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ENVIRONMENTAL INDICATORS FOR ASSESSING THE NATURAL AND TECHNOLOGICAL HAZARDS

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INTRODUCTION

Since the world population is expected to grow substantially during the next decades, raising environmental efficiency may be the only option for preventing depletion of natural resources and controlling the level of pollution. In this sense, the state of the environment reporting is now a legislative requirement at the national and EU level. The environmental issues of concern are presented below:

• **Climate change** — Global warming • Global dimming • Fossil fuels • Sea level rise • Greenhouse gas • Ocean acidification • Shutdown of thermohaline circulation • Environmental impact of the coal industry • Urban Heat Islands

• **Conservation** — Species extinction • Pollinator decline • Coral bleaching • Holocene extinction • Invasive species • Poaching • Endangered species

• **Energy** — Energy conservation • Renewable energy • Efficient energy use • Renewable energy commercialization • Environmental impact of the coal industry • Environmental impact of hydraulic fracturing

• **Environmental degradation** — Eutrophication • Habitat destruction • Invasive species • Soda lake

• **Environmental health** — Air quality • Asthma • Environmental impact of the coal industry • Electromagnetic fields • Electromagnetic radiation and health • Indoor air quality • Lead poisoning • Sick Building Syndrome • Environmental impact of hydraulic fracturing

• **Genetic engineering** — Genetic pollution • Genetically modified food controversies

• **Intensive farming** — Overgrazing • Irrigation • Monoculture • Environmental effects of meat production • Slash and burn • Pesticide drift • Plasticulture

• **Land degradation** — Land pollution • Desertification

• **Soil** — Soil conservation • Soil erosion • Soil contamination • Soil salination • Alkali soils

• **Land use** — Urban sprawl • Habitat fragmentation • Habitat destruction

• **Nanotechnology** — Nanotoxicology • Nanopollution

• **Nuclear issues** — Nuclear fallout • Nuclear meltdown • Nuclear power • Nuclear weapons • Nuclear and radiation accidents • Nuclear safety • High-level radioactive waste management

• **Overpopulation** — Burial • Water crisis • Overpopulation in companion animals • Tragedy of the commons • Gender Imbalance in Developing Countries • Sub-replacement fertility levels in developed countries

• **Ozone depletion** — CFC • Biological effects of UV exposure

• **Pollution** — Environmental impact of the coal industry • Nonpoint source pollution • Point source pollution • Light pollution • Noise pollution • Visual pollution

o **Water pollution** — Environmental impact of the coal industry • Acid rain • Eutrophication • Marine pollution • Ocean dumping • Oil spills • Thermal pollution • Urban runoff • Water crisis • Marine debris • Microplastics• Ocean acidification • Ship pollution • Wastewater • Fish kill • Algal bloom • Mercury in fish • Environmental impact of hydraulic fracturing

o **Air pollution** — Environmental impact of the coal industry • Smog • Tropospheric ozone • Indoor air quality • Volatile organic compound • Atmospheric particulate matter • Environmental impact of hydraulic fracturing

• **Reservoirs** — Environmental impacts of reservoirs

• **Resource depletion** — Exploitation of natural resources • Overdrafting

o **Consumerism** — Consumer capitalism • Planned obsolescence • Over-consumption

o **Fishing** — Blast fishing • Bottom trawling • Cyanide fishing • Ghost nets • Illegal, unreported and unregulated fishing • Overfishing • Shark finning • Whaling

o **Logging** — Clearcutting • Deforestation • Illegal logging

o **Mining** — Acid mine drainage • Environmental impact of hydraulic fracturing • Mountaintop removal mining • Slurry impoundments

• **Toxins** — Chlorofluorocarbons • DDT • Endocrine disruptors • Dioxin • Toxic heavy metals • Environmental impact of the coal industry • Herbicides • Pesticides • Toxic waste • PCB • Bioaccumulation • Biomagnification • Environmental impact of hydraulic fracturing

• **Waste** — Electronic waste • Litter • Waste disposal incidents • Marine debris • Medical waste • Landfill • Leachate • Environmental impact of the coal industry • Incineration • Great Pacific Garbage Patch • Exporting of hazardous waste • Environmental impact of hydraulic fracturing [1, 2].

