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Transformational Learning Network for Resilience

Enabling Ukrainian higher education to ensure a sustainable and [illegible] reconstruction of (post-war) Ukraine

Course. *Sustainable pathways and risk management in times of crises*

Topic. *ENVIRONMENTAL RISKS FROM TECHNOGENIC ACTIVITY*

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Environmental risks from technogenic activity

Plan :

1. Technogenic activity.
2. Risk:
   - general definition;
   - environmental risk.
3. International experience in risk analysis and assessment.
4. Potentially dangerous objects.
5. Risk assessment :
   - types of assessments;
   - types of environmental risk;
   - ways to minimize environmental risks.
6. Legislative and regulatory framework for environmental risk assessment in Ukraine.
7. Assessment of environmental risks of natural components.

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Any human activity that influences climate change, including alterations in atmospheric composition, greenhouse gas emissions, landscape transformations, and the use of natural resources, is referred to as ***anthropogenic activity*** (Law of Ukraine "On the Fundamental Principles of State Climate Policy" dated October 8, 2024, No. 3991-IX).

In the course of various types of technogenic activity, the biosphere increasingly integrates into the ***technosphere*** – a system comprising artificial objects created through human activity and natural objects modified by this process.

The degree of impact of technogenic activity on the natural environment or its individual components is termed ***technogenic load***, with its primary sources being industrial, transport, agricultural, and forestry-related facilities, among others. Since February 2022, an additional source of technogenic impact on the environment has been military actions on the territory of Ukraine resulting from the armed aggression of the russian federation.

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Risk is the probability or frequency of the occurrence of adverse effects within a given area of human presence.
Risk can be defined either as frequency (with a reciprocal time dimension, 1/s) or as the probability of event *A* occurring (a dimensionless quantity ranging from 0 to 1).
In calculations, risk is conventionally denoted by the letter *R* (from the English word "risk").

Risk is a qualitative assessment of danger. Qualitative assessment is expressed as the ratio of the number of adverse outcomes, *n*, to their potential total number, *N*, over a specified period:

$$R = n / N, \quad (1)$$

R – risk of adverse consequences;
n – number of adverse events;
N – total number of possible events.

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Environmental risk – defined as the probability of negative changes in the natural environment or the delayed adverse effects of these changes resulting from environmental impact.

Environmental risk is understood as the probability of unfavorable environmental consequences caused by any alterations to natural objects. In this context, risk is considered as the probability of emergency events occurring within a specific period, expressed in quantitative parameters. More often, the technogenic aspect of environmental risk is analyzed – the probability of technogenic accidents that can cause significant harm to the environment or human health.

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Environmental risks from technogenic activity

Activities of international organizations in risk analysis and assessment

- ✔ Canadian Centre for Occupational Health and Safety (CCOHS) provides information on environmental safety legislation, hazard types, their effects on human health (considering substance properties), reference materials, and training courses aimed at ensuring safe working conditions in industrial settings.
- ✔ International Chemical Safety Cards (ICSCs) are publicly available and contain information on the health effects of specific pollutants .
- ✔ In the United States, the Centers for Disease Control and Prevention (CDC) oversees occupational safety and health. Its key divisions include the National Center for Environmental Health / Agency for Toxic Substances and Disease Registry (NCEH/ATSDR) and the National Institute for Occupational Safety and Health (NIOSH). Both departments focus on assessing environmental risks associated with pollution and developing strategies to mitigate such risks.

Environmental risks from technogenic activity

Activities of international organizations in risk analysis and assessment

- ✔ The Risk Assessment Information System (RAIS) of the U.S. Department of Energy provides data on the physicochemical properties, carcinogenic potential factors, reference doses, and concentrations of priority chemical substances. The system includes a calculation module for risk-based concentrations, considering multiple exposure pathways for chemicals entering the human body. This information system is equipped with a risk calculation program that integrates data from the U.S. and other countries.
- ✔ The United States Environmental Protection Agency (EPA) is also engaged in assessing risks to public health. It provides methodological frameworks for risk assessment (models and tools for environmental risk assessment), guidelines, and information on the health effects of specific pollutants.
- ✔ One of the functions of the National Institute for Public Health and the Environment (RIVM) in the Netherlands is to provide information on substance toxicity and risk assessment methodologies for human exposure to excessive pollution levels.

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Risk assessment involves analyzing its causes and the scale of its manifestation in a given situation.
The risk of technogenic accidents with severe consequences is commonly associated with chemical and petrochemical plants, nuclear and thermal power stations, mines, and sewage treatment facilities.
The probability of such accidents largely depends on the effectiveness of environmental protection activities. For Ukraine, the risk of accidents is considered to be directly dependent on three groups of factors and can be expressed by the following equation:

$$R = 6{,}77 - 0{,}56X_1 - 0{,}43X_2 - 0{,}27X_3, \qquad (2)$$

X_1 – effectiveness of local authorities' environmental policy;
X_2 – capital investments in resource-saving and environmental protection equipment;
X_3 – effectiveness of the implementation of state environmental programs.

