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Research on the Effects of Specific Radionuclides on Health

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Abstract: **Radionuclides affect human health and living organisms through external and internal exposure. This causes acute effects at high doses and an increased risk of cancer and genetic damage at long-term low-level exposure. Radionuclides generally affect health, toxicology and public health through chemical and radiation effects - internal uptake (ingestion/inhalation) of specific isotopes such as I-131, Cs-137 and Sr-90 leads to local accumulation in critical organs and an increased risk of cancer and functional disorders. The main routes of entry of hazardous radionuclides into the human body are through air, water, food and injured surfaces. It is very important to conduct radiation reconnaissance of the isotopes distributed in the environment and their energy state. Public health protection responds to the presence or change in the composition of radionuclides through monitoring, dietary restrictions and protective measures (evacuation, iodine prophylaxis). Radionuclides have a combined effect, causing on the one hand a radiation component (ionizing damage to DNA) and on the other hand a chemical/toxicological component (for example, heavy metals such as uranium have nephrotoxicity).**

Keywords: radiotoxicology, air, soil, water, food, radionuclides, uranium, strontium, iodine, cesium, human organism, impact, organs, tissues, impact.

I. Introduction

Radionuclides are unstable atomic nuclei that release ionizing radiation through radioactive decay and interact with biological systems in ways that carry important public health consequences [1, 6, 12]. This chapter explores the multifaceted effects of radionuclides on population health by integrating physical, ecological, and epidemiological viewpoints. Its purpose is to offer a systematic overview of the issue, outline the methods used for assessment and surveillance, review empirical findings, and draw practical conclusions and recommendations relevant at the national level as well as for local hotspots such as the Veliko Tarnovo region [2], [35], [46], [50].

Radionuclides—both natural (uranium, thorium, radon) and anthropogenic (cesium-137, strontium-90, NORM/TENORM)—are inherent components of the geochemical environment and an unavoidable part of our surroundings [2], [11], [21], [37]. Their potential hazard to human health and ecosystems depends on concentration, origin, energy released, and exposure pathway [10]. In Bulgaria, uranium deposits, former uranium mines, certain industrial sites, and local geological conditions create the potential for localized hotspots that require focused monitoring and management [3], [18], [22], [41], [44]. Monitoring efforts have been conducted in the past, notably under the PHARE programme at the end of the 20th century and by Plovdiv University in 2010, but periodic re-surveys are necessary because radionuclide distributions change over time and ongoing surveillance is required.

The primary aim of this study is to establish a scientifically robust framework for understanding sources and mechanisms of radionuclide exposure [33], [39]. To that end, the chapter describes monitoring and assessment techniques, proposes a structure for an operational protocol for local surveys, and offers practical and legislative recommendations to reduce risk [8], [29], [36], [42], [48].

II. Research methods

To achieve the set goals, the following have found a place in the structure of the article:

- historical and regulatory context of the issue under consideration;
- describing sources and routes of exposure to the main radionuclides;
- biological mechanisms of radionuclides' impact on living organisms;
- methodology for monitoring the presence of radionuclides in air, water and soil;

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- epidemiological approaches to detecting the presence of certain radionuclides [15], [25];
- operational protocol for sampling and reporting based on the Veliko Tarnovo district;
- risk assessment in the event of the possible detection of radionuclides;
- remediation [16], [28], [43];
- legislative and communication measures aimed at limiting the possibilities for the release of radionuclides and limiting their impact on the environment;
- methodological appendix and extended tables.

Historical and regulatory context:

Purpose: Trace the development of scientific knowledge, policy, and the regulatory framework that shape radionuclide management.

Content: A timeline of key events; review of national and European legislation and standards for permissible levels and control methods; evaluation of past monitoring programmes and their outcomes; identification of regulatory gaps and proposals for updates [4], [14].

Sources and exposure pathways:

Purpose: Describe the main natural and anthropogenic sources and the routes by which people and ecosystems are exposed.

Content: Classification of sources such as geological deposits, mining, industrial sites, nuclear incidents, and agricultural technologies; transmission pathways including air, water, soil, and food; factors affecting mobility and bioavailability; exposure scenarios for different population groups including workers, local communities, and vulnerable subpopulations [5], [38].

Biological mechanisms of impact:

Purpose: Explain how ionizing radiation and specific radionuclides interact with biological systems.

Content: Physicochemical properties that determine biological behavior; cellular and molecular damage mechanisms such as DNA lesions and oxidative stress; distinctions between external and internal exposure; dose–response relationships and latency periods; organ- and age-specific vulnerabilities [13], [31], [40].

Monitoring methodology for air water and soil:

Purpose: Present practical, scientifically grounded methods for detecting and quantifying radionuclides.

