.3% for  $^{137}\text{Cs}$  and 0.5% for  $^{90}\text{Sr}$  of the total amount released into the environment. The lateral distribution of accidental radionuclides in the drained areas

of the ChNPP CP is rather varied due to the unequal depth of the reservoir in different parts (6-20 m) and the fact that the bottom of the reservoir is very uneven and has numerous depressions (IAEA, 2019; Lypska et al., 2022). Due to drainage, active processes of primary succession are taking place in the CP site, i.e., radical changes and formation of new phytocoenoses and faunal communities with high biodiversity. It should be noted that during the period of decommissioning of the cooling pond (2014-2017), the species diversity of phytocoenoses increased from 14 (2001 study) to more than 50 (including 9 woody) plant species (Paskevych & Gorodetskyi, 2018). The presence of various species of predatory mammals was recorded in the drained areas, as well as an increase in the

number and species composition of mouse-like rodents, which are the main prey of birds and mammals.

Thus, drained areas of a reservoir are an attractive place for many species of animals to search for food and habitat. It should be noted that mouse-like rodents (Rodentia Muroidea) can be both definitive and intermediate or reservoir hosts in the developmental cycle of many parasitic diseases, including zoonoses, which can lead to infection of other animals and humans too. As they are extremely fertile, heterogeneous and highly dependent on the availability of feed and climatic conditions, as well as the impact of radiation contamination, they can also be carriers of extremely dangerous pathogens such as hantaviruses, *Leptospira*, *Bartonella spp.*, *Anaplasma phagocytophilum*, *Neoehrlichia mikurensis*, *Borrelia burgdorferi* and *Babesia microti* (Jeske *et al.*, 2022). Researchers in Austria have raised questions about the interaction of different pathogens in the host, the countermeasures of the host immune system, the impact of host-pathogen interaction on the host's health, and the spread of infectious agents among wild rodents and from them to other animals or humans. Thus, out of 110 rodents of four species tested in 2008 (40 *Clethrionomys glareolus*, 29 *Apodemus flavicollis*, 26 *Apodemus sylvaticus* and 15 *Microtus arvalis*), specific antibodies to Dobrava-Belgrade hantavirus were detected, Tula hantavirus, lymphocytic choriomeningitis virus, orthopox virus and rickettsial virus, as well as multiple infections involving up to three pathogens (Banović *et al.*, 2022). At the same time, molecular analysis revealed the prevalence of various *Babesia* and *Hepathozoon* species at 0.09% each, and *Sarcocystis* at 0.06% in small and medium mammals in Texas, USA (Modarelli *et al.*, 2020). The four-year period of observation of mouse-like rodents in the Masurian Lakes of Poland also showed the prevalence of such pathogens as *Haemobartonella sp.*

(63.9%), *Bartonella spp.* (27.7%), *Babesia microti* (9.0%), *Trypanosoma sp.* (8.4%) and *Hepatozoon lavieri* (3.1%). The prevalence of the latter is closely related to the presence of their transmission vectors, such as fleas (Siphonaptera) and ticks (Ixodida and others), which are often found in populations of mouse-like rodents (Gomes *et al.*, 2018; Grzybek *et al.*, 2020; Ramos *et al.*, 2023). Mouse-like rodents are also important intermediate and paratenic hosts for carnivore parasites, including the important zoonotic agents *Toxoplasma*, *Echinococcus* and *Toxocara*. At the same time, during the study of the *Microtus socialis* species on the territory of the Askania-Nova F.E. Falz-Fein Biosphere Reserve, researchers found only representatives of *Trypanosoma spp.* and *Babesia spp.* (Karbowiak *et al.*, 2002). '*Candidatus* Neoehrlichia mikurensis' causes inflammatory disease in people with underlying medical conditions, but the microorganism also affects immunocompetent individuals who are asymptomatic. It is transmitted in Europe by the *Ixodes ricinus* tick, but rodents can be reservoir hosts (Portillo *et al.*, 2018). Thus, small rodents play an extremely important role in parasite-host relationships and are the main reserves of zoonotic and vector-borne pathogens (Portillo *et al.*, 2018; Baltrūnaitė *et al.*, 2020). Molecular studies, which provide greater sensitivity and specificity in identifying different types of pathogens, should be supplemented by genetic analysis of parasites.

