DE GRUYTER OPEN

ACTA ENVIRONMENTALICA
UNIVERSITATIS COMENIANAE (BRATISLAVA)

ISSN 1339-9802 (online)

ECOLOGICAL RISK ASSESSMENT FRAMEWORK

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Abstract

Purpose of this paper is to draft shot information about framework for ecological risk assessment compile according Guidelines and short description of phases from which this method consists. During description of particular procedures, the meaning of used terms is introduced and explained. The framework for risk assessment is presented as a useful tool for risk management and selection of available cleanup and remedy technologies, and costs of alternative actions.

Key words: risk assessment, ecological effects, risk characterization, framework, outputs

Recommended form of citation: *Fargašová, A., 2016. Ecological Risk Assessment Framework. Acta Environ. Univ. Comenianae (Bratislava). 24(1): 10-16.*
DOI: 10.1515/aeuc-2016-0002

INTRODUCTION

At present, for environmental quality determination are used such tools as environmental and ecological risk assessment (ERA, EcoRA) which framework involves the examination of risks from natural events (flooding, extreme weather events, etc.), technology, practices, processes, products, agents (chemical, biological, radiological, etc.) and industrial activities that may influence ecosystems, animals and people (ANONYMUS 2010, U.S. EPA 1992, 1996). For correct environmental risk assessment, it is important to understand the concept of hazard and risk. Whereas, hazard is any source (substances, machines, energy forms, or the way work is carried out) which can cause harm or adverse effects, risk is the probability that harm will actually be done during the work or by the way something is used. Risk = hazard x exposure (PAUSTENBACH 2002; SUTER & BARNTHOUSE 2006; U.S. EPA 2012).

METHODS

The methods used for ecological risk assessment come out from U.S. EPA Guidance Document (2008) and U.S. EPA Framework Manual (2012) and their structure and aims are analysed in the main part of the article which describes ideas, framework and outputs of ecological risk assessment.

FRAMEWORK AND OUTPUTS OF RISK ASSESSMENT

Environmental risk assessment

In general, the term *environment* represents physical surroundings common for everything living include air, water, land (ANONYMUS 2004). Environmental risk assessment incorporates the risk to all ecosystems, including man, exposed or impacted through these media. It doesn't involve the risks to individuals or the general public initiated by consumer products or work exposure, where other specific legislation applies (SUTER et al. 2005). There are slightly different steps to risk assessment, depending on whether you are performing a human health risk assessment or an ecological risk assessment.

Human health risk assessment is a process that is used to evaluate the toxic properties of the chemicals and to evaluate the conditions under which people are exposed to that chemical. It is used to determine how a population exposed to a substance could be affected in terms of adverse health effects.

An *ecological risk assessment* (EcoRA) is a scientific process used for evaluation of potential negative effects to plants, animals, and the environment from exposure to toxic contaminants. Ecological risk assessment does not involve the negative effects to man or domestic animals (SUTER et al. 2001). During the risk assessment process, actual and predicted potential influences of contaminants on animal and plant populations or communities that occupy or could occupy affected localities (meadows, forests, lakes, wetlands, streams, estuaries) are evaluated. It is necessary to accept ecological risk assessment as a science for identification of the stressors (physical, chemical, biological) that are able through adverse effects affect and modified ecosystems and their structure and vitality (CORMIER et al. 2000). EcoRA is used as a tool for decision making by regulators. All findings and statements incorporate science into risk-based decision making (U.S. EPA 1998; SETAC 2004).

Ecological risk assessment is relatively new science created in the 1980s as an equivalent to human health risk assessments. Its role is to make environmental decisions. The appropriate theory for ecological risk was developed through the 1980s by the staff of the Environmental Sciences Division of Oak Ridge National Laboratory (ANDERSEN et al. 2005). The system of EcoRA come out from that for human health risk assessment but is more complex on the side of ecological systems because it recognizes and identifies different endpoints. Endpoints selection varied in dependence on populations, communities, and ecosystems. Scale and structure of the original environment are critical to assessment of ecological risks. In the framework of the system of ecological risk assessment are likely involved indirect effects and changes in habitats as well as the direct toxic effects (U.S. EPA 2003).

Environmental risk assessment framework

Ecological risk assessment involves following parts: 1) Problem formulation (hazard identification); 2) Analysis phase and 3) Risk characterization (risk estimation).

Problem formulation (hazard identification) – this part represents systematic planning during which are identified cardinal factors to be evaluated in the risk assessment. In this part are collected all available information about the locality and conceptual model, that identifies the stressor characteristics, ecosystems potentially at risk, and ecological effects to be evaluated, form final product. As a *stressor*, can be consider any physical, chemical, or biological entity that can cause an adverse response. *Assessment endpoints* represent particular components of the ecosystem which reflect presence of the stressor with adverse effect on ecosystem. As endpoints, can be chosen individual organisms, population, ecosystems, or habitants with some common characteristic, such as ingestion or exposure. *Measurement endpoints* represent the actual measurements by which is ecological risk evaluated. Through these endpoints are described mechanisms of toxicity and exposure pathways and they represent a measurable biological response to a stressor. In some cases they can relate with characteristics chosen as the assessment endpoint. The endpoints are very often determined by using laboratory models which involve the contaminants, soil/sediments, plants, and organisms, however, they can be also measured directly (U.S. EPA 2000, 2003).

