ICT Tools For Environmental And Human Risk Assessment

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Abstract: Environmental (Ecological) and Human Risk Assessment (*EcoHRA*) is a complex process of assessing the influence of human activities on ecosystem duality and vice versa. The endpoint of *EcoHRA* is a prospective or retrospective assessment of stress factors influence (chemical contaminants, anthropogenic interventions or natural disasters) on ecosystems and their parts. Monitoring and collecting of available information as the source data for *EcoHRA* is a key part of the process for the assessor. The availability and quality of input data determines the complexity and feasibility of the process. In the problem description phase it is possible to use the public available high-quality data from on-line web databases and web services, e.g. toxicological properties of chemicals, GIS characteristics and maps, etc. Fundamentally, the problem relates to the quality and completeness of the data inputs and to the capability of assessor to aggregate key information according to methodical requirements and given situation. Recent development of information and communication technologies provides very powerful platforms for effective processing of multiple data sources. Particularly, web searches, database systems and data mining tools oriented on key environmental components and their descriptors, regionally-specific data aggregation, mapping of exposure and segmentation of the region of interest using Geographic Information Systems technology, automated processing of laboratory tests, namely dose-response curves using eco-toxicologically relevant models, algorithms and statistical packages and probabilistic estimates of risk level and associated uncertainties and their reflection in standardization of used environmental information systems by EEA, EPA, OECD and UNEP.

Keywords: Environmental Data; Environmental Information; Ecological Risk Assessment, Environmental and Human Risk Assessment; Monitoring; ICT; Environmental Information Systems; SEIS.

1. INTRODUCTION

Environmental monitoring is the very important part of *EcoHRA* framework. Environment and environmental impacts are monitored and connected with appropriate data that are collected by responsible organizations like Eurostat, European Environment Agency (EEA), U.S. Environmental Protection Agency (EPA), Organization for Economic Cooperation and Development (OECD), and United Nations Environment Programme (UNEP) in different ways e.g. using sensors, satellites, monitoring facilities and devices, people, etc.

For example, the United Nations (UN) System *Earthwatch* {http://earthwatch.unep.net/) is a broad UN initiative to coordinate, harmonize and catalyze environmental observation activities among all UN agencies for integrated assessment purposes. Through *Earthwatch*, UN agencies work together on global environmental issues, by exchanging and sharing environmental data and information.

The North American Node of UNEP *GRID*, located at the USGS EROS Data Center (http://na.unep.net/), is in the forefront of applying information and communication technologies (ICT) such as remote sensing, Geographic Information Systems (GIS) and web mapping to address the relationships between the environment and human populations.

The Global Monitoring for Environment and Security (GMES), (http://www.gmes.info/), represents a concerted effort to bring data and information providers together with users, so they can better understand each other and make environmental and security-related information available to the people who need it through enhanced or new services.

The International Register of Potentially Toxic Chemicals, or the UNEP Chemicals (IRPTC) helps the world community make better use of existing global resources and to give developing countries the information base to manage chemicals effectively. IRPTC collects information on hazardous chemicals through the Member countries Network. Based on the collected information, data profiles are prepared by contributing network partners, consultants and IRPTC staff.

2. ENVIRONMENTAL MONITORING

Environmental monitoring is shortly analysed in this section. It is the basis of environmental data collection, environmental assessment, reporting and also environmental research and the basis of understanding of environmental problems and trends. Environmental monitoring is therefore a powerful tool for supporting *EcoHRA*, decision-making, enforcing policy decisions, and for assessing compliance with policy regulations and objectives [Gilbert, 1987], [Holoubek, 2004].

Over the last decade, ICTs and new indicators have been developed in many countries to measure environmental impacts and performance, support *EcoHRA,* better integrate environmental and economic decision-making and better communicate environmental information to decision-makers and the public.