Content: Selection of indicator samples and matrices; sampling strategies including locations, depths, and sample volumes/masses; analytical techniques such as gamma spectrometry, alpha/beta counting, and mass spectrometry; detection limits; quality control and calibration procedures; monitoring frequency and alarm criteria [7].

Epidemiological approaches to detecting health effects:

Purpose: Describe study designs and analytical methods used to link exposure to health outcomes.

Content: Study types including ecological, cohort, and case-control designs; individual exposure assessment and use of biomarkers; adjustment for confounders; statistical methods for assessing associations and causality; interpretation of findings and study limitations [49].

Operational sampling and reporting protocol for Veliko Tarnovo district:

Purpose: Provide a concrete, actionable procedure for local surveys and rapid response.

Content: Sampling plan with mapped sampling points and priority zones such as former mines, industrial sites, and water sources; sample types including soil layers 0–10 cm and 10–30 cm, surface and groundwater, air filters, and foodstuffs; sampling frequency covering baseline surveys, seasonal repeats, and post-incident sampling; required analytical methods and laboratory standards; quality assurance measures including replicates, blind samples, and reference materials; alarm thresholds and response steps such as resampling and expanded investigations; report format with standardized tables, geospatial maps, and layperson summaries; communication procedures for notifying local authorities, health services, and the public.

Risk assessment following radionuclide detection:

Purpose: Provide a framework for quantitative and qualitative risk evaluation to support decision making.

Content: Dose assessment models for internal and external exposure; conversion of measured concentrations into expected doses for defined scenarios; use of health risk thresholds; sensitivity and uncertainty analysis; prioritization of interventions based on risk-benefit considerations [19], [27].

Remediation and exposure reduction measures:

Purpose: Describe technical and managerial options to limit impact and reduce exposure.

Content: Short-term measures such as access restrictions, dust control, and water filtration; long-term remediation technologies including excavation and secure disposal, stabilization, and bioremediation; evaluation of effectiveness and costs; post-remediation monitoring requirements; recommendations for priority actions in the local context [20], [45].

Legislative and communication measures:

Purpose: Propose policies and strategies for prevention, control, and public information.

Content: Suggested regulatory updates and standards; institutional coordination mechanisms; crisis communication plans; community education campaigns; transparency measures and stakeholder engagement processes [23].

Methodological appendix and extended tables:

Purpose: Provide technical details and supporting data that underpin the main text.

Content: Detailed sampling and analytical protocols; report templates; tables of reference values and detection limits; worked examples for dose calculations; inventory of equipment and suppliers; supplementary maps and charts.

Uranium, thorium and other radioactive families are part of the earth's crust [4], [13], [17]. Their distribution depends on the geological history and lithology of specific regions [5], [20], [47]. In areas with granitic and metamorphic rocks, a high radon potential is often observed . The largest reserves of uranium ores are in Kazakhstan, Canada, Australia, Nigeria and other countries, with the first 3 countries owning more than 60% of the world's deposits. Bulgaria also has uranium deposits, mainly located in the Rila-Rhodope mountain system, the Central part of the Thracian Lowland and the Stara Planina. Uranium was mined in Bulgaria from 1939 to 1991, when by decision of the Council of Ministers of the Republic of Bulgaria, uranium mining was stopped and all uranium deposits were preserved. In Bulgaria, there were 2 uranium processing plants located in the town of Buhovo 1 near Sofia, and in the village of Eleshnitsa (near Razlog). Currently, these plants are closed. Bulgaria is perhaps the only country that has uranium deposits but does not exploit them. Currently, the largest uranium extraction is carried out in Kazakhstan.

Anthropogenic sources are mainly related to mining activities (uranium mining), mineral processing, industrial processes, use of materials with naturally elevated radionuclide content (NORM/TENORM), as well as historical deposits from nuclear tests and accidents [7], [19], [34]. They are the causes of local increases in radionuclides in soils, sediments and waters. In Bulgaria, uranium mining mines and enterprises have been closed since 1991, but the situation around them is monitored because there are underground rivers whose waters pass through uranium deposits and mines, winds raise dust from the tailings ponds of the closed enterprises in Buhovo and Eleshnitsa and increase the content of radionuclides in the air. On several occasions in Haskovo and other settlements, an increased content of uranium in drinking water was detected, which is determined by the origin of groundwater and leads to restrictions on the use of water sources for drinking purposes. It should not be overlooked that all mineral waters contain a certain amount of radioactive isotopes [8], [14], [32].

