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DEVELOPMENT OF SCIENTIFIC TOURISM AND ENVIRONMENTAL EDUCATION USING THE POTENTIAL OF PSRER: PROSPECTS, PROBLEMS AND LIMITATIONS

Polesie State Radiation and Environmental Reserve (hereinafter referred to as the Reserve) is located in the extreme southeast of Belarus on the territory of the evacuation or exclusion zone of the Chernobyl NPP (hereinafter referred to as the ChNPP EZ) which is most contaminated with radionuclides. Its tasks include the implementation of a set of measures to prevent the removal of radionuclides outside the territory, radiation monitoring, radioecological and radiobiological research, the study of the flora and fauna, the study of the original course of natural processes in ecosystems and landscapes.

The Reserve has been functioning since 1988. Its modern area is 216 thousand hectares or 3.5% of the area of Belarusian Polesie. The Reserve has a binary status: *the territory is contaminated with radionuclides* dangerous for people living here, and it is the largest *nature protected territory* in Belarus. De jure, the Reserve is not a specially protected natural area (hereinafter referred to as SPNA). In fact, it performs all of its functions, and the regime of protection of natural complexes and objects on its lands is stricter than in other SPNAs of the country. This is due to the fact that after the Chernobyl disaster, no economic activity is carried out in the EZ except for a number of security and fire-prevention measures as well as a limited list of works in the experimental economic zone. There is no population in the Reserve. There were 24.5 thousand people who got evacuated after the Chernobyl disaster. The anthropogenic impact on the natural ecosystems of the Reserve has been insignificant for 35 years.

The **natural potential** of the Reserve. Before the Chernobyl disaster, as a result of centuries of human economic activity, a significant part of the natural forest, meadow and swamp ecosystems within its boundaries was completely destroyed and

transformed into anthropogenic agricultural (fields, meadows, pastures, gardens), residential (settlements) and human-induced (farms, mechanical yards, quarries, reclamation systems, peat harvesting, etc.) landscapes. Fertile soils of the north-eastern part of the Reserve were completely deforested, and the villages became "fields". Intensive forestry was carried out in the preserved forests. The floodplains of the rivers were regularly cut down. About 85 thousand hectares of swamps and wetlands, which is 94% of their area or 39% of the Reserve, were drained [1] and turned into hayfields, pastures and fields.

Before the Chernobyl disaster, agrocenoses were widespread on fields; mostly cultivated hayfields - on reclaimed lands; pastures, personal land plots and fruit gardens of agricultural enterprises - near villages, greenery and protective plantings - along the roads. In villages (on household plots, in public gardens, parks, street plantings), a complex dendroflora has formed. It is represented by a specific for each village species composition of fruit and berry plants, ornamental local and introduced woody and shrub plant species (introduction of plants is an accidental or deliberate resettlement of species or varieties of plants in places / regions where they have never been met before) [2, 3]. It means that the aboriginal flora was replaced by anthropophytic one. Anthropophytes are plants that entered the local flora thanks to humans (crop, cultivated, weed and ruderal plants), and any species that constantly grow in habitats created by humans.

35 years have passed since the Chernobyl disaster. This is an insignificant period for nature. However, the landscapes of the ChNPP EZ have undergone significant changes during this time. The absence of economic activity gave an impetus to the processes of natural development in biocenoses altered by exploitation and self-restoration in severely disturbed and transformed ecosystems.

Since the zonal type of vegetation on the territory of Polesie Reserve is forest vegetation, the intrazonal type is represented by swamp, floodplain meadow and water types, the former agricultural (fallow) lands and resettled villages be overgrown with forests, and reclaimed lands became bogged up and be bushy. Forests are a powerful biological barrier to the transfer of radionuclides. Therefore, artificial forest plantations were created on some of the fallow lands of the ChNPP EZ. The composition of those plantations was not always represented by local forest species.

As a result, in 1988-2008, the area of drained land decreased by 3.8 times, the area of swamps and wetlands increased by 2.4 times, forests - by 22.8% [4], forest cover within the boundaries of the Reserve increased from 38.5% in 1975 to 55,9% in 2020.

The forest vegetation that grew here before the disaster develops naturally. It is represented by pine forests, oak forests, black alder forests, birch forests, aspen forests, hornbeam forest, maple forests, ash forests, lime forests, plantings of tree and shrub willows of various ages and composition. Absence of logging has ensured "aging", i.e. increase is age of forests. A part of small-leaved plantations has increased in their structure.