The most common methods for investigating mouse-like rodents for the presence of pathogens of parasitic origin include light microscopy and confirmation of its results using polymerase chain reaction. The latter method allows for the detection of more parasitic pathogens (Baltrūnaitė *et al.*, 2020; Yen *et al.*, 2021).

Studies of the peculiarities of blood-borne parasitic diseases in animals living in radiation-contaminated areas are few or absent. Therefore, it is extremely necessary and

relevant to include studies to determine their prevalence among animals in the complex of radioecological and radiobiological monitoring of the water treatment facility at the stage of its decommissioning in order to prevent the occurrence of zoonoses and vector-borne diseases among animals and humans in the Chernobyl Exclusion Zone and adjacent territories.

The aim of the study is to investigate the spread of blood parasites and the state of the blood system of mouse-like rodents in natural populations under the influence of radioecological conditions of the technogenic transformation of the ChNPP CP.

### Materials and Methods

Radioecological studies were carried out at three test sites (polygons) of the Chernobyl Exclusion Zone (ChEZ). Test site (polygon) 1 (51°21'38.58 "N 30°8'23.50 "E) is located on the coastline of the Chernobyl Nuclear Power Plant (ChNPP) Cooling Pond (CP) (before hydraulic works). The landfill is dominated by sandy loam and sod-podzolic soils. The territory of site (polygon)

2 (51°22'20.60 "N 30°8'26.94 "E) is located on the drained area of the hot part of the ChNPP CP, bordering the northern part of the distribution dam and the location of the abandoned hydrobiological laboratory. The territory of site (polygon) 3 (51°22'20.60 "N 30°8'26.94" E) is located on the first stage dam of the ChNPP CP and the drained hot part of the CP bed. In the areas of the drained bed of the CP, the soil cover is formed by sands (without silt particles) with a significant coverage of the territory with shells left after the massive death of river dreissena (*Dreissena polymorpha*) colonies. Figure 1 shows the location of the research sites (polygons) on the territory of the ChEZ. The exposure dose rate of  $\gamma$ -radiation and the flux density of  $\beta$ -particles above the soil surface were determined at the animal capture sites using the Prypiat  $\gamma$ - and  $\beta$ -radiometer RKS 20.3. Soil samples were taken at the trapping sites using the envelope technique (four samples in the corners and one sample in the middle of the square). Standard laboratory sample preparation procedure including drying, crushing, and sifting was followed for spectrometric measurements.



**Figure 1.** Mouse-like rodents sampling test sites (polygons) within the Chernobyl Nuclear Power Plant Cooling Pond (Chernobyl Exclusion Zone, Chernobyl, Ukraine)

Canberra-Packard spectrometer (model GX40185, Canberra, USA) was used for measurements of  $^{137}\text{Cs}$  in soil samples.  $^{90}\text{Sr}$  activity in soil samples has been determined using the

method of "thick" samples without radiochemical preparations by  $\beta$ -spectrometer "SEB-50" (SPC Spectr, Ukraine) equipped with plastic scintillation detector.

Mouse-like rodents of various species, which are widely used in radiobiological studies as indicators, were captured in the first half of September 2019 using Sherman traps. The duration of trapping at each site was 3 days with daily inspection of the traps. After capture, the animals were taken to the laboratory of the Institute for Nuclear Research (Kyiv, Ukraine), examined, registered with individual numbers and values of the date and place of capture, species name, sex, and body weight. The species affiliation of individuals was determined by morphological characters. Possibly, ectoparasites (larvae of Ixodes ticks and fleas) from the ears and limbs of animals were collected for the future identification. Ixodes ticks were sampled on the territory of the Chernobyl Radiation and Ecological Biosphere Reserve at 4 main locations: Krasno village, Horodyshe village, Mashevo village and near Lake Hlyboke using the standardised “white flag” method.

After preservation collected ticks using 70% ethyl alcohol, the parasites were placed in a freezer at -20°C until further examination. The systematic classification of ticks included the determination of genus, species, sex, and developmental stage and was based on eidonomic features. The study was carried out at the I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine (Kyiv, Ukraine) using an Axio Imager M1 microscope and photo-recording of the results.