As a general statement for Bulgaria, it can be stated that uranium mining was active from 1939 to 1991, with the main areas being along the Rhodope Mountains from Asenovgrad in front of Smolyan to Razlog at the foot of Pirin, the Central part of the Thracian Lowland in the Plovdiv region, the Stara Planina in the Chiprovtsi region, the Iskar Gorge and the Sliven region as a potential but not operating at this stage. The tailings ponds of the uranium processing plants in the Buhovo and Eleshnitsa regions with the available mining waste and some industrial sites in these regions have been documented as potential sources of local pollution. The presence of geological zones with increased radon potential (e.g. areas with granites and metamorphic rocks) such as the Rhodope Mountains, Pirin, the Sofia Plain, the Central Thracian Lowland and others makes a local assessment necessary in these regions.

III. Results and discussion

3.1 Main sources

- Radon ($_{222}Rn$) is a gaseous product of the decay of uranium. The main source is the soil and rocks under buildings, but it is also often released from materials used for construction such as bricks, sand, gravel [15], [24]. In Bulgaria, a national program for the prevention of radon emissions in public buildings, such as kindergartens, schools, etc. is in operation. There are publications on research conducted. One of the sources is materials used in the production of which were materials from Serbia or produced on the territory of part of the territory of the former Yugoslavia, which were contaminated with radioactive isotopes as a result of the bombing of Serbia in 1999 with bombs containing uranium.
- Uranium ($_{238}U$, $_{234}U$), which is naturally present in soils and rocks in areas with uranium deposits. In Bulgaria, this is mainly the Rila-Rhodope region and the Central part of the Thracian Lowland. It can be dissolved in groundwater and enter water bodies on the earth's surface.
- Radium ($_{226}Ra$) is a product of the various uranium families. It is characterized by accumulating mainly in sediments and soils.
- Anthropogenic isotopes such as $_{137}Cs$, $_{90}Sr$, $_{131}I$. Their origin is mainly from nuclear tests and accidents. They are characteristic of sediments and biota and have different half-lives [9], [30].
- NORM/TENORM are industrial wastes with a naturally elevated content of radionuclides, such as in the mining and processing industry. This applies not only to the uranium mining industry, but also to the extraction of other raw materials, because ore deposits usually contain a wide variety of chemical elements in different forms, but not all of them are extracted during extraction. This also includes waste from secondary raw materials, which sometimes contain elements with a content of certain low-activity radioisotopes.

Table 1 Main radionuclides, exposure routes and key effects

Radionuclide	**Exposure routes**	**Key effects**
Rn -222	Inhalation	Lung cancer
^{238}U	Ingestion	Internal irradiation; nephrotoxicity
^{226}Ra	Ingestion; inhalation	Accumulation in bones; bone tumors
^{137}Cs	Ingestion	Internal exposure; accumulation in biota

3.2 Exposure routes

- Inhalation or airborne uptake is the primary route of entry for radon and particulate matter carrying decay products. Gas masks should be used to limit access to the respiratory tract for protection.

- Ingestion of contaminated drinking water (soluble uranium, radium), consumption of fish, fish products and other biota from contaminated water bodies. This also includes consumption of plant products that have been contaminated as a result of a radiation accident. In the event of a radiation accident, food of animal origin from an area contaminated with radioisotopes should not be consumed.
- Direct contact with contaminated soils and sediments during occupational exposures when working with waste, soil treatment, sampling, etc.

3.3 Biological mechanisms

Ionizing radiation, when entering the human or animal body, causes direct (DNA breaks) and indirect (free radical formation) damage. In addition to the short-term or momentary effects that are observed immediately after exposure to radionuclides, long-term effects are also observed, which include an increased risk of malignant diseases (especially lung cancer in the case of radon), bone and kidney effects in the case of accumulation of radium and uranium, as well as potential genetic and reproductive effects at high doses. These effects are very often transmitted genetically to subsequent generations and cause changes at different levels. The chemical toxicity of uranium (non-radiological effect) is important at high concentrations in drinking water and manifests itself primarily as nephrotoxicity. Therefore, one should not overdo the consumption of mineral waters with a high content of radon or other radioactive isotopes and periodic monitoring of mineral water springs and drinking sources should be carried out [26].

The influence of radionuclides should not be overexposed when processing foods with certain radioisotopes in order to increase their durability, storage, and quality.

3.4. Interpretation of results and risk assessment

3.4.1 Mapping and spatial analysis

To begin with, it is necessary to have GIS approaches. It is necessary to do karnography and thus visualize the measured radon values and concentrations of uranium, radium or other isotopes. It is important to use interpolation methods such as kriging for mapping. At the same time, when processing the obtained results, a mathematical analysis of clusters and correlation with geological and hydrological factors should be done. In this way, all factors for the spread of pollution will be taken into account as accurately as possible.

