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IMPORTANCE OF RADIONUCLIDE MONITORING WITH PARTICULAR REGARD TO ENVIRONMENTAL IMPACT ASSESSMENT*

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Abstract. *Background. Observed from a global perspective, there is currently an increasing tendency directed towards protection, on the one hand, and efficient natural resources exploitation for the sake of daily society needs at the other. Whilst the contemporary environmental quality monitoring schemes at the national level recognize the significance of basic physical, chemical and biological parameters as environmental quality indicators, there is insufficient attention given to the radionuclide monitoring. Aims. Having the previous facts in mind, the aim of this paper is directed to: detailed analysis of sources of radionuclides in environment, mechanisms of their transfer in different environmental media and their final fate influencing environmental quality and environmental services. Also, the aim of this paper is to demonstrate the significance of radionuclide monitoring both from the perspective of environmental protection and natural resource availability. Methodology. The outcomes of this paper rely on the environmental quality reports and studies performed by numerous organizations, and it highlights the importance of interdisciplinary approach within the observed field.*

Key words: *Environmental impact assessment, radionuclide, monitoring, indicators, protection*

1. AIMS AND BACKGROUND

At the EU level, the European Union (through European Environment Agency - EEA) gives great significance to the protection and preservation of natural resources and living environment, treating them as the base of sustainable development within the 21st century. Moreover, the United States (through Environmental Protection Agency - US EPA) declares that scarcity of natural resources may be the limiting factor to the further societal and economic development. No less important is the fact that US EPA promotes the concept of Natural Resource Damage (NRD) and Radionuclide Rule which takes into account the damage to the natural resources that have occurred as a result of releases of hazardous substances such as oil or radionuclide as a result of natural resource injury related to the man-driven action.

Contemporary national environmental quality monitoring schemes (operational, survey and surveillance) at the national, regional and local level recognize the significance of basic physical, chemical and biological parameters as environmental quality indicators, within the accepted methodology. Beside the importance of radionuclide monitoring (recognized both by the European Environment Agency – EEA and United States Environmental Protection Agency – US EPA), there is still insufficient attention given to the radionuclide monitoring in different environmental media, and moreover, insufficient attention given in environmental impact assessment approaches, tools and methodologies.

In Serbia, The Serbian Agency for Environmental Protection (SEPA), as a body within the Ministry of Agriculture and Environmental Protection, performs professional tasks related to:

- Development, coordination and management of the national information system for environmental protection,
- The implementation of the national environmental quality monitoring platform,
- Management of the National Laboratory,
- The collection and compilation of environmental data, processing and preparation of reports as the development of procedures for the processing of environmental data and their assessment,
- Keeping data on best available techniques and practices and their implementation in the field of environmental protection, and
- Cooperation with the European Environment Agency (EEA) and the European Network for Information and Observation (EIONET), as well as other duties specified by law [1].

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The Serbian Agency for Environmental Protection Regulations also covers the area of non-ionizing radiation. By the national list of environmental indicators, an indicator of non-ionizing radiation is defined: non-ionizing radiation sources of special interest. Non-ionizing radiation sources of special interest are those sources of electromagnetic radiation that can be harmful to human health. The indicator defines the stationary and mobile sources whose electromagnetic field in the area of increased sensitivity reaches at least 10% of the reference, the limit values laid down for that frequency [2].

Regarding the operations within ionizing radiation, the Serbian Government established the Serbian Radiation Protection and Nuclear Safety Agency, as a stand-alone regulatory agency in the field of radiation protection and nuclear safety in Serbia [3]. For the purpose of conducting the operations within the established purview of the Agency, the following basic internal organizational units have been created:

- The sector for radiation safety and security;
- The sector for nuclear safety and security; and
- The sector for professional supervision and control of the work of licensed and authorized bodies, legal and financial operations, general operations, and public procurement operations.

The sector for radiation safety and security performs the following work:

- prepares the programme proposals for radiation safety and security,
- creates instructions and procedures required for the implementation of radiation safety and security measures,
- prepares the programme of systematic examination of environmental radioactivity,
- prepares the programme of prompt accident announcement, as the proposal of the accident response plan,
- monitors the scope and changes of radioactivity levels, assesses their impact on the population and the environment, and, accordingly, authorizes and supervises the implementation of required measures,
- cooperates with other state and international bodies regarding the response in the event of suspected and actual accidents, as well as other protection and rescue activities [4].