In the resettled villages, there's formation of forest plantations of a species composition that is not permanent and unusual for local forests. They are dominated by mainly introduced species such as ash-leaved maple, white acacia, white poplar; fruit species such as domestic plum; less often local forest species such as birch, aspen, Norway maple, elm and ash. In total, the dendroflora of former settlements includes 111 species and 2 varieties of plants including 48 species and 2 varieties of trees, 61 species of shrubs and 2 types of woody lianas. There are 37 aboriginal and 74 adventive species among them. It means that they have penetrated beyond their primary range either naturally (with air currents or by sea), or unintentionally introduced by humans. Among the adventive species, there are 16 hybrids and hybridogenic species. There are also 11 alien harmful tree and shrub species. The most numerous and aggressive species are ash-leaved maple, white acacia, white poplar, spicata and red elderberry. They pose the greatest threat to the natural phytocenoses of the ChNPP EZ [3, 5, 6].

The absence of operational activity of the preserved natural ecosystems and restoration of disturbed ones have led to the appearance of many rare and protected plant species, sometimes in significant quantities, on the territory of the Reserve.

The modern flora of the Reserve includes 1,162 species and hybrids of vascular plants, including 4 species of lycopods, 7 horsetails, 16 ferns, 13 gymnosperms, 248 monocots and 874 dicotyledons. There are 44 rare and protected plant species among them. The flora of the Reserve has the largest part of forest-steppe and steppe species in the country [7]. The data on the species diversity of bryophytes, lichens, algae, and

fungi are far from complete or are absent [8]. To study these groups of the flora, it is necessary to involve domain specialists [7].

The monograph [7] notes that the Reserve is a unique base for studying the range of plant species cultivated before the Chernobyl disaster, their ability to naturalize and persist for a long time in places of cultivation. It is recommended to conduct population studies of plants, observe critical species, describe chromosome numbers and chromosome races on a local material in view of the possibility of genetic rearrangements and mutations due to the high level of radioactive contamination of biocenoses. Population, morphological and molecular genetic studies of plant species rare for Belarus are needed. The main country-wide populations of such plants are concentrated precisely on the territory of the Reserve. An important aspect of floristic research is constant population monitoring observations of rare species that are limitedly found in the country and have an international conservation status. A special direction is the study of various invasive species.

An urgent ecological problem is the intensive overgrowing of resettled villages with alien invasive plant species and their distribution over the territory of the Reserve. It is necessary to assess their distribution and develop control measures under the conditions of the radiation factor [5].

A particularly interesting case is related to the study of the processes of forest formation that have arisen on fallow lands. An extremely interesting issue is the development of forests in abandoned villages which were formed on the basis of anthropophytic flora with a predominance of introduced and cultivated species (hybrids, varieties), and where the share of local forest species has recently increased. Competitive relationships arise between native and introduced tree and shrub species, in which the role, significance and prospects of each of them are interesting. There are also interesting questions of the settlement of these forests by representatives of various fauna groups.

Many of the above-mentioned promising botanical and phytocenotic studies close to the author can probably be carried out in relation to individual groups of representatives of the wildlife of the Reserve which is also rich and diverse. Vertebrates are represented by 311 species. There are 60 species of mammals (72%

of those identified in the country) including 4 introduced species and 11 species mentioned the Red Book of Belarus. The following species have been registered: 233 bird species (60 species from the Red Book), 11 amphibian species out of 13 known in Belarus (2 species from the Red Book), all the 7 species of reptiles found in the country (one species from the Red Book) [8]. 38 species of fish have been identified in the streams and reservoirs [9]. Information on the diversity of groups of invertebrates is extremely scarce or absent.

As a result of the removal of anthropogenic pressure in the Reserve, favourable conditions have emerged for the habitation of representatives of various fauna groups and the growth of their numbers (the living space and the capacity of forage lands have increased; the disturbance factor has decreased). It ensured the successful reintroduction of the bison into the Belarusian sector of the ChNPP EZ. In the Reserve, a micropopulation of Przewalski's horse forms independently which has spread from the adjacent territory of Ukraine.