3.4.2 Estimation of annual effective doses

When estimating annual effective doses, an appropriate model for conducting the study should be selected. When collecting data and processing and analyzing them, annual effective doses for inhalation of radon or radon compounds, ingestion through drinking water and contact with soil and other surfaces should be calculated. When performing the assessment, conservative assumptions for exposure time and bioavailability factors should be used. The results obtained should be compared with current national standards and compared with international recommended thresholds and measured values in nearby areas from neighboring countries.

3.4.3 Criteria for priority interventions in measurements in different environments.

When measuring in homes, public buildings, schools and kindergartens and detecting radon above the specified action threshold, the priority of the actions is remediation . It is necessary to limit access to the buildings and carry out the appropriate activities to reduce the content of radon compounds [30].

When uranium, radium or other radioisotopes are detected in drinking water above permissible levels, it is recommended to apply purification technologies or alternative water supply [31]. In Bulgaria, such cases occurred several times in one of the water sources in Haskovo and adjacent villages, where the use of water from the water supply network was prohibited until the uranium content was normalized. In the Veliko Tarnovo region, there were no such deviations in terms of radioisotopes, but in the summer of 2025 there was a high content of soil particles and the use of drinking water from the water supply network was suspended for 4 months.

When examining soils and sediments from the bottom of water bodies, specific activities that pose a risk of contact or resuspension of sediments are examined. If necessary, multiple samples are taken to determine the area of contamination and the extent of the presence of radioisotopes or other contaminants. The study should continue until the values of the radioisotopes or other contaminants present are within the permissible limits [32].

3.5. Risk management and technical measures

3.5.1 Measures to reduce the content of radon or radon compounds in residential or public buildings, schools and kindergartens.

1) Improving ventilation and air movement inside buildings. This can be achieved by using mechanical or passive ventilation, depending on the building design, or a combination of both .

2) Sealing joints and foundations to reduce soil gas infiltration. If possible, limit openings to the soil as much as possible so that radon from the earth's crust cannot enter the foundation of the building. There should be a concrete belt around the building to prevent gas from the interior of the earth's crust from coming to the surface in the immediate vicinity of the walls and penetrating the buildings through joints, cracks or other openings in the walls.

3) Installation of a radon barrier in new construction. All construction materials must be checked for the presence of radioactive isotopes or their compounds upon arrival at the construction site and if hazardous components are found, they must be returned to the supplier and not used in construction. At each stage of construction, control must be carried out of the completed and upcoming materials for use in the construction of the building.

4) To build active drainage systems (sub slab depressurization (SSD)) at high values and continuous follow-up monitoring is performed. This system uses an electric fan to create a pressure gradient in the foundation portion of the building to mitigate the potential for vapor intrusion from the subsoil into the building. The types of fans that can be used for SSD can vary depending on the permeability of the foundation material, as well as the type of building, the quality of construction, and the size of the building.

3.5.2 Purification of water in which radon, uranium, radium or other isotopes have been detected can be carried out in several ways.

1) Reverse osmosis is effective for removing soluble uranium and radium.

2) Ion exchange resins are used in the selective removal of uranium and radium.

3) Centralized solutions for small communities are implemented in packaged systems, water delivery by water carriers, or bottled water delivery.

3.5.3 Remediation of soils and sediments

1) excavation and safe disposal or capping of contaminated areas are most commonly used . In these methods, the top 5-10 cm of topsoil is removed, deposited in a repository at a certain depth, and a new topsoil layer is placed.

2) The second most important procedure is chemical stabilization, which uses additives to reduce the mobility of radionuclides in the contaminated area of the soil surface.

3) Phytoremediation requires a longer period of implementation. It involves the use of plants to extract hazardous radionuclides or stabilize the surface soil layer under appropriate conditions.

4) The priority in carrying out topsoil remediation activities is to resolve the contamination problem as quickly and efficiently as possible. The focus is usually placed on areas with the highest risk and the greatest potential for human exposure.