Within recent activities, The Serbian Radiation Protection and Nuclear Safety Agency launched the portal named "Monitoring of radioactivity in the environment in the Republic of Serbia" (MONRADRS). The portal provides an insight dedicated to the public on the activities of monitoring environmental radioactivity in the Republic of Serbia. The illustrative part of MONRADRS portal is shown in Figure 1.

The portal provides information about measuring radioactivity in soil, food, water, rainfall and air. The MONRADRS portal represents one of the first operational platforms providing the necessary data regarding radionuclide concentrations within different environmental media [5].

Figure 1. MONRADRS portal – measuring sites [5]

2. Radiological hazards and risk

A radiological hazard can be defined as a hazardous state or event that constitutes a potential threat and that could inflict damage to humans or to the environment. Radiological hazards can be classified into natural and anthropogenic hazards. Natural hazards occur due to natural phenomena – predominantly meteorological and geological. Anthropogenic radiological hazards mainly occur due to human negligence, they are associated dominantly with industrial facilities and energy production facilities, and they involve explosions, hazardous waste, etc. No less important are the anthropogenic radiological hazards that mainly occur due to the military installations and operations. In wider sense, natural and anthropogenic/artificial hazards are classified into three basic groups: physical, chemical, and biological. Anthropogenic hazards can also be classified into environmental hazards, technosphere hazards, and socioeconomic hazards. Anthropogenic radiological hazards could be mainly classified as technosphere hazards. The technosphere encompasses human settlements, infrastructural facilities, technical and technological systems, as well as other man-made objects (military installations). Technosphere hazards include the hazards of the material work environment and hazards of socioeconomic relations. Hazards of the material work environment comprise the following:

- technical and technological hazards resulting from low quality of the machinery, low-quality and outdated equipment, poor equipment maintenance, low level of physicochemical parameters of the work environment, and low quality of personal protective equipment,

- technical and technological hazards resulting from inadvertent human action, due to negligence, incompetence, or ignorance, and from deliberate human action, performed either in times of peace or in wartime, usually in the form of sabotage,
- organizational and personnel hazards resulting from incompetent organization of the work process and jobs, poor care of employee health, inadequate work discipline, and inadequate employee education for using and handling work tools and personal protective equipment;
- hygienic and medical hazards, which include workspace and workplace hygiene, personal hygiene, and physical examinations.

On the other hand, radiological safety issues are closely connected to decision making. Every decision making implies an exposure to a certain degree of risk. Risky refers to that which is exposed to risk, which can be hazardous and unfavourable. Risk involves the probability of hazard, loss, injury, or other harmful effect. Risk is the probability that a specified goal will not be achieved in full, but only partially. The possibility of eliminating or reducing risk depends on how well the phenomenon containing the risk is known. Risk can cause unwanted consequences, failure of an action, or excessively high loss, but also extraordinary success. The character and scope of risk depend on the situation, and the knowledge about the risk is acquired through the assessment of the situation. The level of risk for a specific activity depends on the willingness to take the risk, realistic assessment of the situation, and the availability of information. Depending on the situation, significance, and effects, risk can have a tactical, operative, and strategic importance, and in the most general sense, one can be either aware or unaware of the risk. In order to solve safety issues and make less risky decisions, a distinction between hazard and risk has to be made:

- hazard – probability/condition of an accident,
- risk – uncertainty of the outcome / loss as one possible outcome.

Hazard analysis requires proper preparation. A technique of using the diagram of this process can be used to identify all the hazards. The diagram encompasses every stage of the work process. Prominent examples of the impact of radionuclides on natural resources include:

- Chernobil disaster,
- Fukushima Daiichi nuclear disaster,
- Tokaimura nuclear plant accident,
- Three Mile island accident, and
- Mayak nuclear plant accident.

When developing the approach to radiological risk management, it is necessary to use the risk characterization resulting from risk assessment. The result of risk assessment has to be combined with the assessment of available risk management options in order to make the decision about risk management [6].