It's worth highlighting the presence of a **geographic (geomorphological) capacity** in the Reserve caused by the peculiarities of the relief structure of its territory. Most of the territory is located in the wide valley of the Pripyat represented by a floodplain and two terraces above the floodplain. In the north and north-east of the Reserve, there is a strip of sections of Khoiniki water-glacial plain covered with loesslike deposits. Its surface is flat, shallow or gently wavy and slightly inclined to the south; relative elevations are mainly 3–5 m. Part of the southwestern territory is occupied by a water-glacial plain with a flat, slightly hilly surface with small areas of moraine plains. Relative elevations of the relief are 2–3 m there, in some places - up to 8–10 m. In the Pripyat valley, there are randomly scattered aeolian hills (created by winds) with a height of 3–8 m which are grouped into ridges up to several hundred meters long [1, 10].

The Reserve has 1,667 floodplain lakes with a total area of 2,430 hectares, 130 ponds and reservoirs (69 hectares). The area of all water bodies is 3,810 hectares or 1.8% of the territory of the Reserve [11].

The soil cover of the Reserve is very diverse. The close occurrence to daylight surface of groundwater on 70.5% of the Reserve area has caused a variety of semi-hydromorphic and hydromorphic soils [12].

The **climatic factor** is important for the territory of the Reserve. Over the past 30–40 years, the region has experienced climate warming and an increase in aridity of the climate, i.e. dryness [13, 14]. Due to the fact that the Reserve is located in the extreme southeast of the country, the climate of its territory is gradually acquiring features of a forest-steppe one. The consequence of warming is the penetration of new southern representatives of flora [7] and fauna into the territory of the Reserve. Under the influence of climate, changes are predicted in the species composition, structure and productivity of forests [15] and other plant communities as well as fauna complexes. These changes are of undoubted interest for the natural sciences at an interdisciplinary level.

The functioning of a meteorological station on the territory of the Reserve and the presence of a base of 30-year meteorological observations can allow connecting the nuances of the dynamics of vegetation cover, various groups of fauna and flora with climate changes.

Radiation aspect. During the Chernobyl disaster on April 26, 1986, large volumes of radioactive material were released from the reactor. According to the information for May 10, 1986, the dose rate of gamma radiation exceeded 5,000 μR/h throughout the 30-km zone of the Chernobyl nuclear power plant [4]. The biogeocenoses of the Reserve concentrate about 30% of ^{37}Cs, 73% of ^{90}Sr and 97% of $^{238\text{-}241}$Pu isotopes that fell on the territory of Belarus during the Chernobyl disaster[16]. Due to the decay of ^{241}Pu (half-life of 14.4 years), the activity and reserves of ^{241}Am (half-life of 432.2 years), which is an alpha emitter and much more toxic than ^{241}Pu (beta emitter), will grow in the ecosystems of the Reserve until 2060.

To date, the amount of ^{137}Cs, ^{90}Sr has decreased by more than twice in relation to the amount emitted. Nevertheless, the radiation situation in the Reserve remains very difficult. These radioisotopes as well as $^{238\text{-}241}$Pu and ^{241}Am determine the radiation context and form dose loads on the biota of the Reserve.

Radionuclides are distributed very unevenly throughout the territory of the Reserve. In the near zone of the reactor, the concentration of “hot” particles in the soil is high [4] which are destroyed due to the impact of environmental factors and are a source of secondary radioactive contamination of ecosystems. High density of radioactive contamination of soil provides a high level of radionuclide accumulation

by components of forest biocenoses [17, 18] including floristic objects that are characterized by individual specificity of radionuclide accumulation [19].

The presence of transuranium isotopes (^{238,239,240}P and ^{241}Am) in the natural environment of the ChNPP EZ with half-lives up to several tens of thousands of years excludes the possibility of people living in the Reserve in the foreseeable future. The most optimal is its use as a nature conservation area and a "field scientific laboratory".

The territory of the Reserve has a rather significant **historical potential.** These are sites of Stone and Bronze Ages (6), ancient settlements (6) included in the State List of Historical and Cultural Heritage of the Republic of Belarus as well as 13 other archaeological monuments (sites, a burial ground without a barrow, settlements) not included in the specified List.

Generations of people living within the boundaries of the modern territory of the Reserve have gone through many dramatic historical events. All the main points are documented in the district books "Memory" and other literary sources. There are 60 monuments and memorial sites of World War II and subsequent events on the territory of the Reserve. These are fraternal and individual burials (graves of Soviet soldiers and partisans who died during World War II, graves of victims of fascism, Soviet activists), monuments to the natives of these places who died in the Great Patriotic War, places where partisan detachments were based and places of the villages burnt down. Some of them are included in the State List of Historical and Cultural Values of the Republic of Belarus.