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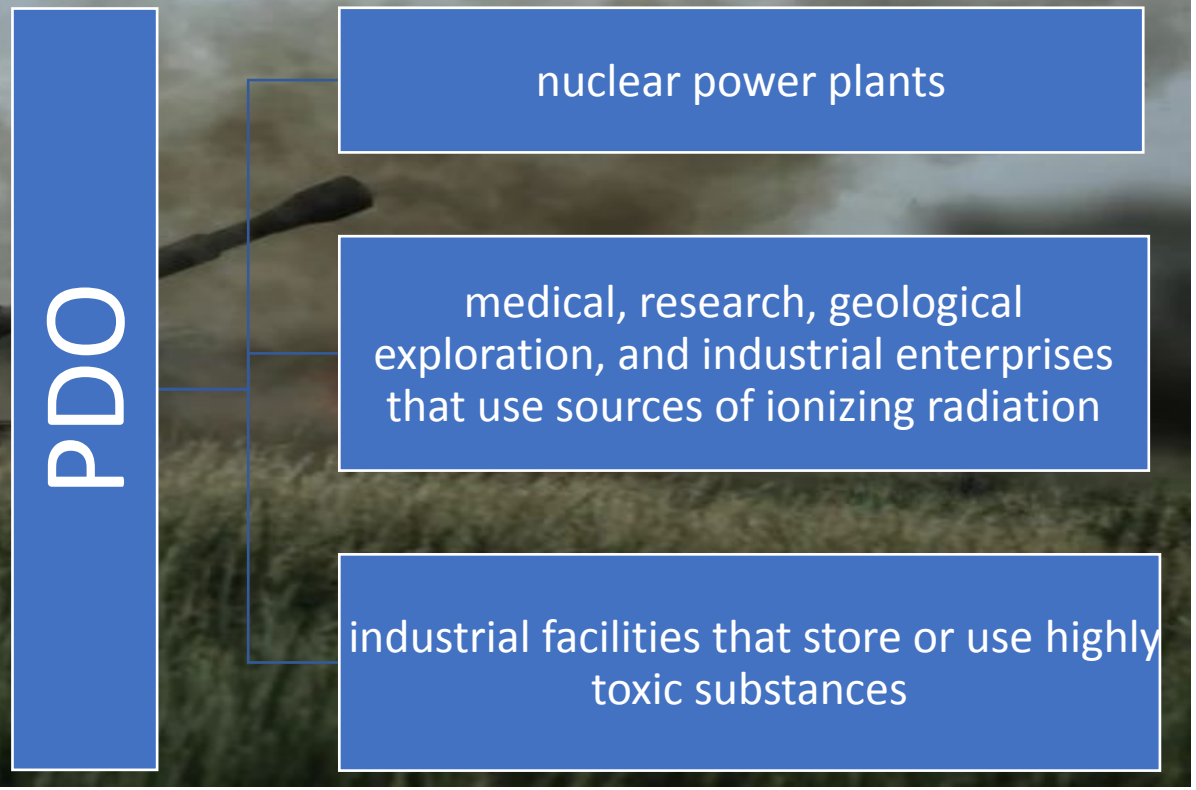
Potentially dangerous objects (PDO) – is the object where dangerous substances, biological agents, or other materials are used, manufactured, processed, stored, or transported, and which, under certain circumstances, may pose a real threat of an accident.

Today, additional sources of environmental risk must be considered, particularly risks associated with military actions : «a quantitative measure of environmental hazard that reflects the possibility of negative consequences for biosphere components and humans, including their life and health, arising from the organized use of various types of military forces (branches of the Armed Forces of Ukraine and other military formations established under Ukrainian law), as well as the armed forces and other military units of an adversary during operations and combat actions».



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Safety risks – these are characterized by low probability but severe consequences with rapid manifestation. Examples include industrial accidents.

Health risks – these have a high probability of occurrence but often result in less severe consequences, sometimes with a delayed effect.

ASSESSMENT OF ENVIRONMENTAL RISKS FROM TECHNOGENIC ACTIVITIES

Environmental risks – these may have either natural or anthropogenic origins.

Goodwill risks – these relate to public perception of the activities of a specific facility and its connection to sustainable natural resource use, which ultimately impacts environmental conditions.

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ENVIRONMENTAL RISK

risk of ecosystem instability (P) – this refers to the acceleration of degradation processes in flora and fauna due to actual or potential environmental pollution

risk to human health (R) – this represents the probability of adverse health effects in the population

The environmental risk of ecosystem instability:

$$P = f_i(K_i, H_i), \qquad (3)$$

K_i – the current state of ecosystem components;
H_i – current or potential anthropogenic impact.