Monitoring institutions of many countries have received important autonomy to help ensure the independence and quality of their data, Hřebíček et al [2006], Olson [2003]. The integration of national information systems with international networks EIONET - European Environment Information and Observation Network (http://www.eionet.europa.eu/) and UNEP has been improved, including those co-ordinated by the governing bodies of international environmental conventions like UNEP, OECD or EEA, EPA, etc.

Here something could be added on the value of optimisation and co-ordination of monitoring networks. The Group on Earth Observations (or GEO) (http://earthobservations.org/) is coordinating international efforts to build a GEOSS: Global Earth Observation System of Systems. This emerging public infrastructure is interconnecting a diverse and growing array of instruments and systems for monitoring and forecasting changes in the global environment. GEO's current Members include 72 countries and the European Commission. Important role play NASA - National Aeronautics and Space Administration (http://www.nasa.gov/), ESA - European Space Agency (http://www.esa.int/), Russia and China with their satellite monitoring systems.

Despite this progress, a number of important weaknesses remain. Some current environmental monitoring systems in many countries do not meet priority demands. Some important environmental areas in *EcoHRA*, such as hazardous waste, heavy metals and other toxic substances, particulate matter, acidification, indoor air quality, drinking water, groundwater and wildlife outside protected areas, are not properly monitored in many countries. Inventories are lacking in several countries of waste of high potential hazard, which were (or continue to be) dumped on landfill sites, especially in rural areas. In a number of countries, biological monitoring systems are too cumbersome and expensive to manage. Monitoring practices to monitor environmental effects of armed conflicts in those countries where these conflicts occurred are practically nonexistent.

There is, furthermore, a contrast between the large volume of data produced by ICTs and the difficulty in using these data in *EcoHRA* to support decision making. On-line data banks of time-series data are poorly developed in a number of European countries and therefore in the EEA. This handicaps, in particular, analysis of cause-effect relationships, Hejč et al [2006].

According to the Communication COM(2008) 46 final, the SEIS (Shared Environmental Information System) has been developed and will be able to provide the knowledge base required to design, implement and evaluate the environmental and other policies. The SEIS will enable up-to-date quality data and information covering all elements of the DPSIR (Driving forces, Pressures, State of the environment, Impacts and Responses) framework of EcoHRA.

The general objectives of the SEIS are:

- to secure a clear political agreement in EU around a set of principles on which the SEIS is to be based;
- to continue rationalising the *knowledge base* through the assessment and streamlining of existing reporting requirements within environmental legislation while implementing information and communication technology solutions for electronic reporting;
- to establish and implement data and information sharing agreements in addition to an efficient ICT infrastructure to facilitate the discovery, assessment, access and sharing of environment-related data and information;
- to reinforce and, where necessary, establish monitoring infrastructures and surveys for the collection and archiving of *fit-for-purpose* environment-related data that are cost effective and flexible but can be sustained over the long term.

Most countries have increased the amount of environmental data and information provided to the public to follow Aarhus convention and Directive 2003/4/EC. Most of them now produce annual state of the environment reports that contain data from main sources. An increasing number provide this information through the web data basis. However, not everywhere is free and easy access to environmental information ensured for the general public, Hejč et al [2007].

Environmental authorities lack both monitoring experts and technical equipment in many countries. Industrial facilities also lack financial resources and are therefore not able to equip the sources of pollution with appropriate monitoring devices. Both the equipment that is available and sampling methods have become obsolete. As a result, routine monitoring activities have been handicapped or even discontinued altogether. The reliability and accuracy of air and water quality information is often questionable in many respects. Thus, it is impossible to fully evaluate the current environmental situation in these countries. Furthermore, ongoing national monitoring systems could hardly be integrated in international (global or regional) programmes of UNEP (GEO).

Another aspect to be covered is the dissemination of knowledge: Across the various European Countries, monitoring networks (GMES, EIONET) and monitoring strategies are at a different level of development. Fortunately, the development of SEIS will improve this level. Its co-ordinated action is, amongst others, aimed at harmonising efforts across Europe and exchange of knowledge with regard to:

- Development of monitoring strategies, optimising the cost/benefit ratio and taking transboundary activities into account. In case of the European Water Framework Directive (WFD) the latter is for instance done on the basis of the pre-defined basin-approach.
- Integration of modelling, unifying GIS (INSPIRE directive), and monitoring.