Peripheral blood was collected from the carotid artery under ether anaesthesia. The following parameters were determined on a haematological analyser (Mindray BC-2008 Vet): white blood cell (WBC), red blood cell (RBC), haemoglobin (HGB), haematocrit (HCT), as well as red blood

cell parameters mean corpuscular volume (MCV), erythrocyte haemoglobin concentration (MCH), erythrocyte volume distribution (RDW); platelets (PLT), platelet count (PCT), mean platelet volume (MPV), platelet distribution width (PDW).

The blood smears were prepared from a drop of blood, dried and delivered for further examination to the Faculty of Veterinary Medicine of the National University of Life and Environmental Sciences of Ukraine. They were fixed and stained using a Leukodif 200 (LDF 200) dye kit according to the manufacturer’s instructions. Each smear was examined under the immersion system of a Micros Viola MC30 microscope (×10 eyepiece and ×100 objective).

To assess the level of parasitic infection in mice, the smear was examined in 100 fields of view. The results were used to calculate average intensity of infection (II), the number of parasites per infected animal on average; extensiveness of infection (EI), the number of infected animals to the number of examined animals in percentage terms. The experimental part of the work was carried out in accordance with the “General Ethical Principles for Experiments on Animals” (2018) and in compliance with the international requirements of the European Convention for the Protection of Vertebrate Animals Used for Research and Other Scientific Purposes (Strasbourg, 1986).

### Results and Discussion

Based on the radiometric studies, it was established that the experimental sites differ significantly in radiation conditions, namely, the highest exposure dose rate of  $\gamma$  radiation ( $EDR\gamma$ ) was recorded at polygon 2 and the  $\beta$ -particle flux density at polygon 1 (Table 1).

**Table 1.**  $EDR\gamma$  and  $\beta$ -particle flux density (beta) at the points of capture of mouse-like rodents (50 points at each site)

Site (polygon)	PED $\gamma$ , mR/h			Beta, imp cm <sup>-2</sup> min <sup>-1</sup>		
	Average	Standard deviation	Range	Average	Standard deviation	Range
1	0.37	0.07	0.29-0.51	688	232.18	435-1200

Table 1. Continued

Site (polygon)	PED $\gamma$ , mR/h			Beta, imp cm <sup>-2</sup> min <sup>-1</sup>		
	Average	Standard deviation	Range	Average	Standard deviation	Range
2	0.22	0.03	0.07-0.40	115	43.98	72-250
3	0.93	0.44	0.7-1.20	254	141.03	102-620

Source: authors' development

The data presented in Table 1 show that the spatial distribution of EDR $\gamma$  and the flux density of  $\beta$ -particles at the test sites vary in a wide range. According to the average values of EDR $\gamma$ , the landfills are in the range: 3>1>2, and by the density of  $\beta$ -particle flux above the soil surface 1>2>3. The density of soil contamination at test site (polygon 1) with <sup>137</sup>Cs was in the range of 8.16÷10.23 MBq/m<sup>2</sup>, <sup>90</sup>Sr – 5.44÷9.35 MBq/m<sup>2</sup>, <sup>241</sup>Am – 0.72÷0.91 MBq/m<sup>2</sup>. At test site (polygon 2), the density of soil contamination was much lower, namely <sup>137</sup>Cs – 1.32÷2.20 MBq/m<sup>2</sup>, <sup>90</sup>Sr – 0.76 ÷ 1.25 MBq/m<sup>2</sup>, <sup>241</sup>Am – 0.15÷0.21 MBq. As for the 3rd polygon, it occupies an intermediate position in terms of radionuclide contamination density: <sup>137</sup>Cs – 3.35÷6.51 MBq/m<sup>2</sup>, <sup>90</sup>Sr – 1.33÷4.74 MBq/m<sup>2</sup>, <sup>241</sup>Am – 0.22÷0.54 MBq/m<sup>2</sup>. The density of soil contamination with <sup>137</sup>Cs at polygon 1 was 5.6 and 1.9 times higher than at polygons 2 and 3, respectively, and <sup>90</sup>Sr – 7.5 and 2.5 times higher.