The analysis phase – during this part of ecological risk assessment is evaluated the exposure of ecological receptors to stressors – *exposure assessment* and the relationships between stressors levels and ecological effects – *ecological effects assessment*. *Exposure assessment* quantifies the exposures of ecological receptors (animals, plants and microorganisms) to site contaminants. During this process, quantitative data about contaminant release, its migration and fate are collected; the receptors that may be exposed are determined; and the concentrations to which the receptors are exposed are measured. Contaminant amount entered into the receptor depends on the following factors:

– the contaminant physico-chemical properties,
– the way the contaminant penetrate into the organism (skin absorption, ingestion, inspiration, etc.),
– the nature of the receptors (behavior, life patterns).

Ecological effects assessment determined relations between the contaminant concentration and the intensity of adverse effect on receptors. This is expressed as “dose – response curve” and provide information about *how much* toxicant is associated with *how strong* adverse effect. For this attribute relationship literature reviews, field studies, and toxicity tests are used. Literature reviews provide information about organisms’ variability, their ability to tolerate various toxicants in different concentrations and characteristics about species under study. Field studies offer direct evidence of a link between contamination and ecological effects and toxicity tests are used for direct evaluation the contaminated media effects on the survival, growth and reproduction of test organisms (UNEP/IPCS 1999; SUTER et al. 2001; ASKER 2011; BOTSFORD 2002; BREITHOLTZ et al. 2006).

Risk characterization (risk estimation) – is the final part of risk assessment and is based on results comparison from the exposure assessment with those from the ecological effects assessment. Investigators try to answer the following questions:

– Are ecological receptors really at present exposed to site contaminants at levels capable of causing harm, or is future exposure likely?
– If adverse ecological effects are observed or predicted, what are the types and severity of these effects?
– What are the uncertainties associated with the risk assessment?

The risk assessment process finished with control which could seek following measures to reduce or eliminate the risks identified. The risk characterization provides a risk description through presentation of the risk results in both numerical, graphical and descriptive terms. This step provides information on the confidence the risk assessor has in the results, and identifies a threshold for adverse effects. During all ecological risk assessment parts, investigators use new information and insights to refine their hypotheses which used risk managers for management plans preparation. Risk management can advise to reduce or modify the source, by managing or breaking the pathway and/or modifying the receptor (U.S. EPA 1992, 2000; SUTER et al. 2001).

Environmental characterization

For risk assessment quantification, the function expressed the relationship between toxicity and exposure is used and describes basic relationship between concentration and adverse effect intensity, e.g. “dose – response curve”. Each risk assessment process consists of multiple steps, begins with

Available online at: www.degruyter.com/view/j/aeuc
doi: 10.1515/aeuc-2016-0002

toxicity and exposure estimation, and break up with risk characterization. The most important are data frrom the analysis phase. The science of ecotoxicology wants to catch up the data needs for ERA process that relies on concentration-dependent benchmarks as its primary assessment of risk. Real links between observed effects at a population level and toxicity data (i.e., dose-response, biomarker, bioassay, etc.) are missing for most chemicals and species. As such, most of the current ERAs utilize toxicity data that are questionable in terms of the reality of application to the species or endpoints being assessed. This is a key limitation of the ERA process to contaminated sites (U.S. EPA 2012).

The basis of toxicological and ecotoxicological characterization is in laboratory studies. These studies are internationally administered and reflect adverse effect to animals or plants exposed to a range of concentrations of the stressor being studied. Toxicity can be characterized by mortality or by sublethal effects within the range of doses tested (ASKER 2011).

An important aspect of toxicological evaluation is determination of the relationship between magnitude of exposure and extent and severity of observed effects commonly referred to as dose-response. From this relation, can be obtain not only dose levels at which adverse effects occur, but also no observed effect concentration (NOEC). For risk assessment, the lowest NOEC, LD50, etc. dose is used to estimate risk.

Exposure represents direct contact between receptor and contaminant in the environment, workplace, at home, or in the air, food, water, or soil constitutes. Exposure concentrations may be either estimated or measured, based on the amounts and manner in which the contaminant is used, its physical and chemical properties, and data from laboratory and field experiments. Exposure assessments determine people, wildlife, and plants to stressors present at the environment. The extension of exposure depends on the type of use (crop, lawn, and garden treatment; mosquito control; indoor pest control, etc.), application method, rate and frequency of application or release, along with the contaminant breakdown, partitioning, and movement in the environment (e.g. COVELLO & MERKHOFER 1993; DWYER et al. 1997). Only if exposure approaches or exceeds dose levels are determined as harmful during ecotoxicological studies, an adverse effect is predicted.