- Truly representative and comparable (amongst others because of harmonisation of methodologies) data-sets.

3. ECOLOGICAL AND HUMAN RISK ASSESSMENT

The ecological and human risk assessment (is a rapidly evolving discipline that is quickly being incorporated into the daily routines of industry and government. The *EcoHRA* framework has recently been completed or is under development in numerous countries of Europe [EU, 2003], in USA [EPA, 2001], [EPA, 2003], and Canada. In present time, many specific approaches and models exist in numerous sub-disciplines of *EcoHRA*, [Dolislager et al, 2007], such as chemical-property and fate estimation, toxicity, biological uptake, and population effects with limited co-ordination across these sub-disciplines [Holoubek, 2004].

The basic components of the *EcoHRA* framework are summarised in the Figure1.

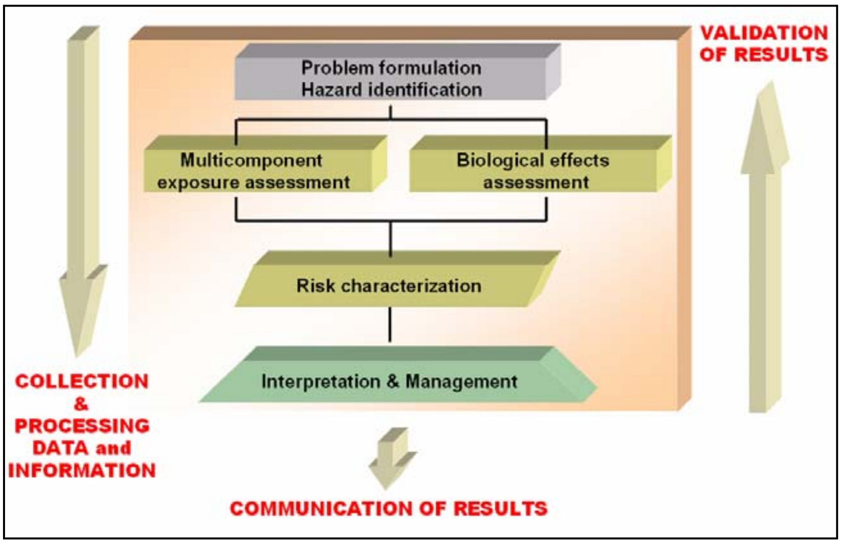

Figure 1: The key methodological step of the *EcoHRA* framework [Holoubek et al, 2004]

The *EcoHRA* framework shows the trends of global harmonization of *EcoHRA* and development of common methods, data, ICT and criteria and pooled resources to obtain more cost-effective, consistent, and flexible systems with reduced duplication of effort and incompatibilities, [Stewart et al, 2007].

The basic components of traditional ecological and human risk assessment are [Holoubek et al, 2001]:

- Stressors - released into the environment;
- Receptors - living in and using that environment;
- Response - of receptor to the stressors.

Measurements of exposure and effects represent the interactions between the components. Conventional *EcoHRA* depends on measurements of exposure and effects to calculate an estimate of risk. The regional concept of ecological and human risk assessment (*ReEcoHRA*) requires additional consideration of scale, complexity of the structure, and regional spatial components [Holoubek et al, 2001]: sources - release stressors; habitats - where the receptor reside; impacts - to the assessment endpoints. The *ReEcoHRA* uses multiple stressor assessment, where the number of possible interactions increases combinatorially. The stressors are derived from diverse sources; receptors are often derived from diverse sources, Figure 2. Receptors are often associated with a variety of habitats. One impact can lead to additional impacts.