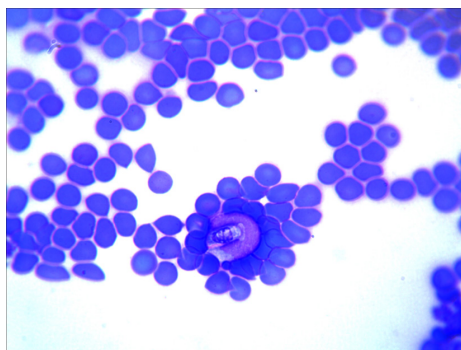
Among the captured mouse-like rodents (Rodentia Muroidea), representatives of the genera Apodemus and Myodes were identified. Samples of animals at the polygons were as follows: polygon I – 14 (*M. glareolus* – 7, *A. flavicollis* – 7), polygon II – 11 (*Apodemus* – 5, *A. agrarius* – 5, *M. glareolus* – 1) and polygon III – 8 (*A. flavicollis* – 6, *A. agrarius* – 2) animals.

A total of 68 ticks of the family Ixodidae were collected. The species identification of the parasites revealed that the captured individuals belonged to two species: *Dermacentor reticulatus* and *Ixodes ricinus*, with the former dominating. It accounted for 98.5% of all parasites. According to the literature, the *Dermacentor reticulatus* tick is involved in the

spread and transmission of pathogens such as *Babesia spp.* (*B. microti* and *B. canis*) and *Rickettsia spp.* (*R. rickettsii*, *R. slovaca*, *R. raoultii*), (Raoult et al., 2002). The developmental cycle of these pathogens is closely related to mouse-like rodents, mainly as reservoirs of pathogens. Moreover, the detection of *B. microti* in *D. reticulatus* was associated with the species of the tick's host rodent. *B. microti* was more common in *Microtus spp.* than *Apodemus spp.* (Dwuźnik et al., 2019). Studies have also established the possibility of *Dermacentor reticulatus* and *Ixodes ricinus* ticks being involved in the transmission of *Hepatozoon spp.* pathogens, despite the fact that *Rhipicephalus sanguineus* was previously considered the only transmission vector (Hornok et al., 2013; Hamšíková et al., 2016).

Blood smears revealed the presence of blood-borne pathogens in 93.8% of the animals studied. Among the pathogens of these diseases were found: *Babesia spp.*, rickettsiae (*Ehrlichia spp.*, *Mycoplasma spp.* (*Haemobartonella spp.*), *Spirochaeta spp.*

The study of the species composition of parasites in blood smears of animals revealed the pathogens *Babesia spp.* (56.6%), *Rickettsia spp.* (53.3%), *Ehrlichia spp.* (23.3%). For the first time in Ukraine, the pathogen *Hepatozoon spp.* was recorded in blood smears of 5 animals (Fig. 2). Representatives of the species *A. flavicollis* – 3 cases and *M. glareolus* – 2 cases. These animals lived at the polygon I. It should be noted that animals from the experimental polygon I, in a number of generations, permanently lived in this area and received the highest radiation load compared to other experimental groups.



**Figure 2.** *Hepatozoon spp.* in a blood smear fixed and stained with Leukodif 200 (LDF 200) dye set from a mouse of the species *Apodemus flavicollis* (magnification ×1000)

Source: authors' development

The high extensiveness of the infestation in animals from the experimental polygons was recorded: 1 – 100%, 2 – 90.9%, 3 – 87.5%. In mouse-like rodents infected with blood parasites, almost all species were dominated by individuals affected by 2-3 species of parasites. Thus, in 56.6% of the examined animals, the presence of several species of parasites in one host was detected, namely, in polygons 1, 2 and 3 – 71.4%, 44.4% and 66.7%, respectively. The structure and specificity of the parasitofauna of mouse-like rodents in the experimental polygon I was almost equally determined by the red (*M. glareolus*) and yellow-throated mice

(*A. flavicollis*), in II – by *A. agrarius* (63.6%), and in III – by *A. flavicollis* (75%), however, the few species present at the landfills also contribute to the prevalence of blood-borne diseases. Table 2 presents the results of studies of the prevalence of blood-borne pathogens in different species of rodents at the research sites.

The presence of hyperinvasive individuals in the host population may be the result of a certain synergy of parasites of different species, when high infection with any species leads to a decrease in host immunity and makes it more accessible to other parasites.

