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Geophysical and tectonic modernization of geoecological monitoring system of territories near nuclear fuel cycle objects of Ukrainian Southeast

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SUMMARY

Development of atomic engineering is unique possible way of industrial development of Ukraine as new independent state. But objects of nuclear fuel cycle are potential sources of radioactive pollution of an environment. Modern ecological situation in southeast of Ukraine – Industrial Pridniprov'ye – may be characterized as crisis. There are some enterprises of Ukrainian nuclear fuel cycle (enterprises of extraction and primary processing of uranium raw materials, storages of low-active wastes and nuclear power plant) here. Existing geoecological monitoring system does not fully consider radio-ecological factor on territories near the nuclear objects of Ukrainian Southeast. Modernization of this system, including complex of geophysical methods and working out of radio-ecological block, is actual. Significant volume of tectonical information about features of Earth's crust faults is the basis of prognostication concrete azimuths of dangerous radiological influence of natural-technogenius accidents for concrete region. Because one of the major factor, that determined both ecological and radiological situation at any region, are faults. Using the example of the nearest territories of Zaporizhzhya nuclear power plant – the main of enterprises of energy producer of Ukrainian Southeast – the need for attention to tectonic factor in areal monitoring radiological geophysical researches is shown.

Introduction

Last years the problems of safety of an environment is got the special urgency for Ukraine. Good health and well-being of the man require a harmonious environment, which should be viewed as a natural radiant of improvement of conditions of human activity. But the modern ecological situation in Ukraine can be characterized as crisis. Environmental contamination has achieved such level when it can influence health of the population negatively. The principal causes of a crisis ecological situation are priority development of a mining complex and imperfection of the legal and economic mechanism of an environment protection.

The southeast of Ukraine is the industrial advanced territory, which one includes series of regions. Mining, metallurgical and chemical industries, mechanical engineering are advanced here. Some enterprises of a nuclear fuel cycle (NFC) of Ukraine are concentrated at Industrial Pridniprov'ye: Kirovograd, Dnipropetrovs'k and Zaporizhzhya regions.

The development of atomic engineering is the unique possible way of industrial development of Ukraine as the new independent state. Present Ukrainian NFC provides the social-economic development of the state. But the objects of NFC are potential sources of radioactive pollution of an environment. Usually last ones are considered as result of accident on the Chernobyl atomic power station in 1986. However, there is also other threat both for territory of Ukraine and for other countries of East and Central Europe the objects of a nuclear-fuel cycle of Ukrainian Southeast such, as the enterprises of extraction and primary processing of uranium raw materials and also storages of considerable quantity of low-active wastes from uranium enrichment. The main of them are located on the territory of Industrial Pridniprov'ye. Radioactive pollution could insert into surrounding territories. There is the possibility of radionuclides transferring through the river Dnipro to the Black Sea and further to the Mediterranean Sea (Pihulevskyi et al., 2018). It is needed an operative researching storages and surrounding territories as ways of radionuclides transferring. But the modern system of geoecological monitoring does not fully consider the radio-ecological factor in the nearest territories of the objects of NFC of Ukrainian Southeast and also does not consider total effect from different industrial objects. Modernization of existing system, including the complex of geophysical methods (Menshov et al., 2010; Pihulevskyi et al., 2019; Tyapkin et al., 2014) with the special attention for modern local geodynamics (Tiapkin et al., 2017), is actual.

Modern ecological and radiological problems of Industrial Pridniprov'ye

The territory of Industrial Pridniprov'ye and especially its center – the Dnipropetrovs'k region is extremely technogenic loaded territory. It occupies 5,3% of the territory of the country and provides about 12% GNP and 50% of extraction minerals, which are very important for Ukraine and Europe, 7,5% of the inhabitant of the country lives at this region. It is the territory with developed industrial complex, one of the largest in Ukraine. The leading places in the complex are ferrous metallurgy (44,8% from nation-wide product), mechanical engineering and metal working (~22%), food (~10%), the chemical and petrochemical industry (8,5%). Such concentration of different industries is the reason of the environmental contamination: volume of emissions of polluting substances in atmosphere – 18% from nation-wide emission, volume of dump of turnaround waters – 14,5% from nation-wide. More than 8,5 billion tons an industrial and household waste are stored in territory about 13 thousand in hectares. About 200-250 million tons of waste are formed annually and only 40% of them are utilized. More than 2 billion cubic meters of sewage are arrived in superficial waters annually that makes ~25% of total of sewage in Ukraine. Including radiological problems it is interesting to consider maps of consequences of Chernobyl accident it is easy to see, that the region is not loaded on plutonium isotopes, but the center and south-east part of Dnipropetrovs'k region is polluted on cesium (Fig.1,*a,b*). The map of ecological situation, including technogenic loading shows different "picture" (Fig.1,*c*)