TABLE 2: POINTS WITH DOCUMENTED ELEVATED/SIGNIFICANT RADIONUCLIDE VALUES IN BULGARIA

No.	Location	Matrix	Radionuclide(s)	Reported value (units)	Comment / data status
1	**National (representative survey)**	Indoor air (residential)	**Rn -222**	**Arithmetic mean 111 Bq /m³; GM 81 Bq /m³** (2778 dwellings, 2015–16)	National survey; shows spatial variability between areas.
2	**Buhovo (historic uranium sites)**	Soil	**238U, 235U, 234U**	**238U = 2489 Bq / kg ; 235U = 117 Bq / kg ; 234U = 2107 Bq / kg** (measured contaminated samples)	Locally highly contaminated tailings pond samples; example of a hot spot.
3	**Rilo -Rhodopes (selected mineral springs, Southwestern/ Southern Bulgaria)**	Mineral/drinking water	**226Ra, 210Pb, U (soluble)**	Examples: **226Ra 13–168 mBq /L; U up to ~21 µg /L** (variable values in different sources)	Data from regional surveys; values vary by source.
4	**Kozloduy (nuclear power plant area, monitoring)**	Waters, sediments, soils	**137Cs, 90Sr, natural U/ Th**	Long-term monitoring; values within control levels, with local variations (annual reports)	Regular annual reports and monitoring; data are public in the operator/supervisory reports.
5	**Yovkovtsi Lake (V. Tarnovo, local studies)**	Water, sediment, biota	Natural radionuclides (U/ Ra series)	Local spectra and measurements; numerical series are fragmentary in reports	Conference /local reports available ; no centralized public database.
6	**Black Sea coast (Varna, Burgas, etc.)**	Marine sediments, biota	**137Cs, 40K, 226Ra, 232Th, 210Pb**	Spatial variability; 137Cs in sediments traces historical deposits (values from surveys)	Scientific and monitoring studies; values depend on sediment type and local input.
7	**Industrial sites (example: Kronoshpan, Veliko Tarnovo)**	Soil, dust, air	(mostly non-background emissions; radionuclides not systematic	Public inspections and temporary shutdowns; no systematic	Targeted radiation sampling around the site is recommended.

No.	Location	Matrix	Radionuclide(s)	Reported value (units)	Comment / data status
			ally reported)	radiation series	

IV. CONCLUSIONS

Radionuclides constitute a complex environmental and public health challenge that demands a coordinated, multidisciplinary response. Effective management requires the integration of robust scientific monitoring, targeted technical interventions, continuous health surveillance, clear legislative frameworks, and proactive public communication. Each component reinforces the others: monitoring identifies problems and guides remediation; health surveillance detects and quantifies impacts; legislation establishes standards and responsibilities; and transparent communication builds public trust and enables timely protective actions.

Sustained, periodic studies are essential. Radionuclide distributions and exposure pathways change over time due to natural processes, land use, and human activities. Regular re-surveying, data analysis, and public reporting ensure that risk assessments remain current and that hotspots are detected early. For Bulgaria and for regions such as Veliko Tarnovo, priority actions include systematic mapping of radon, uranium, and other radioisotopes in housing, soils, and water sources, together with the establishment of a long-term risk management framework that links monitoring results to concrete mitigation measures.

Capacity building and institutional coordination are critical. Successful implementation depends on trained personnel, accredited laboratories, interoperable data systems, and clear lines of responsibility among national and local authorities, health services, and environmental agencies. Financial support and sustained political commitment are required to maintain monitoring networks, fund remediation, and deliver community outreach and education.

Community engagement and transparency must be central. Clear, timely communication of findings, health implications, and recommended actions empowers residents and stakeholders to participate in risk reduction. Public registers, accessible maps, and plain-language reports increase accountability and facilitate local decision making.

In sum, a proactive, evidence-based programme that combines monitoring, remediation, regulation, health surveillance, and public engagement will reduce exposure, protect public health, and create a resilient framework for managing radionuclide risks at national and regional levels.

Operational Next Steps

1 Launch pilot monitoring and consolidate local data

Scope: Implement pilot radon surveys in representative housing types and targeted water testing at key supply points.

Deliverables: Baseline dataset, standardized sampling protocols, and a centralized database of historical and new measurements.

Timeline: 6–12 months for initial pilot and data consolidation.

Lead: Ministry of Environment in partnership with regional health authorities and accredited laboratories.

2 Create an intermediate working group

Composition: Experts in radiation protection, hydrology, epidemiology, environmental chemistry, and representatives from local government and civil society.

Mandate: Oversee pilot activities, review data quality, advise on sampling expansion, and coordinate stakeholder communication.

Deliverables: Terms of reference, meeting schedule, and interim technical guidance.

Timeline: Establish within 1–2 months of pilot launch.

3 Prepare a national radon map and public register

Scope: Aggregate pilot and historical data to produce a geospatial radon risk map and an open public register of measured values and monitoring sites.

Deliverables: Interactive map, downloadable datasets, and a public portal with explanatory materials.

Timeline: 12–18 months for initial map; ongoing updates thereafter.

Lead: National radiation protection authority with GIS support from academic partners.

4 Develop subsidized remediation and training programmes

Scope: Design financial incentives and technical assistance for radon mitigation in homes, remediation of contaminated sites, and water treatment where needed.