ENVIRONMENTAL INDICATORS

State of the environment reporting is a system for delivering useful information and assessments about the environment to all parts of the society including the public, government, industry, and NGOs. For this scope, a set of environmental indicators are developed, validated and used to track changes to the quality and condition of the air, water, land, and ecological systems–and their resident biota–on various geographic and temporal scales. The OECD (Organization for Economic Cooperation and Development) uses three basic criteria to describe “ideal” indicators: 1. policy relevance and utility for users, 2. analytical soundness, and 3. measurability.

Indicators can be used at international and national levels in state of the environment reporting, measurement of environmental performance and reporting on progress towards sustainable development. They can further be used at national level in planning, clarifying policy objectives and setting priorities. Environmental indicators may be used as a powerful tool to raise public awareness on environmental issues. Providing information on driving forces, impacts and policy responses, is a common strategy to strengthen public support for policy measures.

In relation to policy-making, environmental indicators are used for three major purposes:

1. to supply information on environmental problems, in order to enable policy-makers to value their seriousness;

2. to support policy development and priority setting, by identifying key factors that cause pressure on the environment;

3. to monitor the effects of policy responses [3].

FUNCTIONS AND DEFINITIONS OF ENVIRONMENTAL INDICATORS

Functions The OECD terminology points to two major functions of indicators**:**

• they reduce the number of measurements and parameters that normally would be required to give an *exact* presentation of a situation.

o *Note: As a consequence, the size of an indicator set and the level of detail contained in the set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.*

• they simplify the communication process by which the results of measurement are provided to the user.

o *Due to this simplification and adaptation to user needs, indicators may not always meet strict scientific demands to demonstrate causal chains. Indicators should therefore be regarded as an expression of "the best knowledge available*".

Definitions

• **Indicator**: a parameter or a value derived from parameters, which points to, provides information about, and describes the state of a phenomenon/environment / area, with a significance extending beyond that directly associated with a parameter value.

• **Index**: a set of aggregated or weighted parameters or indicators.

• **Parameter**: a property that is measured or observed.

CRITERIA FOR SELECTING ENVIRONMENTAL INDICATORS

The methodologies of analysis for the state of environment evaluation of a given area make use of several environmental indicators. As indicators are used for various purposes, it is necessary to define general criteria for selecting indicators and validating their choice. Three basic criteria are used in OECD work: policy relevance and utility for users, analytical soundness, and measurability (*Extract from "Environmental indicators for environmental performance reviews", OECD, 1993).*

Policy relevance and utility for users	An environmental indicator should: • provide a representative picture of environmental conditions, pressures on the environment or society's responses; • be simple, easy to interpret and able to show trends over time; • be responsive to changes in the environment and related human activities; • provide a basis for international comparisons; • be either national in scope or applicable to regional environmental issues of national significance; • have a threshold or reference value against which to compare it, so that users can assess the significance of the values associated with it.
Analytical soundness	An environmental indicator should: • be theoretically well founded in technical and scientific terms; • be based on international standards and international consensus about its validity; • lend itself to being linked to economic models, forecasting and information systems.
Measurability	The data required to support the indicator should be: • readily available or made available at a reasonable cost/benefit ratio; • adequately documented and of known quality; • updated at regular intervals in accordance with reliable procedures.

The PSR (Pressure, State, Response) model has initially been developed by the OECD to structure its work on environmental policies and reporting. It considers that:

• human activities exert pressures on the environment and affect its quality and the quantity of natural resources ("*state*");

• society responds to these changes through environmental, general economic and sectorial policies and through changes in awareness and behavior ("*societal response*").

The PSR model highlights these **cause-effect relationships**, and helps decision makers and the public see environmental, economic, and other issues as interconnected. It therefore provides a means of selecting and organizing indicators (or state of the environment reports) in a way useful for decision makers and the public, and of ensuring that nothing important has been overlooked.