The considerable proportion of investigated region is located on the southeast part of the Ukrainian Shield (Precambrian bedrock). The granite intrusions with the increased contents of radionuclides: uranium-radium and thorium sets (Proterozoic Dniprovs'k-Tokovs'k magmatic complex) have received rather widespread distribution here. These rocks determine local increase of capacity of an exposition

doze of γ-radiation (till 25-30 mcR/hours) in valleys of the rivers and streams. It is explained by their short bedding or outcrop. The low values of radioactive background (7-14 mcR/hours) are determined by the clay overlying (~10 m), which one is a reliable screen from radiation influence of Precambrian bedrock on the most part of the region.

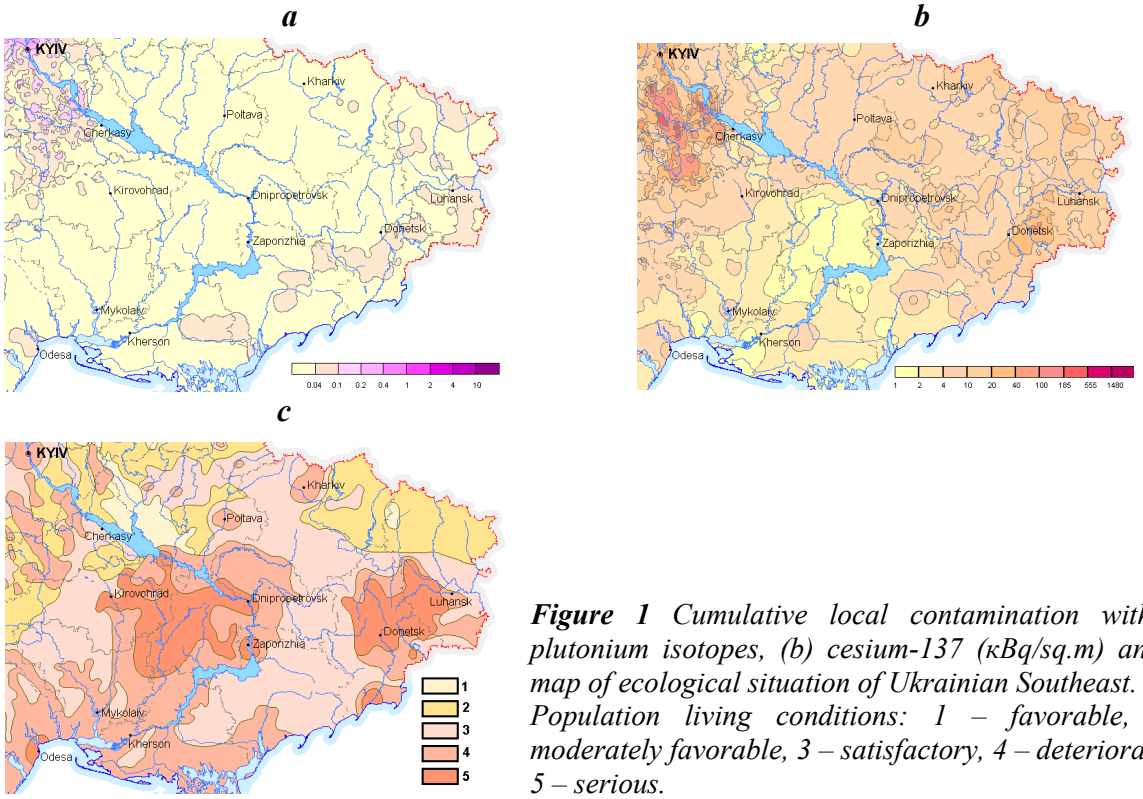

Figure 1 *Cumulative local contamination with (a) plutonium isotopes, (b) cesium-137 (κBq/sq.m) and (c) map of ecological situation of Ukrainian Southeast. Population living conditions: 1 – favorable, 2 – moderately favorable, 3 – satisfactory, 4 – deteriorated, 5 – serious.*