Finally, 92 abandoned settlements with schools, communities centres and other public buildings as well as production facilities and complexes (feed-processing plant, a pig farm, dairy farms, a bakery, drainage systems and others) are of interest from the viewpoint of acquaintance with the living conditions and everyday life of the population, the level of development of agricultural production in the mid-1980s. Monuments dedicated to them have been erected in a number of resettled villages.

The above-mentioned analysis shows how rich and diverse the biota of Polesie Reserve is; where various natural processes take place under the influence of a radiation factor, minimal anthropogenic influence and changing climate.

These are only some of the pressing scientific problems and issues concerning

most of the vegetation and flora. Undoubtedly, other natural objects of the Reserve also require scientific research and observation. In this viewpoint, the Reserve is actually a "natural laboratory".

Among many directions of scientific research and practical developments identified for the future on the territory of the Reserve, we would like to especially highlight "*...the possibility of arranging a test site and* ***establishing an international research centre*** *which could be a platform for addressing environmental issues, conducting research in the field of radiobiology, radioecology, flora, fauna, dynamics of ecosystems under conditions of limited anthropogenic load...*" [20, 8]. To work in this centre, it is planned to attract specialists from various fields of knowledge from Belarus and abroad. A visit to the Reserve for scientific purposes is defined as scientific tourism.

In July 2021, the experts from the NGO "Green Cross Belarus" raised a point of holding international scientific field forums in Polesie Reserve and Dnepro-Sozhsky Reserve. Their goal is to study the species diversity and various aspects of the functioning of the ecosystems on these territories, to assess the current state and predict their dynamics in the south-east of Belarus under conditions of radiation pollution and modern climatic changes. A.V. Kulak, Lead Researcher of the Laboratory of Terrestrial Invertebrates of the Scientific and Research Centre under the National Academy of Sciences of Belarus for Bioresources, Candidate of Biological Science, noted: "*... it's proposed to use such a form of studying individual components of biogeocenoses of both territories, for instance, conducting research field forums-seminars by special groups including academic and university specialists from both Belarus and foreign countries, postgraduate students, naturalists, volunteers...*".

I believe that the proposed annual forums-seminars can lay the foundation for the formation of a research centre and become the first practical step towards it.

The important tasks at the current stage of development of the Reserve are the following: to grant the status of a specially protected natural area and to include it in the scheme of the national ecological network; to develop an environmental management plan for the Reserve; to establish a centre for the reintroduction and naturalization of economically significant and rare species of animals and plants

including experiments of rewilding (an environmental ideology aimed at restoring ecosystems as they used to be before human intervention which is carried out by returning large animals to their original places of residence from which they were displaced as a result of human activity; the return of such animals triggers a number of processes that contribute to the increase in biodiversity); to draw up a normative document defining the procedure for carrying out activities taking into account the specifics of radioactive contamination of the Reserve territory [8]. Many questions in solving these and other problems can be resolved by holding field forums-seminars.

Scientific results and materials of the forums will be included in the interdisciplinary informational guide on the Reserve. It will be regularly updated. **Environmental education.** Polesie Reserve has a huge and diverse natural and, to a lesser extent, cultural and historical potential. Undoubtedly, its complexes and objects can and should be used as "natural classes" where representatives of various segments of the population, especially young people, will be able to acquire knowledge in the field of botany, zoology, geography, ecology, nature protection, history, radiation safety and other fields. This calls for the development of scientific and educational programmes and events (excursions, field classes, tours, expeditions, seminars, thematic schools, individual actions, etc.) on the territory of the Reserve.

In terms of excursions around the territory of Polesie Reserve, some work has already been done. Based on the existing natural capacity of the former settlements and accumulated scientific knowledge and taking into account the processes and changes taking place in ecosystems and biogeocenoses, we have developed an educational route of 95 km long with the duration of 7 hours long.

However, when organizing various forms of scientific and educational tourist activities and environmental education on the territory of Polesie Reserve, we face a number of problems. First of all, the Reserve is a regime object, which is due to the factors of radiation pollution and the proximity of the state border. Therefore, when organising visits to the territory of the Reserve by third parties, in addition to agreements and contracts with the administration of the Reserve, it is necessary to obtain passes to the ChNPP EZ and the border zone. Second of all, due to the high level of pollution of ecosystems, there are restrictions on the duration of the stay of people on this territory. Third of all, according to Belarusian legislation, the presence

of people under 18 years old on the territory of the ChNPP EZ is not allowed. This is a major limiting factor in attending this “green school” and conducting educational activities for pupils.

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