Deliverables: Subsidy schemes, contractor accreditation standards, training curricula for technicians and public health staff, and pilot remediation projects.

Timeline: Policy design and pilot roll-out within 12–24 months.

Lead: Ministries of Health and Environment with local government implementation.

Expected Outcomes and Implementation Considerations

Outcomes: Establishment of a reliable monitoring network; comprehensive regional and national maps of radon and other radioisotopes; evidence-based remediation actions in priority areas; improved public awareness and reduced exposure for vulnerable populations.

Implementation considerations: Secure multi-year funding; ensure laboratory accreditation and quality assurance; adopt interoperable data standards; build local technical capacity; and design communication strategies that are culturally appropriate and accessible.

Funding and governance: The plan requires committed funding streams and a clear governance model that assigns responsibilities for monitoring, data management, remediation, and public communication. Pilot results should be used to refine cost estimates and to mobilize national and international support.

REFERENCES

[1] International Commission him/her Radiological Protection . (2010). ICRP Publication 115: Lung cancer risk from radon and progeny and statement him/her radon . ICRP [Accessed: Feb. 13, 2026].

[2] United Nations Scientific Committee him/her the Effects of Atomic Radiation . (2008). Sources and effects of ionizing radiation (UNSCEAR 2008 Report). United Nations [Accessed: Feb. 13, 2026].

[3] World Health Organization . (2009). WHO handbook him/her indoor radon : A public health perspective . World Health Organization [Accessed: Feb. 13, 2026]..

[4] European Commission . (2013). Council Directive 2013/59/ Euratom laying down basic safety standards for protection against the danger arising from exposure this ionizing radiation . Official Journal of the European Union [Accessed: Feb. 13, 2026]..

[5] Vassilev G., (2005), Radio ecology , Tita consulting , Sofia ;

[6] Vasilev, V., Stefanova, D., Popescu, C. (2023). Human capital management and digitalization - From good practices and traditions to sustainable development; Book Chapter: Digitalization, Sustainable Development, and Industry 5.0: An Organizational Model for Twin Transitions, pp. 41–65; https://doi.org/10.1108/978-1-83753-190-520231004

[7] Dimitrov B., (2019), Problems in the special preparation for nuclear, chemical and biological protection, Collection of reports from a scientific conference, IV International Scientific Conference High Technologies. Business. Society 11-14.03.2019, Borovets, Bulgaria, Volume Iii "Society", pp. 263-265, ISSN 2535-0005

[8] Loktionov , OA, Fedotova , EV, Kondrateva , OE, Dolchinkov , NT, Kuznetsov , NS (2023), Actual and design wind loads for overhead transmission lines in the Central European part of Russia, IOP Conference Series: Earth and Environmental Science This link is disabled., 2023, 1281(1), 012050

[9] Dolchinkov N., (2023), Optimizing energy efficiency in the conditions of a global energy crisis, Optimizing Energy Efficiency During a Global Energy Crisis, 2023, ISBN: 9798369304006 EISBN: 9798369304013, https://doi.org/10.4018/979-8-3693-0400-6 pp . 1–9

[10] Todorov , DN, (2019), State of the population disclosure systems in the changing radiation situation in Bulgaria , Vide. Technology. Resources - Environment , Technology, Resources , 1, pp . 54–58

[11] Adamovics A., Poisa L. (2017) Evaluation of chemical content in different energy crops. In: The 8th International scientific conference "Rural development 2017: Bioeconomy Challenges": abstracts book, Kaunas, Lithuania, 23-24th November, 2017 Aleksandras Stulginskis University, Ministry of Agriculture of the Republic of Lithuania - Kaunas, pp. 199.-202.

[12] V. Vasilev, D. Stefanova, and M. Icheva (2024). Green human resource management as a component of sustainable organizational development in environmental and natural economics, ETR, vol. 1, pp. 402–407, Jun. 2024, https://doi.org/10.17770/etr2024vol1.7966

[13] L. Poiša, L. Antypova , (2023), Evaluation of the Effects of Herbicides him/her the Weeds and the Productivity of Hybrids Maize . Environment. Technology. Resources. Rezekne, Latvia. Proceedings of the 14 th International Scientific and Practical Conference, vol. 1, pp. 195–199, Jun. 2023, https://doi.org/10.17770/etr2023vol1.7204.