Assessment and characterization of the risk to ecological systems, including a large amount of nontarget aquatic and terrestrial organisms as well as surface and ground water, is younger and more complex science than that of human health risk assessment. Ecological risk assessment covers a greater range of complex issues and more species than does human health risk assessment. It follows fish, aquatic invertebrates, aquatic and terrestrial plants, nontarget insects, birds, wild mammals, reptiles, and amphibians.

Each species within an ecosystem fulfils specific ecological role. The primary producers of the energy in any terrestrial or aquatic ecosystem are plants which are able to capture sunlight, convert it to energy used for new plant growth. They are situated at the beginning of the food chain. When organisms consume plant tissues and are, in turn, consumed by another organism, the energy flows through the food chain. For example, one-celled microscopic organisms – green algae are a staple food for invertebrates – water fleas and mysid shrimp, and they become food for young fish and small fish species. The fish are then consumed by predators such as larger fish, amphibians, birds, and aquatic mammals. Because of the dynamics of the flow of energy, perturbations of the most seemingly minor species may lead to observable (measurable) impact on the entire ecosystem. However, because of the ability of organisms and populations to adapt to perturbations, resilient effects on one or more components of an ecosystem may result in minimal ecological change.

Ecological risk assessments outputs

Ecological risk assessment is using to support the regulation of hazardous waste sites, industrial chemicals, and pesticides, and the management of ecosystems affected by chemical, physical, and biological stressors. While chemical stressors involve all chemical substances produced by man, physical stressors include physical factors, such as fires, dust, or barriers, that result from human activity. As physical stressor, might be, for example, introduced sediments released by logging that smother river-bottom invertebrates, or secondarily, warmer water temperatures that kill salmon or trout. As biological stressors introduced in the environment by human activity could be account exotic species or genetically modified organisms, which may either kill, eliminate, or crossbreed with indigenous species, and so change the ecosystem (U.S. EPA 1996; JÄNSCH et al. 2005; LERCHE & GLÄSSER 2006; ASKER 2011).

Evaluation of such versatile spectrum of stressors requires flexibility. Flexibility allows fill in each phase of risk assessment new facts which provide proponents of ecological risk assessment making effective environmental decisions (U.S. EPA 1992). The quality of the whole process is supported by following features:

– The process is iterative, which allows risk assessors to incorporate new information into the risk assessment.
– Like health risk assessment, it expresses changes in ecological effects as a function of changes in exposure to stressors.
– It evaluates uncertainty in the data and models, which allows risk managers to focus research on areas that will reduce uncertainty.
– It provides a basis for comparing and ranking risks, so that risk managers can focus attention on the greatest risks first.
– The analyses consider both scientific issues and management goals.

Ecological risk assessment and its conclusions, recommendations and proposals are very important and useful for risk management and assist in the selection of site remedies. The ecological risk assessment should identify threshold contamination levels for adverse effects (U.S. EPA 2008, 2012). On the basis of threshold values the effectiveness of remedial technics should be suggest and they can be used for cleanup goals arrangement (U.S. EPA 1992; DUPRAS et al. 2012).

The risk assessment affords information whether a risk is present and define a range or magnitude of that risk. With this information, a site risk manager must interconnect the results from risk assessment with other considerations to make and justify risk management decisions. To other considerations are incorporated existing background levels of contamination, available cleanup technologies, and costs of alternative actions and remedy selections.

CONCLUSION

ERA is a scientific process and involves a critical review of available data for identification and quantification of the risks associated with a potential threat.

Human health and ecological risk assessments often produce preliminary proposals and may be based on limited data and/or very conservative assumptions. The precision and comprehension of the risk assessment depends on quantity and accuracy of research data assumptions. The more precise and comprehensive is the risk assessment and the greater confidence in conclusions is drawn, the more specific risk management and regulatory decisions could be done. However, if initial risk assessments indicate no cause for concern, a more refined risk assessment may not be necessary.

During process of ecological risk assessment scientific information are used to identify potential environmental risks associated with some compounds or products released into the environment or used by man. The quality of regulatory decisions depends on documented scientific research, an understanding of the strengths and weaknesses of the specific risk assessment, and sound professional judgment in drawing conclusions from compiled data. The role of risk assessments is precise identification of favourable facts and any details required for compound or product critical evaluation. Clear, concise, and thorough ecological risk assessments provide to decision making process more valuable and permit informed debate on compound/product use; ultimately, the registration of a compound must withstand scientific inquiry, public scrutiny, and legal review.

ACKNOWLEDGEMENTS

This work was funded by the grant of Ministry of Education, Science, Research and Sport of the Slovak Republic VEGA 1/0098/14 and this contribution is the result of the project implementation ITMS 26240120014 "Center of excellence for protection and use of landscape and for biodiversity" supported by the ERDF.

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Available online at: www.degruyter.com/view/j/aeuc
doi: 10.1515/aeuc-2016-0002