**Table 2.** Pathogens of blood-borne diseases in some species of mouse-like rodents in three experimental polygons

Species of animals and the presence of blood-borne pathogens in microscopic examination (%)			
Pathogens of blood-borne diseases	<i>Myodes glareolus</i> (n=8, mainly polygon I)	<i>Apodemus flavicollis</i> (n=15, I, II i III polygons)	<i>Apodemus agrarius</i> (n=6, mainly polygon II)
<i>Rickettsia spp.</i>	87.5	46.7	16.7
<i>Ehrlichia spp.</i>	25.0	13.3	16.7
<i>Bartonella spp.</i>	12.5	0	0
<i>Babesia spp.</i>	37.5	66.7	50.0
<i>Hepatozoon spp.</i>	25.0	20.0	0
<i>Haemobartonella (Mycoplasma) spp.</i>	12.5	33.3	50.0
Spirochaetes	12.5	0	16.7

Source: authors' development

The presented data indicate the presence of epidemically dangerous pathogens on the drained areas and the Chernobyl Exclusion Zone coastline. Given that since 2018, a significant increase in the number of animals has been recorded at the polygons II and III, which is likely due to both migration processes and comfortable conditions for animal reproduction, namely due to the availability of a rich food base, these areas may become foci of parasitic diseases in the future.

The average intensity of infection (AI) (the number of all parasites per infected animal) was determined: at the polygon I, this indicator was 2.12 for *M. glareolus* and 2.0 for *A. flavicollis*; at the polygon II – *A. flavicollis* (1.8) and *A. agrarius* (1.6); at polygon III – *A. flavicollis* (1.8) and *A. agrarius* (1.7). Authors did not find any significant differences in the values of intensity of infection (II) for different sites and species. In the red mole (*M. glareolus*), Authors observed 7 species of blood parasitic pathogens with the dominance of *Rickettsia spp.* and in the yellow-throated and field mice – 5 and 7, respectively, with the dominance of *Babesia spp.* It should be noted that in the study populations, individuals of different age groups had unequal (uneven) infection, the highest parasitic load was in young individuals, which may be due to intrauterine infection of the fetus during pregnancy. Data are confirmed by C.M.R. Turner (2009), where *Hepatozoon* and *Grahamella spp.* were detected mainly in young individuals of mouse-like rodents, while older animals were susceptible to infections caused by *Babesia* and *Trypanosoma spp.* This statement is supported by the facts of infection of pregnant females and those that have already given birth. There were no sex differences in the presence of parasitic pathogens in the groups of experimental animals.

Data on the prevalence of blood-borne diseases among such species of mouse-like rodents

as *M. glareolus*, *A. flavicollis* and *A. agrarius* reveal for the first time the prevalence of such pathogen as *Hepatozoon spp.* in Ukraine. The highest prevalence of this agent (25%) is similar to the data of Hungarian (17% among *M. glareolus* species) and Lithuanian researchers, where it is 32% and is the most common among such rodent species as *Myodes glareolus* and *Microtus agrestis* (Rigó et al, 2016; Baltrūnaitė et al., 2020). However, according to the results of microscopic studies, the prevalence of this pathogen among mouse-like rodents in the Chernobyl radioactive contamination zone is lower than the data obtained by Lithuanian researchers, where this figure was 40.8%, and according to the polymerase chain reaction, it reached 100% (Baltrūnaitė et al., 2020). At the same time, the pathogen was isolated from ectoparasites: Ixodes ticks and fleas of the species *Megabothris turbidus* (Rothschild), *Ctenophthalmus assimilis* (Taschenberg) and *Ctenophthalmus agyrtes* (Heller) (Rigó et al., 2016), which indicates their direct involvement in the life cycle.

Authors did not detect *Hepatozoon spp.* in *A. agrarius*, which also coincides with the data of the microscopic examination of internal organs in rodents from the Estonian study and may indicate the absence of a certain arthropod species as ectoparasites that transmit this pathogen or the absence of circulation of this pathogen in the bloodstream during blood sampling. According to the results of a recent study, *Hepatozoon spp.* was found in such rodent species as *Clethrionomys rufocanus*, *Clethrionomys rutilus*, *Clethrionomys glareolus* and *Microtus agrestis*. And it was not detected in such species as *Microtus arvalis*, *Apodemus agrarius* and *Apodemus flavicollis* (Laakkonen et al., 2001; Jeske et al., 2022). However, the highest prevalence (25%) of *Hepatozoon spp.* was found in *M. glareolus* according to results of research. These data coincide with the results of Lithuanian researchers (Baltrūnaitė et al., 2020). According

to Austrian scientists, pathogens such as *Lep-tospira borgpetersenii*, *Bartonella spp.*, *Borrelia miyamotoi* and *Neoehrlichia mikurensis* were found in striped field mice (*Apodemus agrarius*), while *Babesia*, *Anaplasma*, *Ehrlichia* and *Rickettsia spp.* were not detected (Jeske *et al.*, 2022).