[14] N.T. Dolchinkov, N. I. Padarev, Radioactive Waste Storage as an Element of National Security, , Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume V, 81-87, DOI: https://doi.org/10.17770/etr2025vol5.8502

[15] N. I. Padarev, N.T. Dolchinkov, Analysis of a Radiological Incident in Nuclear Power Plant and Simulation of the Radioactive Material Dispersion, Environment. Technology. Resources. Rezekne, Latvia Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume V, 213-217, Environment. Technology. Resources. Rezekne, Latvia Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume V, 213-217, DOI: https://doi.org/10.17770/etr2025vol5.8468

[16] Vambol , S., M. Alqahtani , F., Todorov Dolchinkov , N., Ilyas , M., Yeremenko , S., Sydorenko , V. ... Dzhulai , O., (2025), Investigation of the Transfer Radioactive Contamination from the Chernobyl Zone and its Impact on Radiation in the Environment., Ecological Engineering & Environmental Technology, 25(12), 2024, ISSN 2719-7050, pp . 70-84. https://doi.org/10.12912/27197050/193261

[17] Dolchinkov N., (2025), Management of Plastic Waste Processing and Recycling in Water Pollution Reduction , Economics Ecology Socium , Volume 9, Issue 3, 2025, e-ISSN 2786-8958, ISSN-L 2616-7107, https://doi.org/10.61954/2616-7107/2025.9.3-5, pp. 62-78

[18] Azarov SI (2011), Doslidzhennia approach 137 Cs in the atmosphere pry forest fire in Chornobyl zoni / SIAzarov , VLSydorenko , OVRudenko , AVPruskyi // Pozhezhna bezpeka : teoriia i praktyka . – 2011, – No. 9. – P. 5–10.

[19] Suleymanov, A. (2018). Theoretical and tactics bases of providing of safety at emergencies . Lap Lambert Academic Publ .

[20] Aripkhodzhaeva , MB, Suleimanov , AA (2019). Adaptability of units in complex emergency conditions using UAVs : The article describes the improvement of the adaptability of units in complex emergency conditions using drones (1st edition). Lap Lambert Academic Publishing . https://nbn-resolving.org/urn:nbn:de:101:1-2019111804353795315711

[21] SP Abduraxmonova NG , Xolmatova S. SH. , Nasirova SH. M. , Narziyev EN Yusupxodjayeva (2020), Problems of ensuring the safety of sports activities and reducing injuries , Journal of Critical Reviews , Vol 11, ISSN-2394-5125 Vol 7, pp . 428-432

[22] Dolchinkov N., Mirsharipova ZM, Aripkhodzhaeva MB (2025), Decision support system for rescuers ' safety based him/her biomonitoring and geographical information system (GIS) ," Emergencies And Fire Safety. Problems And Innovations " Scientific And Technical Electronic Journal , ISSN: 3060-5016, 2025 vol 3, pp 12-18

[23] Agzamova IA, Adilov AA , (2011) Urban Zoning Based him/her Aggressiveness and Corrosion Properties . Republican Scientific and Technical Conference . Collection of Abstracts . - Tashkent , 2011, pp . 189-191.

[24] Khasanova OT (2020), Problems of Protecting Aboveground Structures from Aggressive Environments . Problems and Prospects of Innovative Engineering and Technologies in Environmental Protection . International Scientific and Practical Online Conference . September 17-19, 2020. pp . 462-464.

[25] Khasanova OT, Nizamova DO (2020), Problems of the Environmental Situation in Reservoirs : The Aydar-Arnasai Lake System as an Example . Ecology security current problems . Republic scientific-practical conference materials collection . Uzbekistan Republic national guard military-technical institute . September 15 , 2020 . pp . 99-102

[26] Griban VG (2020), Establishment of methods of innovative development in the field of training for law enforcement professionals [Griban VG, Melnikov VL, Chobitko II // Current problems of ensuring the national security of the state : abstracts of the 3rd International Scientific and Practical Conference (leaf) fall 26, 2020). – K.: Institute of Password of Ukraine , 2020. pp . 23-25.

[27] Griban VG (1998), Comparative characteristics of some forms of response construction in programmed learning in human and animal physiology // Proceedings of the Republican scientific-methodological conference him/her issues of scientific organization of the educational process and application of technological methods of teaching . Tbilisi , 28 p.

[28] Anichkin I.Yu. (2016), Case technology in the distance learning system // Innovative technology in teaching / Proceedings of the 1st international scientific-methodological conference . - Tyumen , 2016, pp . 40-42.

[29] Karalliedde, L., Wheeler, H., Maclehose, R., and Murray, V., (2000), Possible immediate and long-term health effects following exposure to chemical warfare agents . Public Health 4(114): 238-248.

[30] Waysbort, D., Manisterski, E., Leader, H., Manisterski, B., and Ashani, Y., (2004), Laboratory Setup for Long-Term Monitoring of the Volatilization of Hazardous Materials : Preliminary Tests of O-Ethyl S-2-(N,N-Diisopropylamino)ethyl Methylphosphonothiolate on Asphalt. Environmental Science and Technology 7(38): 2217-2223.