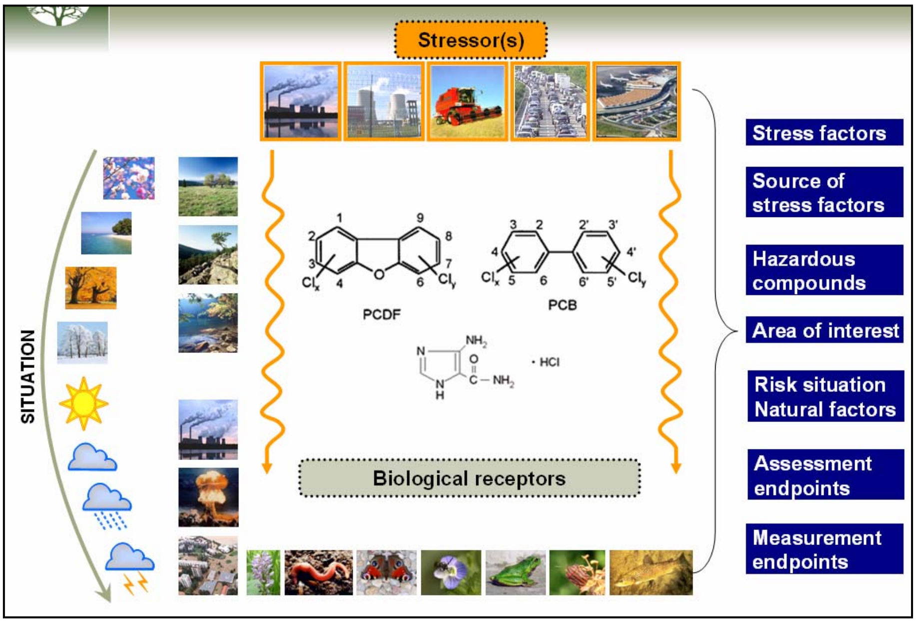

Figure 2: The basic components of the *ReEcoHRA* framework [Holoubek et al, 2004]

The basic approaches of *ReEcoRA* framework are [Holoubek et al, 2001]:

- To evaluate the risk components at different locations in the region; Risk characterization defines the likelihood that humans or wildlife will be exposed to hazardous concentrations. Thus, risk characterization describes the relationship between exposure and toxicity. Risk assessors identify species likely to be exposed, the probability of such exposure occurring, and effects that might be expected.
- Rank the importance of these locations;
- Combine this information to predict the relative risk among these areas;
- The number of possible combinations that can results from this approach depends on the number of categories that are identified for each risk component.
- Each identified combination establishes a possible pathway to a hazard.

Assessing and characterizing risk to ecological systems, including a myriad of non-target aquatic and terrestrial organisms as well as surface and ground water, is a much younger and more complex science than that of human health risk consideration. Ecological risk assessment considers a greater range of complex issues and covers more species than does human health risk assessment: fish, aquatic invertebrates, aquatic and terrestrial plants, non-target insects, birds, wild mammals, reptiles, and amphibians.

The first step of *EcoHRA* on the local or regional level - problem formulation, see Figure 3, has these basic steps:

- Identify local specific or regional characterisation of a study site or region;
- Qualitative evaluate of contaminant release, migration and fate of stressors (pollutants);
- Identify contaminants with potential ecological effects; receptors; exposure pathways; known effects;
- Select endpoints of concern;

- Specify objectives and scopes.