The parasitemia did not exceed 1-3 parasites per 100 microscope fields of view (in most cases, single agents were observed in the smear),

which, in authors opinion, indicates carriage rather than clinical course. This suggests that mice mainly play the role of reservoirs of blood-borne pathogens. The basis for this assumption was the results of haematological studies, as well as the presence of small rounded and filamentous forms of parasites in the smears. Table 3 shows the main indicators of peripheral blood of different species of mouse-like rodents.

**Table 3.** Peripheral blood parameters of different species of mouse-like rodents

Indicator	Animal specie		
	<i>Myodes glareolus</i> (n=8, mainly polygon I)	<i>Apodemus flavicollis</i> (n=15, I, II and III polygons)	<i>Apodemus agrarius</i> (n=6, mainly polygon II)
Leukocytes, 10 <sup>9</sup> /L	5.86±0.99	4.22±0.47	5.2±0.86
Lymphocytes, %	59.7±2.72	46.91±3.67	54.5±3.55
10 <sup>9</sup> /L	3.45±0.61	1.99±0.3	1.9±0.32
Granulocytes, %	33.26±2.07	46.3±4.03	37.63±4.09
10 <sup>9</sup> /L	2.03±0.38	1.98±0.30	2.83±0.49
Eosinophils, %	3.88±0.91	6.59±1.55	1.88±0.72
10 <sup>9</sup> /L	0.23±0.05	0.28±0.06	0.1±0.04
Monocytes, %	6.33±0.34	6.47±0.57	7.87±1.59
10 <sup>9</sup> /L	0.34±0.06	0.27±0.03	0.47±0.16
Erythrocytes, 10 <sup>12</sup> /L	8.23±0.45	8.19±0.33	8.95±0.47
Haemoglobin, g/L	121.25±2.18	133.5±5.16	142.2±5.04
Hematocrit, %	39.57±0.94	43.78±1.81	48.48±2.77
Mean red blood cell volume (MCV)	48.87±2.18	53.53±0.9	54.37±2.06
Mean haemoglobin content per red blood cell (MHC)	14.95±0.74	16.22±0.24	15.93±0.39
Red blood cell distribution width (RDW-SD)	17.07±0.48	15.31±0.27	18.02±1.01
Erythrocytes pathology (% of animals):			
Anisocytosis	12.5	6.7	-
Joly bodies	25.0	66.7	50.0
Polychromatophilia of erythrocytes	12.5	40.0	50.0
Thrombocytes, 10 <sup>9</sup> /L	332.62±40.8	407.4±4.92	384.83±41.25

**Source:** authors' development

It was found that most of the leukogram indicators had only a tendency to change (increase/decrease): an increase in the percentage of eosinophils and monocytes against the background of a decrease in lymphocytes. However, it should be noted that in all experimental animals, an increase in the absolute number of

leukocytes, granulocytes and monocytes was observed compared to the data of non-irradiated controls (Lypska *et al.*, 2020), while eosinophils had only a tendency to increase in experimental animals from polygons I and II. The presence of a blood-borne parasitic infection did not lead to a significant decrease

in erythrocytes in the peripheral blood, but it should be noted that in all blood smears, erythrocyte pathology was recorded: Joly bodies and nuclear erythrocytes, anisocytosis, polychromatophilia, which indicates a violation of the maturation of erythroid cells and may be due to the presence of pathogens of infectious and protozoan diseases in the body. A significant number of polychromatophiles were detected in the blood smears of 9 animals, which is 28.1%. Among them were 6 blood smears from animals of the species *Apodemus flavicollis*, 1 from *Myodes glareolus* and 2 from *Apodemus agrarius*. Thus, the results of studies have provided new data on the prevalence of pathogens of various diseases among mouse-like rodents, which require further detailing using modern methods (Colle et al., 2019; Baltrūnaitė et al., 2020; Alabí et al., 2021). Also, for the first time, the influence of radiation factors such as EDRy and the flux density of  $\beta$ -particles on the circulation of *Rickettsia spp.*, *Ehrlichia spp.*, *Bartonella spp.*, *Babesia spp.*, *Hepatozoon spp.*, *Haemobartonella (Mycoplasma) spp.* and spirochaetes in the population of mouse-like rodents *Myodes glareolus*, *Apodemus flavicollis* (Melchior) and *Apodemus agrarius* (Pallas) was revealed.