[31] Columbus, I., Waysbort, D., Marcovitch, I., Yehezkel, L., and Mizrahi, DM, (2012), VX fate on common matrices: Evaporation versus degradation. Environmental Science and Technology 7(46): 3921-3927.

[32] Petrova, D., Vlahova, B., Lengerov, A., Zlateva-Petkova, T., Improvement of Constructive-Technological Approaches Reducing Innovative Obsolescence of Industrial Technologies in the Context of Industry 4.0, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 180–186.

[33] Petrova, D., Vlahova, B., Lengerov, A., Zlateva-Petkova, T., Study of the State of Innovation Development and Obsolescence in the Republic of Bulgaria of Companies from the Mechanical Engineering Sector, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 187–194.

[34] Petrova, D., Innovative Obsolescence in Mechanical Engineering and Singleness of Indicators, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2024, 3, pp. 221–224.

[35] Toneva, D., Dimitrova, D., Some aspects of the water crisis in Bulgaria, 5th International Scientific Practical Conference „Environment. Technology. Resources ", Published by Rezekne Academy of Technologies, Latvia. Volume I, pp. 373-377, ISSN 1691-5402, ISBN 978–171389957–0.

[36] Rachovski, T., Petrova, D., Ivanov, I., Automated Creation of Educational Questions: Analysis of Artificial Intelligence Technologies and Their Role in Education, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2024, 2, pp. 465–467.

[37] Petrova, D., An Approach to Modeling Innovation Obsolescence, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 175–179.

[38] Loktionov, O.A., Fedotova, E.V., Kondrateva, O.E., Dolchinkov, N.T., Kuznetsov, N.S. Actual and design wind loads for overhead transmission lines in the Central European part of Russia, IOP Conference Series: Earth and Environmental Science This link is disabled., 2023, 1281(1), 012050

[39] L. Poiša, L. Antypova, Evaluation of the Effects of Herbicides on the Weeds and the Productivity of Hybrids Maize. Environment. Technology. Resources. Rezekne, Latvia. Proceedings of the 14 th International Scientific and Practical Conference, vol. 1, pp. 195–199, Jun. 2023, https://doi.org/10.17770/etr2023vol1.7204.

[40] Stanchev G., Technical obstacles to speech intelligibility, Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference June 27-28, 2024, Vol. 3, pp 300-305

[41] Simeonov M., M. Marinov, Determine the location of nodes in wireless sensor network by using genetic algorithm, Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference June 27-28, 2024, Vol. 2, https://doi.org/10.17770/etr2024vol2.8059 pp 247-252

[42] N. I. Padarev, Adjusting the Quantity of Surfactants in Decontamination Solutions. Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume V, 219-223, DOI: https://doi.org/10.17770/etr2025vol5.8469

[43] Bulatom. (2022). Nuclear Energy - The Basis for Sustainable Development. https://www.bulatom-bg.org/ [Accessed: Feb. 13, 2026].

[44] Council of Ministers of the Republic of Bulgaria. (2020). Integrated Plan in the Field of Energy and Climate of the Republic of Bulgaria 2021 – 2030. Author. [Accessed: Feb. 13, 2026].

[45] Council of Ministers of the Republic of Bulgaria. (2019).Resolutions and decisions of the Council of Ministers of the Republic of Bulgaria, Sofia. Author. [Accessed: Feb. 13, 2026].

[46] Dolchinkov, N., & Karaivanova-Dolchinkova, B. (2021). Modern plans for development of production of electricity worldwide and energy independence of Bulgaria, Scientific conference "Radiation safety in the modern world", NSU "V. Levski", 392-399.

[47] Haralampiev, M. (2020). The development of atomic energy and nuclear arsenals. Collection of reports from the Scientific Conference "Current Security Issues", 6, 123-133.

[48] IAEA. (2023, May 1). International Atomic Energy Agency. https://www.iaea.org/ [Accessed: Feb. 13, 2026].

[49] Dolchinkov N., N. Nichev, Gamma-background radiation control systems as a factor of Bulgaria's national security, Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 15th International Scientific and Practical Conference. Volume IV, Print ISSN 1691-5402, Online ISSN 2256-070X, https://doi.org/10.17770/etr2024vol4.8225, pp 83-88

[50] Dolchinkov N., Karaivanova-Dolchinkova, B.E., Impact of Types of Electromagnetic Radiation on Living Nature, 14th International Scientific and Practical conference Environment. Technology. Resources. Vide. Technology. Resursi, 2023, ISSN 1691-5402, 1, pp. 55–59