The zone of an increased background (up to 30 mcR/hours) is exhibited also outside of limits of the Ukrainian Shield in east of region as anomalous zone, which one occupies the considerable area (almost bodily Western Donbas). The surface contamination of locality by technogenic radionuclides achieves up to $18{,}5\times10^{10}$ Bq/km^2 (for Cs^{137}) and up to $0{,}75\times10^{10}$ Bq/km^2 (for Sr^{90}) in this territory. Here the radioactive pollution of small rivers sometimes achieves $18{,}5\times10^{-3}$ Bq/m^3 and more, with the average contents of radionuclides in Dnipro-river $(3\text{-}7{,}5)\times10^{-5}$ Bq/m^3.

There are local anomalies (up to 3000 mcR/hours), which bound extremely with the enterprises of nuclear-fuel cycle in territory of region. These sites of storage of liquid low radioactive wastes are special danger in this territory. The huge quantities of liquid radioactive wastes were merged in upper reaches of girders without special antifiltration opening-up of bottom – bed and blocking dams during several decades. For example, there are such 9 storage of the hazardous wastes of uranium raw processing in immediate proximity to west from Dnipro-city. They contain 36 million tons of radioactive substances by general activity $\sim2{,}8\times10^{15}$ Bq on the floor area 165,5 hectares. These storages are constant sources of contamination of underground waters (migration of a liquid phase), lower atmospheric slices and soil (raise dust of dehydrated sites of these storages). The total activity of radioactive wastes stores in Dnipropetrovs'k and Kirovograd regions is $\sim5{,}5\times10^{15}$ Bq (Pihulevskyi et al., 2018; Tyapkin et al., 2009).

Development of radiological units of local integrated geoecological monitoring systems

In Ukraine geoecological monitoring for the objects of NFC does not fully consider the radio-ecological factor both in the nearest and far territories and total effect from different industrial objects. In case of the accident, it will be difficult to predict consequences of radioactive pollution of components of an environment. Therefore the system of complex ecological multiscale monitoring for the technogenic

loaded territories is active working up now in Ukraine. Modernization of existing monitoring system, including a complex of geophysical methods and working out of the radio-ecological block, is actual. The significant volume of tectonical information about features of Earth's crust faults is the basis of prognostication the concrete azimuths of dangerous radiological influence of technogenius and natural accidents for concrete region. Because one of the major factor, that determined as ecological and as radiological situation at any region, are the faults. The settlements and large industrial manufactures gravitate to the rivers, which network is completely predetermined by systems of faults. The traces of the largest of faults have width from several kilometers up to several tens kilometers on Earth's surface. The modern activation of faults reshapes the basic features of a geological environment determining its ecological parameters. The information about tectonic structures of region is a basis of the long-term prognosis of development of natural radiation situation. According to rotational hypothesis of structure formation in some tectonic epoch under the influence of forces of planetary stresses, it occurs a stirring up of the systems of the Earth crust's faults formed earlier. Each system consists of some faults, hierarchically subordinated, of two mutually orthogonal directions. In the limits of Industrial Pridnieprov'ye as well as on all territory of the Ukrainian Shield there are clearly fixed six systems of faults with the following stretching azimuths: 0° and 270°, 17° and 287°, 35° and 305°, 45° and 315°, 62° and 332°, 77° and 347°. The analysis of geomorphological indications of the revealed faults has allowed to determine their fragments, which stirring up at the newest time. That is why the greatest radioactive pollution in all geosphere are connected to faults (Tyapkin et al., 2009).

Below, using the example of the Zaporizhzhya nuclear power plant (ZNPP) – the main of enterprises of energy producer of Ukrainian Southeast – the need for attention to tectonic factor in areal radiological researches is shown. ZNPP is located in the south-eastern part of the Middle-Dnipro megablock of the Ukrainian Shield near the Orikhiv-Pavlograd juncture zone (OPJZ), which is bounded by steeply falling linear tectonic structures – faults. Here according to geological-geophysical data (Svistun et al., 2021) the structure of Precambrian foundation is very complex with numerous tectonic faults, which have different directions of extension and depths (Fig.2).