As a contemporary trend, perhaps still not sufficiently recognized, the risk-based approach to radiological hazards management could be usefully applied to the issue of aspects ranking and its prioritization. Within this approach, the significance of the radiological hazards aspects (and its impacts) is defined based on the total score of the mathematical product between the degree of impact significance and the likelihood of occurrence, according to the defined criteria. At the other hand, the proofs of environmental impacts assessment consist of:

- environmental basis,
- potential impacts prediction,
- mitigation measures, and
- monitoring,

while the risk-based approach to environmental management rely on the consideration of:

- hazard identification (in sense of likelihood),
- exposure assessment, and
- risk characterization.

Risk, viewed in terms of consequences of operational activities of installations connected to radiological hazards, should be analysed based on the function of probability of a risk event and the measurement of potential degradation of environmental quality. Risk events, i.e., operational activities that could affect the degradation of air, water, or soil quality, should be determined based on the analysis of each stage of the technological processes of installations connected to radiological hazards [7].

Observed from the human perspective, the most prominent are the health risks associated with the radiological hazards. Within the scope of Republic of Serbia, the most widely familiar are the cases of so called Balkan endemic nephropathy (BEN), a kidney dysfunction probably caused by the long term exposure to some radionuclide compounds (although not fully confirmed), mainly distributed within the Balkan mountains region, i.e. Eastern Serbia area [8].

The possible toxic mechanisms of uranium compound nephrotoxicity are shown in Figure 2.

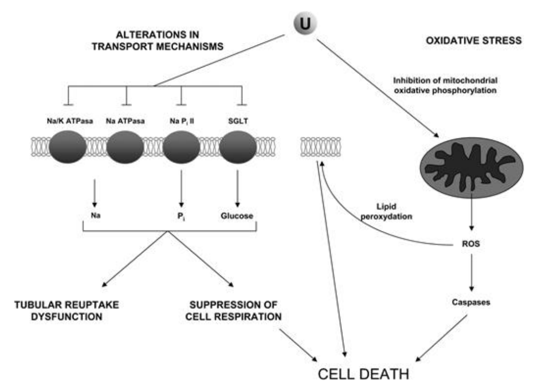

Figure 2. Uranium nephrotoxicity mechanisms [9]

As discussed in scientific literature, there is an environmental hypothesis for the cause of Balkan endemic nephropathy that suggests that the spatial distribution of BEN is related to the biogeochemistry of the environment and hydrogeochemistry of groundwater from affected regions. Such literature data shows that uranium concentrations were above WHO suggested limits in many well and spring water samples within the affected regions [8].

Regarding importance of radionuclide monitoring both in surface and potable water, Serbian drinking water quality limits are in place for uranium, as a chemical parameter and gross alpha and beta radioactivity as radiological parameter [10].

3. Conclusions

From the environmental perspective, an organization whose activity negatively impacts natural resources and the environment must take measures to preserve natural resources, conserve natural resources and prevent environmental pollution and continuously improve the efficiency of the resource protection system and the environmental protection system. The system of implementation of environmental protection is based on the implementation of legal regulations and international standards. Planning and organization of environmental protection in sense of radiological hazards must be focused on the prevention of negative impact of human actions on environmental systems. This requires a complete shift in the way of thinking and forming of opinions, and the fundamental value – human-environment-nature – as a new starting point.

Mechanisms of communication, coordination, cooperation and collaboration are important in a radiation safety system, to achieve desired results – reducing the consequences of adverse radiation events, in regular or emergency situations. The effects of the environment are particularly important for the radiological safety system, because it affects the functioning of entire organization, and defines the image of the organization. Knowledge on radiation hazards and adverse events, preventive measures, organizational activities focused on reducing the number of accidents and incidents, and decreasing the consequences of that events must be accumulated and shared. The problem of efficient collection, accumulation, and sharing knowledge on radiation safety, adverse events, experience of employees, and data on accidents, incidents and radiation hazards emerges in many large-scale systems. There are different perspectives observing the effectiveness of radiation safety. Technical characteristics are prerequisites for the efficient radiation safety system during the initial period of safety system development. There are some costs of the radiation safety system (development, maintenance), based on the intensity of monitoring, applied technologies, and the reliability of the system. The efficient safety system means that it is precisely defined in correlation with activities and events. The environment affects the efficiency of system by formal acknowledgement on radionuclide importance in the environment, legislation, safety technologies, available standards and databases that can be used. More efficient reaction on radionuclide accidents and incidents can be obtained by periodical improvement of safety system described by a set of indicators, selection of more appropriate measures and continuous improvement of the system.

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