Depending on the purpose to use the PSR model, it can be easily adjusted to account for greater details or for specific features. One example of adjusted versions is the Driving force-Pressure-State-Impact-Response (DPSIR) model used by the European Environmental Agency (EEA).

Driving forces are the social, demographic and economic developments in societies and the corresponding changes in life styles and overall levels of consumption and production patterns. The major driving forces are population growth and changes in needs and activities of individuals. The driving forces provoke changes in overall levels of production and consumption and thereby exert pressure on the environment. Indicators, provide a representative picture of pressures on the environment [4].

Indicators of environmental pressures give information on the pressures exerted on the environment. They are closely related to production and consumption patterns; they often reflect emission or resource use intensities, along with related trends and changes over a given period.

Indicators of environmental conditions (state) are designed to give an overview of the quality of the environment and the quality and quantity of natural resource that can be affected by pressures.

Indicators of impact. The Impact component presents data on the impact of the change of the state of the environment on the foregoing factors.

Indicators of response. Societal responses show the extent to which society responds to environmental concerns. They refer to individual and collective actions and reactions, intended to:

- mitigate, adapt to or prevent human-induced negative effects on the environment;
- halt or reverse environmental damage already inflicted;
- preserve and conserve nature and natural resources.

Indicators can be classified into 4 simple groups which address the following questions:

1. **'What is happening to the environment and to humans?' (Type A or Descriptive Indicators)**: describe the actual situation with regard to the main environmental issues, such as climate change, acidification, toxic contamination and wastes in relation to the geographical levels at which these issues manifest themselves.

2. **'Does it matter?' (Type B or Performance indicators**): performance indicators compare (f) actual conditions with a specific set of reference conditions. They measure the 'distance(s)' between the current environmental situation and the desired situation (target): 'distance to target' assessment. Performance indicators are relevant if specific groups or institutions may be held accountable for changes in environmental pressures or states

3. **'Are we improving?' (Type C or Efficiency indicators**): express the relation between separate elements of the causal chain. Most relevant for policy-making are the indicators that relate environmental pressures to human activities. These indicators provide insight in the efficiency of products and processes.

4. **'Are we on the whole better off?' (Type D or Total Welfare indicators):** express the environment quality related with the wellbeing of the population and the status of public health. These indicators provide insight in the efficiency of radiation costs.

At EU level there is a EEA core set of indicators, a useful tool for prioritizing which environmental information is most useful as part of a shared European environmental information system. The core set supports EU policy priorities, is regularly updated, and is of known quality. The core set of indicators is designed for various users, who have a variety of information needs.

The establishment and development of the EEA core set of 37 indicators has been guided by the need to identify a small number of policy-relevant indicators that are stable, but not static, and that give answers to selected priority policy questions. They should, however, be considered alongside other information if they are to be fully effective in environmental reporting. All the topics address EU policy priorities, as described in the EEA strategy (1).

The core set covers:
• six environmental themes:
1. air pollution and ozone depletion,
2. climate change,
3. waste,
4. water,
5. biodiversity,
6. terrestrial environment
• four sectors
1. agriculture,
2. energy,
3. transport
4. fisheries [5-7].
EEA core set of indicators are present in table 1.

T a b l e 1

EEA core set of indicators

Theme	No.	Indicator title
Air pollution and ozone depletion	1	Emissions of acidifying substances
	2	Emissions of ozone precursors
	3	Emissions of primary particulates and secondary particulate precursors
	4	Exceedance of air quality limit values in urban areas
	5	Exposure of ecosystems to acidification, eutrophication and ozone
	6	Consumption of ozone-depleting substances
Biodiversity	7	Threatened and protected species
	8	Designated areas
	9	Species diversity
Climate change	10	Greenhouse gas emissions and removals
	11	Projections of greenhouse gas emissions and removals and policies and measures
	12	Global and European temperature
	13	Atmospheric greenhouse gas concentrations
Terrestrial	14	Land take
	15	Progress in management of contaminated sites
Waste	16	Municipal waste generation
	17	Generation and recycling of packaging waste