Large-scale radiological researches have begun here since the early 1990s. The spatial distribution of natural (Ra^{226}, Th^{232}, K^{40}) and technogenic (Cs^{134}, Cs^{137}, Sr^{90}) radionuclides is investigated in the soil (depth –15 cm) along a network of 2×2 km (ZNPP near zone) and 5×5 km (far zone). Natural and technogenic (including H^3) radionuclides in water are investigated in wells (in settlements) and ponds between settlements along a network 10×10 km (ZNPP near zone) and 20×20 km (far zone). There are no dangerous problems with local radiological load here. The dose load on the population as a result of external exposure is 0,4-4 mcSv/year – less than the dose limit for the population. But, at the same time, a zone of anomalies of low values of Ra^{226} specific activity was identified within OPJZ (red dashed line in Fig.2). The coincidence of its direction with the main direction of OPJZ (~17°) indicates the tectonic origin of this zone. Further, detailed comprehensive monitoring geological and geophysical researches, incl. petrophysical magnetic soil research (Menshov et al., 2010; Menshov et al., 2020), are necessary to determine the nature and predict changes in individual anomalies within the identified zone.

Conclusions

The development of atomic engineering is the unique possible way of industrial development of Ukraine as the new independent state. Nevertheless, the objects of the nuclear fuel cycle are potential sources of radioactive pollution of an environment both for territory of Ukraine and for other countries of East and Central Europe.

Modernization of existing geoecological monitoring system both in the nearest and far territories of Ukrainian nuclear fuel cycle objects, including the complex of geophysical methods with the special attention for modern local geodynamics, is actual.

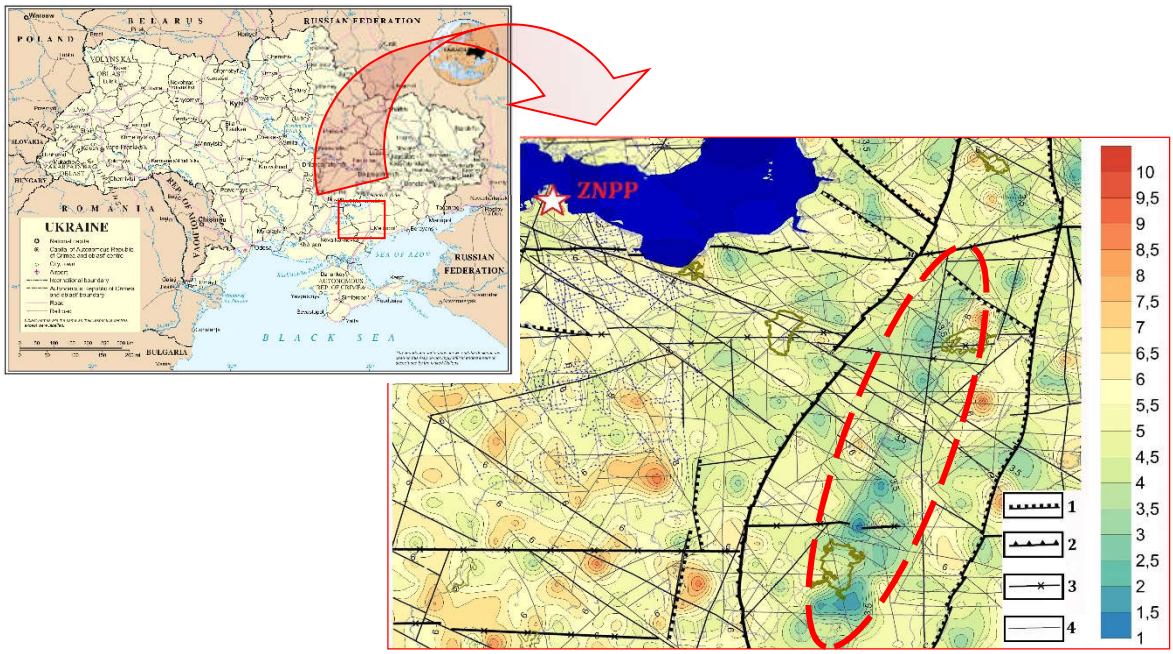

Figure 2 *Specific activity of Ra^{226} (Bq/kg) with fault tectonics near ZNPP. Tectonic faults: 1 – dropping; 2 – uplifts; 3 – spreading; 4 – small faults with unknown morphological and kinetic characteristics.*

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