Characteristics of Environmental Risks Related to Environmental Impact and Human Health

Category	Human	Environment
Nature of Impact	Continuous One-time (in case of accidents)	Continuous One-time (in case of accidents)
Risk Group	Local population Enterprise personnel	Biota, ecosystem
Duration of Impact	Short-term Medium-term Long-term	Short-term Medium-term Long-term
Consequences	By severity: Fatal (risk of death), Non-fatal (risk of injuries, diseases) By detection time: Immediate, delayed	By distribution: Local, regional, global

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Contribution of Pollutants to the Formation of Technogenic Environmental Impact Levels

Pollutant Group	Contribution, %
Heavy metals	28
Persistent organic pollutants	27
Mixed waste (organic and inorganic)	20
Pesticides	15
Radioisotopes (^{137}Cs, ^{90}Sr, etc.)	6
Gases (SO_x, NO_x, CO, CO_2, O_3, etc.)	3
Microorganisms created by genetic engineering methods	1

Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030" (Goal 4):

- ✔ reducing air and water pollution levels;
- ✔ decreasing anthropogenic pressure on the ecosystems of the Black and Azov Seas;
- ✔ improving soil quality and implementing an effective system for enhancing soil fertility;
- ✔ introducing environmental risk management based on real-time modeling using advanced information technologies to protect natural ecosystems, public health, and well-being;
- ✔ ensuring and promoting the use of modern pesticides and agrochemicals with minimal negative impact on flora, fauna, and human health;
- ✔ integrating the environmental component into Ukraine's national critical infrastructure protection system;
- ✔ implementing a sustainable waste and hazardous chemical management system.

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Legislative and regulatory framework for environmental risk assessment in Ukraine

- ✔ Methodology for Determining Risks and Their Acceptable Levels for Declaring the Safety of High-Risk Facilities (Order of the Ministry of Labor and Social Policy of Ukraine dated December 4, 2002, No. 637);
- ✔ Methodological Recommendations "Health Risk Assessment for the Population from Air Pollution" (Order of the Ministry of Health of Ukraine dated January 17, 2022, No. 89);
- ✔ Methodology for Assessing the Risks of Technological Emergencies and Fires (Order of the Ministry of Internal Affairs of Ukraine dated October 13, 2023, No. 836);
- ✔ Methodological Recommendations "Assessment of Carcinogenic and Non-Carcinogenic Risks to Human Health from Chemical Air Pollution" (Order of the Ministry of Health of Ukraine dated October 18, 2023, No. 1811).

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Environmental risk of degradation of water objects

environmental risk — related to the organoleptic properties of water

environmental risk — related to the sanitary-toxicological properties of water

environmental risk — based on hydrobiological data

Total environmental risk of water body degradation:

$$ER = 1 - (1 - ER_1) \times (1 - ER_2) \times \dots (1 - ER_n), \quad (4)$$

ER – total environmental risk of water body degradation;
ER_1, ..., ER_n – environmental risk of each pollutant.

Water Quality Class	Characteristics of Water Resources	*ER* Value
I Excellent	Water bodies in their natural state, usually oligotrophic, with clear water or low humus content. Suitable for all types of use.	< 0,1
II Good	Water bodies close to their natural state or slightly eutrophicated. Suitable for all types of use.	0,1 – 0,19
III Satisfactory	Water bodies under slight impact from wastewater, diffuse pollution sources, or other influences. Quality generally meets the requirements of most water uses.	0,2 – 0,59
IV Unsatisfactory	Water bodies are significantly polluted due to wastewater discharge, surface runoff, or other factors. Suitable only for uses with lower water quality requirements.	0,6 – 0,89
V Poor	Water bodies are severely polluted by wastewater, surface runoff, or other influences.	0,9 – 0,1

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Environmental risk assessment for soil cover

- ✔ assessment of health risks to the population due to soil contamination by heavy metals;
- ✔ environmental risk assessment in the transportation of hazardous waste and cargo;
- ✔ environmental risk assessment of solid waste landfill operations;
- ✔ environmental risk assessment of contamination in agricultural products;
- ✔ environmental risks of pesticide contamination in biogeocenoses.

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Comprehensive health risk assessment should consider the ***total carcinogenic risk*** and the *total hazard index* of pollutant exposure to the human body through all possible pathways from various environmental sources.

Carcinogenic risk:

$$CRu = CRa + CRs + CRr, \quad (5)$$

CRu – the total risk of developing cancer due to the presence of carcinogenic pollutants in the natural environment;
CRa – the risk of developing cancer due to the presence of carcinogenic pollutants in the atmospheric air;
CRs – the risk of developing cancer due to the presence of carcinogenic pollutants in the soil;
CRr – the risk of developing cancer due to the presence of carcinogenic pollutants in surface waters.

Hazard index for population morbidity:

$$HIu = HIa + HIs + HIr, \quad (6)$$

HIu – the total hazard index for population morbidity at the current level of environmental pollution;
HIa – the hazard index for population morbidity at the current level of atmospheric air pollution;
HIs – the hazard index for population morbidity at the current level of soil pollution;
HIr – the hazard index for population morbidity at the current level of surface water pollution.