Theme	No.	Indicator title
Water	18	Use of freshwater resources
	19	Oxygen-consuming substances in rivers
	20	Nutrients in freshwater
	21	Nutrients in transitional, coastal and marine waters
	22	Bathing water quality
	23	Chlorophyll in transitional, coastal and marine waters
	24	Urban wastewater treatment
Agriculture	25	Gross nutrient balance
	26	Area under organic farming
Energy	27	Final energy consumption
	28	Total energy intensity
	29	Total energy consumption
	30	Renewable energy consumption
	31	Renewable electricity
Fisheries	32	Status of marine fish stocks
	33	Aquaculture production
	34	Fishing fleet capacity
Transport	35	Passenger transport demand
	36	Freight transport demand
	37	Use of cleaner and alternative fuels

The work of the EEA is built around a conceptual framework known as the DPSIR assessment framework. DPSIR stands for ‘driving forces, pressures, states, impacts and responses’. DPSIR builds on the existing OECD model and offers a basis for analyzing the interrelated factors that impact on the environment. Some other relevant priorities (chemicals, noise, industry, consumption, material flows) have not yet been included [8].

ENVIRONMENTAL INDICATORS FOR ASSESSING THE NATURAL AND TECHNOLOGICAL HAZARDS

BACKGROUND

The environment is complex, and discerning environmental trends can be difficult. Environmental indicators help track changes in the environment by selecting key measures – which may be physical, chemical, biological – that provide useful information about the whole system.

The term *natural disaster* refers to natural phenomena produced by the dynamics operating within the Earth's surface and atmosphere that result in extensive social, economic and environmental damage. They are qualified as "major" when they exceed the capacity of those affected to deal with them with their own resources and, as a result, outside aid becomes necessary.

Technological accidents are characterized by their marked anthropic origin and mainly occur in relation to industrial activity and transport (i.e. accidents deriving from the transport of dangerous goods (by road and rail), maritime accidents involving oil spills and accidents occurring at industrial facilities).

Natural phenomena should be included alongside technological accidents when considering potential social and environmental impacts. Recent years have seen a large number of natural disasters that have produced high numbers of victims.

It is very important to define a set of environmental indicators of the natural and technological hazards because using indicators it is possible to evaluate the fundamental condition of the environment without having to capture the full complexity of the system. Indicators are based on the best scientific understanding currently available so that changes in these simple measures can be related to more complex environmental trends. When time series data for an indicator show a trend, then there is a need to provide some interpretation of the trend and its implications. Therefore an indicator must be backed by a sound theoretical framework so that accurate interpretations can be made.

According to European Environment Agency: "*An indicator is a measure, generally quantitative, that can be used to illustrate and communicate complex phenomena simply, including trends and progress over time. 'An indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. An indicator is a sign or symptom that makes something known with a reasonable degree of certainty. An indicator reveals, gives evidence, and its significance extends beyond what is actually measured to a larger phenomenon of interest'* (IETF, 1996)" (www.eea.eu.int).

A widely used framework for environmental indicators arises from a simple set of questions:

1. What is happening to the state of the environment or natural resources? ⇒ **state indicators**; indicators of changes or trends in the physical or biological state of the natural world.

2. Why is it happening?: **pressure indicators**; indicators of stresses or pressures from human activities that cause environmental change.

3. What are we doing about it? **response indicators** measures of the policy adopted in response to environmental problems.

Environmental indicators simplify state of the environment reporting in two important ways because:

• indicators have a well-understood meaning and can be measured regularly. Trends in the indicators are thus readily interpreted to yield valuable information about important aspects of the environment.

• environmental indicators can be an aid to communication. They allow information about the environment to be communicated effectively.

The environmental indicators of the natural and technological hazards must be selected on the basis that they should:

- reflect a valued element of the environment or an important environmental issue;
- have relevance to policy and management needs;
- be useful for tracking environmental trends at a range of spatial scales from the local to the national;
- be scientifically credible;
- be cost effective;
- serve as a robust indicator of environmental change;
- be readily interpretable;
- be monitored regularly, either by existing programs or by new programs that might be established in the future at reasonable cost;
- reflect national programs and policies.