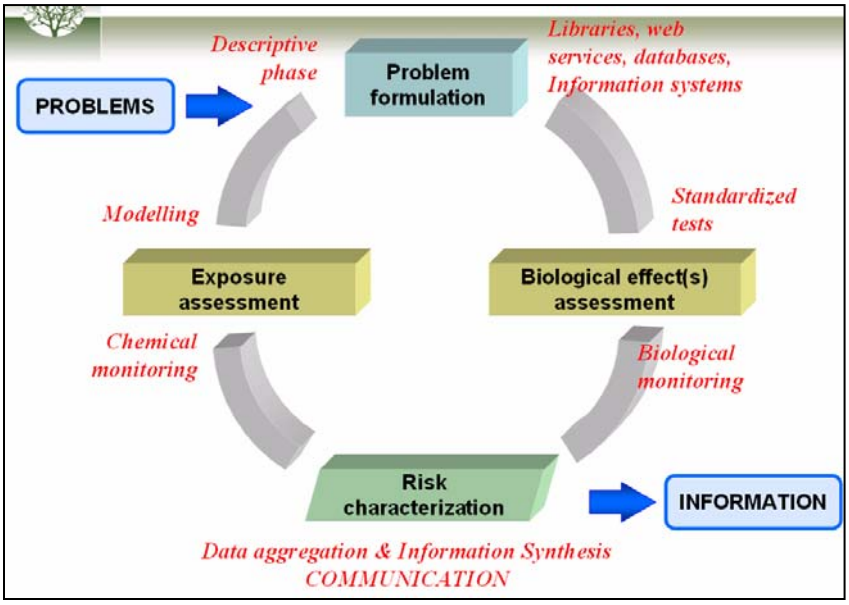

Figure 3: The *EcoHRA* framework and related methods and information sources.

The multicomponents exposure and human risk assessment mainly are mainly focused on quantifying of releases, migration and fate, characterisation of receptors and measurement or estimation of exposure point concentration.

Risk characterisation as a final step of whole procedure contents current adverse effects, future adverse effects, uncertainty analysis and ecological and human significance.

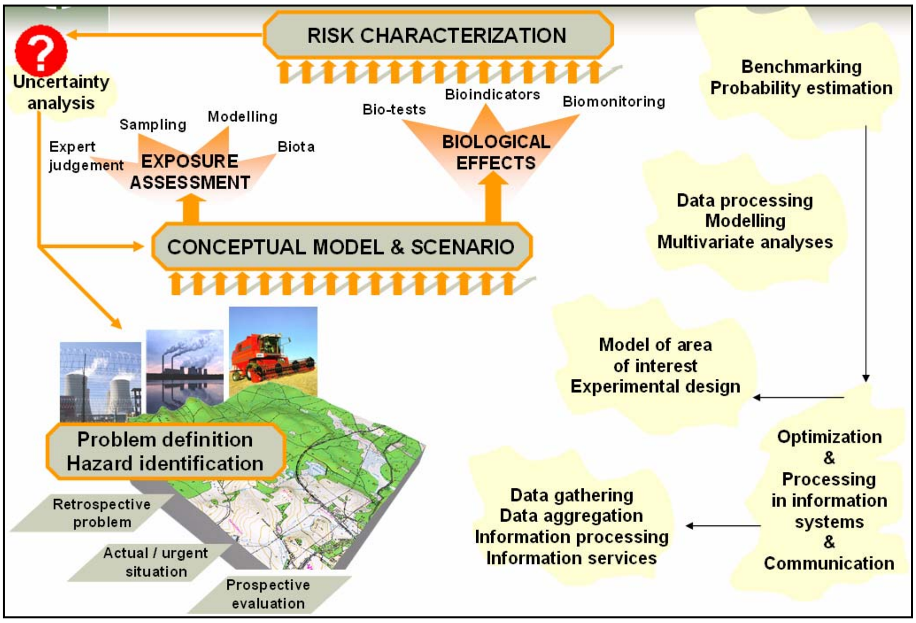

Figure 4: The *EcoHRA* risk characterisation and related used tools and information sources.

4. REQUESTS ON COMPONENTS OF ICT TOOLS

All ICT tools (databases, information systems, environmental models) have to be accessible through standard web browsers (MS Explorer, Mozzila, Firefox, Opera, etc) like for example are web information systems RAIS [Dolislager et al, 2007] or SADA [Stewart et al, 2007]. It is expected that they will have friendly Graphical User Interface (GUI). Their query formats will have to be the easy-to-use with GUI for selection of input or result data that could be consistent across the given ICT tool. The efficient help system with tutorial could be available for the user through the selection and information retrieval process.