### Conclusions

Thus, the species composition of parasites and their abundance is a direct reflection of the peculiarities of the biology of mouse-like rodents: their number, specificity of feeding, behavioural reactions and distribution, on the other hand, characterises their hosts as first-order conspecifics with a wide ecological valence, which is an important link in the food chains of terrestrial ecosystems and the spread of parasitic pathogens.

In the red mole (*M. glareolus*), authors observed 7 species of blood parasitic pathogens with the dominance of *Rickettsia spp.* and in the yellow-throated and field mice – 5 and 7, respectively, with the dominance of *Babesia spp.*

*Hepatozoon sp.* in Ukraine firstly was registered in mouse-like rodents *M. glareolus*.

The presence of a blood-borne parasitic infection did not lead to a significant decrease in erythrocytes in the peripheral blood. But it should be noted that in all blood smears, erythrocyte pathology was recorded. A significant number of polychromatophiles were detected in the blood smears of 9 animals, which is 28.1%. Among them were 6 blood smears from animals of the species *Apodemus flavicollis*, 1 from *Myodes glareolus* and 2 from *Apodemus*.

The studies revealed an increase in the number and species diversity of both parasites and their hosts, which indicates an intensive development of blood-borne diseases in elementary (newly formed) populations in the areas around the ChNPP CP and is a possibility of developing an unfavourable epidemiological situation. In this regard, there is a need for further studies of the distribution of blood-borne pathogens and species diversity in natural populations of the ChNPP Zone. At the next stage of research, authors plan to confirm the results of the microscopic examination using polymerase chain reaction and appropriate set of primers for each of the pathogens.

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### Conflict of Interest

None.

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**Анотація.** Особливістю проведеного дослідження є вивчення актуального питання – впливу зовнішніх і внутрішніх факторів на поширеність збудників кровопаразитарних хвороб. До одного з найважливіших зовнішніх факторів впливу належить експозиційна доза  $\gamma$ -випромінювання, оскільки відлов мишоподібних гризунів здійснювався на полігонах осушеного ложа водоймища-охолоджувача Чорнобильської атомної електростанції. Тому метою роботи було дослідити мишоподібних гризунів на наявність збудників кровопаразитарних хвороб у природних популяціях під впливом радіоекологічних умов техногенної трансформації водоймища-охолоджувача Чорнобильської атомної

електростанції. Мишоподібні гризуни родів *Apodemus* і *Myodes* були досліджені з трьох різних місць водойми-охолоджувача з використанням паразитологічних методів. Радіологічними методами було визначено рівень забрудненості зазначених трьох місць відлову мишоподібних гризунів з використанням  $\gamma$ - і  $\beta$ -дозиметра Прип'ять RKS 20.3. Дослідженням мазків крові мишоподібних гризунів із трьох експериментальних полігонів водоймища-охолоджувача Чорнобильської атомної електростанції виявили наявність збудників кровопаразитарних хвороб у 93,8% тварин. Зокрема, ідентифіковано таких збудників, як *Rickettsia spp.*, *Ehrlichia spp.*, *Bartonella spp.*, *Babesia spp.*, *Hepatozoon spp.*, *Haemobartonella (Mycoplasma) spp.* і спірохети. Встановлено поширеність збудників зоонозів серед мишоподібних гризунів Чорнобильської зони радіоактивного забруднення, а також її залежність від рівня радіоекологічної забрудненості відповідних полігонів. Отже, за результатами проведених досліджень встановлено наявність збудників кровопаразитарних хвороб серед мишоподібних гризунів, які є як проміжними, так і їх дефінітивними хазяями, у тому числі з небезпечних зоонозів, що, за умови застосування своєчасних і комплексних превентивних заходів, дозволить не допустити зараження ними людини

**Ключові слова:** паразитарні хвороби; рівень опромінення; *Myodes glareolus*; *Apodemus flavicollis*; *Apodemus agrarius*