As users of information about the environment become more familiar with the agreed indicators, they will be able to absorb this information more quickly, because a technological hazard may lead to the contamination of more than one environmental compartment Thus the efficiency of decision-making should be enhanced by the usage if he environmental indicators. Environmental indicators (ante or post-hazard) can also help focus and rationalize environmental monitoring programs by drawing attention to the critical measures required to evaluate environmental trends and conditions.

ENVIRONMENTAL INDICATORS AND THEIR USEFULNESS FOR ASSESSING THE NATURAL AND TECHNOLOGICAL HAZARDS

In recent decades, natural hazards have caused greater damage than before. To protect human lives and properties, it is essential to take action and for this purpose to know the environment trend is very important and, in this sense, the environmental indicators represent the key element to construct a good and correct strategy.

Assessment of the environmental contamination caused by technological hazards may require considerable resources. Therefore, assessment must be tailored according to the resources available. If rare or protected habitats/species are threatened by pollutants released from an accident they must be the main focus for protection, impact assessment and remediation. Where resources are available, as much as possible should be done to protect, assess and remediate the general environment.

The ecological consequences of any given technological hazard will be related to the chemicals involved, mode of dispersion and the physical and biological nature of the receiving habitat(s). Given the heterogeneity of hazard/accident causes and chemicals involved, as well as the diversity of habitats that may be impacted, assessing the environmental impact of accidents will be complicated. A basic frame work for considering the steps that may be taken to assess the environmental impact of accidents is as follows:

- determine the chemical(s) involved and develop and adapt analytical procedures for detection if none are in current usage;
- determine the environmental distribution of the chemicals in relevant environmental media;
- assess biological impact.

After determining what components of the environment received the pollutants it is then necessary to determine the spatial extent of pollutant distribution and the levels of pollutants in the affected environment. With complex chemical mixtures, the major difficulty in assessing the extent of pollution often knows which compounds were released. Chemicals may also have differing dispersion properties, leading to complex distribution patterns for cocktails.

Knowledge of a pollutant's physical-chemical properties may help to predict the ecological impact of that chemical. Most manufactured compounds in common usage have been well characterized. Even if detailed characterization has not been carried out for the individual chemical of interest, environmental behavior can usually be predicted from knowledge of chemical structure and the behavior of related compounds. In table 2 are presented the most relevant indicators of the natural and technological hazards [9-11].

T a b l e 2

Environmental indicators for natural and technological hazards

Hazard	**Hazard's indicator**	**Environmental indicators**	**Observation**
Water scarcity / Drought periods	– average precipitation, – average river discharge, – average soil moisture, – groundwater level – severity, – duration, – return periods and timing of drought events due to temporal decrease of precipitation, – river discharge, – soil moisture, – groundwater and water stored in lakes and dams below some threshold level	– soil moisture – average soil moisture – groundwater level	– A period of drought is taken to mean a dry period that is sufficiently long enough to cause a substantial decrease in river flow, water levels in lakes and/or exhaustion of soil moisture, as well as a decrease in groundwater levels to below normal values
		Environmental indicators post hazards (before the environment remediation)	
Flood	– severity, – duration, – return periods and timing of flooding events due to increase of precipitation, – river discharge above some threshold level and sea level rise	– soil quality indicators – water quality indicators – underground water quality indicators	

Forest fires	– severity, – duration, – characteristics of the fuel (vegetation type, density, humidity content), – characteristics of the topography (slope, altitude, solar aspect angle) – meteorological conditions (rainfall, wind direction and speed, air humidity, surface and air temperature)	– soil quality indicators – air quality indicators	
Storms	– severity, – duration, – meteorological conditions (rainfall, wind direction and speed, air temperature), – groundwater and water stored in lakes and dams below some threshold level	– soil quality indicators – water quality indicators – air quality indicators	
Landslides	– tilting or cracking of concrete floors and foundations, – soil moving away from foundations, – broken water lines and other underground utilities, – leaning telephone poles, trees, retaining walls, or fences, – offset fence lines or retaining walls, – springs, seeps, or saturated ground in areas that have not typically been wet, – new cracks or unusual bulges in the ground or street pavement, – rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content),	– composition and type of material that makes up the ground near the surface – ancillary structures such as decks and patios tilting and (or) moving relative to the main house	

	– sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb, – sudden decrease in creek water levels though rain is still falling or just recently stopped.		
Heat waves	– frequency, – intensity, – duration, – mean daily temperature, – dew point	– greenhouse gas concentrations – soil moisture – average soil moisture – groundwater level	
Snow and cold	– intensity, – duration, – mean daily temperature		
Technological hazard			
		Environmental indicators to be used post hazard in order to remediate the environment	
Road accidents causing possible environmental damage	– weather conditions such as prevailing wind direction, atmospheric inversions and precipitation as all of these factors will determine environmental fate, – chemicals involved in accidents, – surface area	– soil quality indicators – water quality indicators – underground water quality indicators – air quality indicators	– When categorizing road and rail accidents, dangerous goods are considered those substances that, in the case of an accident during transport, may represent a hazard to the population, property and the environment. Possible environmental damage is considered to occur when the existence of a leak or spillage (on land, in water or into the atmosphere) with a potentially pollutant effect is reported.

			– Possible environmental damage caused by such accidents most frequently affects soil, followed by water and the atmosphere. In many cases, a single accident can affect two or even all three environments. For example, it is possible that a spillage or leak first affecting soil may then reach a river course or, if the pollutants evaporate, the atmosphere.
Rail accidents causing possible environmental damage		– soil quality indicators – water quality indicators – underground water quality indicators – air quality indicators	– When categorizing road and rail accidents, dangerous goods are considered those substances that, in the case of an accident during transport, may represent a hazard to the population, property and the environment. Possible environmental damage is considered to occur when the existence of a leak or spillage (on land, in water or into the atmosphere) with a potentially pollutant effect is reported. – Possible environmental damage caused by such accidents most frequently affects soil, followed by water and the atmosphere. In many cases, a single accident can affect two or even all three environments. For example, it is possible that a spillage or leak first affecting soil may then reach a river course or, if the pollutants evaporate, the atmosphere.

Oil spills due to maritime accidents		– water quality analyses	– Maritime accidents involving oil tankers, and those transporting chemical substances, are those that cause greatest damage to the environment. Oil spills cause enormous damage to marine ecosystems, affecting every aspect of the same. Moreover, clean-up processes and operations can also be very harmful to marine habitats, fauna and flora. Nevertheless, they are necessary as natural recovery is extremely slow.
Discharges of dangerous chemical substances due to industrial accidents	– weather conditions such as prevailing wind direction, atmospheric inversions and precipitation as all of these factors will determine environmental fate, – causes of chemical accidents, – chemicals involved in accidents.	– soil quality indicators – water quality indicators – underground water quality indicators – air quality indicators	– The accidents are those covered by the Seveso Directive, i.e. accidents occurring in industry (chemical, pharmaceutical, energy industry, etc.), and include storage, distribution and sale of dangerous substances or products. – Other types of accident not covered by the Seveso Directive include mining accidents [12].

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ЕКОЛОГИЧНИ ИНДИКАТОРИ ЗА ОЦЕНКА НА ПРИРОДНИТЕ И ТЕХНОЛОГИЧНИТЕ РИСКОВЕ

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(Р е з ю м е)

В статията са представени екологичните индикатори за оценка на природните и технологичните рискове, разгледани като количествени показатели, които отразяват състоянието или тенденциите на условията на околната среда. Екологичните индикатори могат да се използват на международно и национално ниво при отчитане състоянието на околната среда, измерване на екологичната ефективност и отчитане напредъка към устойчиво развитие. Материалът е структуриран, както следва: в раздел първи са поставени екологичните въпроси, отнасящи се до предизвикателствата на XXI в.; в раздел втори е представено по-задълбочено описание на екологичните индикатори, техните функции и критериите за подбора им; в раздел трети се дискутира произходът на природните бедствия и технологичните аварии, както и полезността на екологичните индикатори за оценка на природните и технологичните опасности. Оценките за природната среда потвърждават ползата от използването на показателите за ефективност и нуждата от използване на индикатори с цел подобряване управлението на околната среда и вземането на решения.