Further, we shortly describe the basic components of ICT tools which could be available for *EcoHRA*.

4.1 Databases

This ICT tools could contain fully-searchable databases, for example:

- **Toxicity Values.** This database could be a fully-searchable database of chemical (organics and inorganics) and radionuclide human health toxicological values. This is needed to perform risk evaluations and assessments in accordance with the standard methods of the Risk Assessment e.g. [EPA, 2003]. It is possible to download these values from EPA's Integrated Risk Information System (IRIS), or incorporates data from another sources, e.g the Health Effects Assessment Summary Tables (HEAST), the Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs), World Health Organization (WHO) values, and California Environmental Protection Agency (CalEPA), etc.
- **Toxicity Profiles.** EPA and EU legislation provide many excellent toxicity profiles that deal with the most important chemicals on a national and international scale [Patterson et al. 2002].
- **Chemical-specific factors.** During both the exposure and the dose-response (toxicity) assessments of a risk assessment, various chemical-specific parameters are needed to determine dose and risk. In support of this need, is appropriate for instance ICT tool, which provides a fully-searchable database of over 20,000 chemical records for 22 parameters of 1635 chemicals and radionuclides combined like the RAIS Chemical-specific Factors [Dolislager et al, 2007].
- **Established Regulatory Limits for Surface Water and Groundwater.** Various national agencies, EEA and EPA use toxicity and risk information to establish drinking water criteria for specific chemicals in environmental media. Verifying that current or future contaminant levels are below or above the criteria is an important task in risk assessment. This ICT tool could provide a fully-searchable database for surface water and groundwater criteria established by EU legislation and state agencies.

4.2 Ecological Benchmarks

There are few web-accessible information sites, which provide both human health and ecological toxicity information. In addition to its human health toxicity values, ICT tools could contain a appropriate standard ecological benchmarks for given chemicals. Screening ecological benchmarks are used to identify chemical concentrations in environmental media (surface water, sediment, and surface soil) that are at or below thresholds for effects to ecological receptors, specifically a range of aquatic organisms, soil invertebrates, and terrestrial plants.

This ICT tool can help risk assessors ensure that contaminants of potential concern that are to be dropped in the risk assessment on the basis of negligible contribution to human health risk are not in fact risk drivers for ecological receptors.

4.3 Human Health Risk Exposure Modelling

Very important could be ICT tool on modelling human health risk exposure. This tool will provide the ability to calculate web-based risk estimates in real time. This tool will allow users to upload small data sets for a first-pass risk assessment. Users should first familiarize themselves with the applicable guidance documents and special cases information provided as links on the page.

4.4 Links to Additional ICT Tools

We can recommend the official web-based EPA Soil Screening Guidance calculation tools for both chemicals (http://rais.ornl.gov/calc_start.shtml) and radioactive isotopes (http://rais.ornl.gov/rad_start.shtml) and the official EPA online calculation tools for radionuclide PRGs (http://epa-prgs.ornl.gov/radionuclides/) and EPA Radionuclide Dose Compliance Concentrations (http://epa-dccs.ornl.gov/).

5. CONCLUSIONS

The principal role of ICT tools in *EcoHRA* cannot be narrowed only to standardized monitoring, gathering and aggregation of primary environmental and related data. All phases of the *EcoHRA* process (hazard identification, exposure assessment, dose-response monitoring, etc) are intrinsically associated with some level of uncertainty and so the final conclusions are based on stochastic analytic methods. At this point we must accentuate key role of GIS technology, multivariate processing of ecological bioindicators and finally very important dose-response modeling and probabilistic characterization of risk. Each of these methods, and many others as well, represent unique field of computational science with its own methodology and progress and developed ITC tools. Notwithstanding the methodical variety, *EcoHRA* must assimilate only verified approaches with sufficiently robust algorithms, suitable to heterogeneous or incomplete data. Reliable computational methodology and appropriate ICT tools bridge the gap between environmental and experimental data and makes the whole *EcoHRA* process as effective as it is possible.

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