COMPARATIVE ECOLOGICAL RISK ASSESSMENT MODELS

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Abstract

Importance of ecological risk assessment gradually increases for areas with planned and unplanned urban development and for unsettled areas. Especially, pursuant to national, AB and international laws, as well as improvement works and sanctions by laws, legislations and agreements for existing pollutions, the issue of determining the risk values possible future pollutions by scientific methodologies gets more importance day by day. Either methodological approach or points of view and priorities vary by every country in ecological risk assessment. In the Article, various ecological risk assessment models are discussed with their strengths and weaknesses.

Key words: *Ecological Risk Assessment, Environmental Risk Evaluation, Human Health Risk Assessment, Risk Assessment Models, Risk Management*

1. INTRODUCTION

Increase in environmental pollution due to rapid industrialization in developed countries has revealed that pollution control operations in environmental management works cost cheaper that cleaning works made after the pollution (UNEP 1992). Based on this fact, Ecological Risk Assessment is being used since the end of 1980s as a tool in environment management. This tool is used for understanding and estimating the relations between human activities and the negative ecological effects caused by these activities. This way, Ecological Risk Assessment creates a basis for decisions in environmental management and in this scope, current data, estimations, uncertainties are assessed systematically (Küçükali 2009). Ecological Risk Assessment gets its basis from Environmental Risk Assessment method (Holmes & Singh 1993).

2. MATERIALS AND METHODS

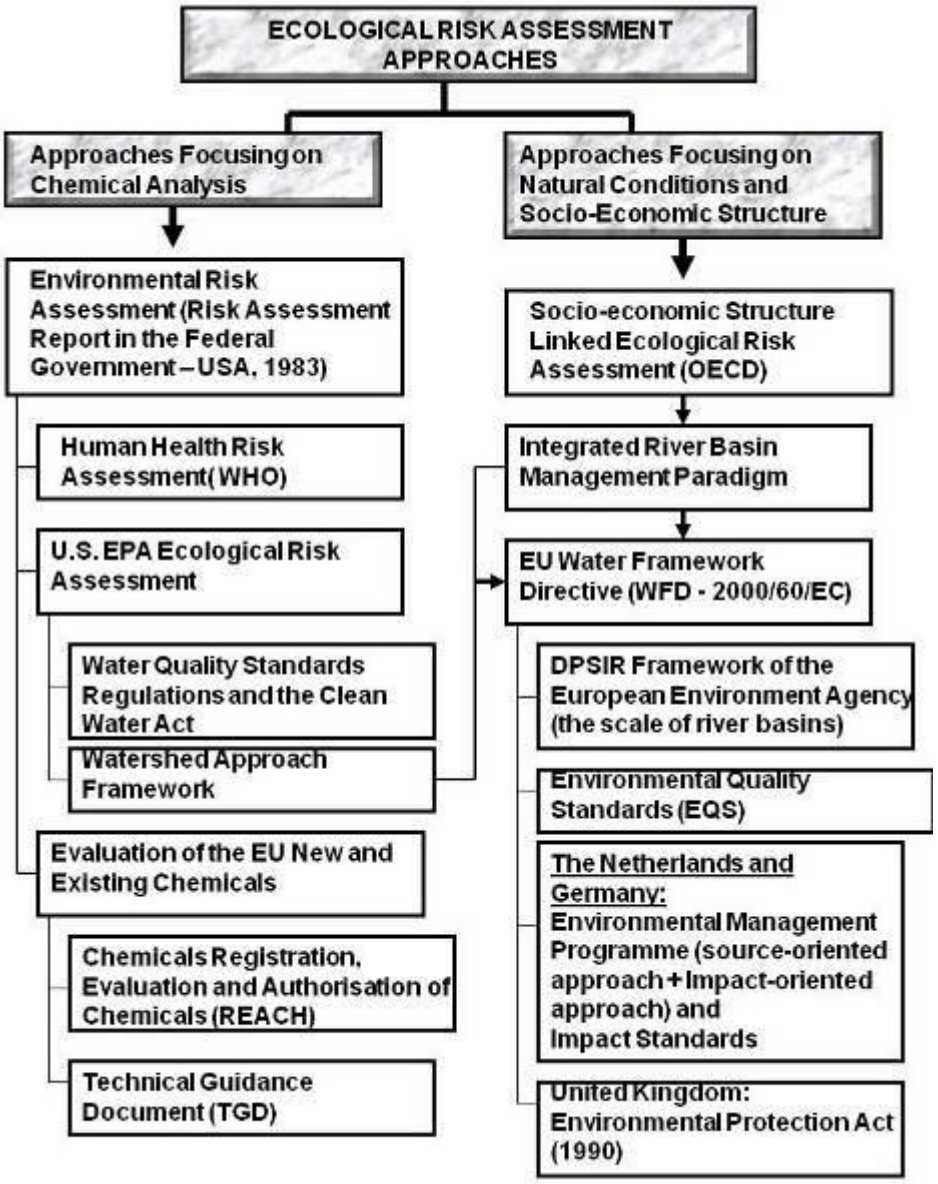
There are certain operation steps common in all Environmental Risk Evaluation models. These are:

1. Finding out the problem
2. Identifying the damages
3. Evaluation of the spread
4. Evaluation of impacts
5. Evaluation of findings
6. Risk estimation

Many Ecological Risk Assessment models have been developed in different countries according to their characteristics. When we examine these models, we can have a classification in two top titles, which display methodologically different features (Fig.1.):

1. Ecological Risk Assessment models that focus on chemical analysis
2. Ecological Risk Assessment models that evaluate natural conditions and socio-economical impacts as well as chemical analysis

In order to determine the risks on human health caused by chemicals from industrial facilities, National Science Academy (NAS) made a Environmental Risk Assessment study in USA in 1983, and a model has been developed. This method has been improved by taking European Union's New and Existing Chemical Substances legislations as basis. It is also the improved version of the risk assessment methodology specific for the field and the operations performed (Adams & Power 1997).



First documents that define and establish the process of Ecological Risk Assessment were prepared by U.S. Environmental Protection Agency (EPA), which are: Guidelines for Ecological Risk Assessment (US EPA 1998), Ecological Risk Assessment Guidance for Superfund (US EPA 1989) and Ecological Risk Assessment and Risk Management Principles for Superfund Sites. At the same time, Suter's books, named "Risk Characterization for Ecological Risk Assessment of Contaminated Sites" and "Guide for Developing Conceptual Models for ERA" (Suter 1999) have important position in Ecological Risk Assessment literature.

2.1 U.S. Environmental Protection Agency

U.S. Environmental Protection Agency (EPA) focuses on chemical analysis in Ecological Risk Assessment. EPA methodology; focusing especially on pollution risk assessment studies, evaluate the risks created by chemicals on organisms. At the same time, based on Water Quality Standards Regulations and Clear Water Act covered in U.S.A environmental legislations, risk assessment is again made by focusing on chemical analysis. EPA -Ecological Risk Assessment methodology is, generally, as follows.

Ecological Risk Assessment is a process that evaluates the possibility and capability of being exposed to one or multiple negative ecological impacts (US EPA 1992). For environmental decision-making process; it systematically detects and evaluates the relations between data, assumptions, uncertainties and negative impact sources, and ecological impacts. The assessment can include chemical, physical and biological impact sources; one or more impact sources can be evaluated. There are 3 main stages in Ecological Risk Assessment; identification of problem, determining of the analysis and risk.

Below, assessments of chemical analysis based on parametric parameters in EPA's Ecological Risk Assessment methodology are given. Acquired results are discussed with risk managers (relevant public institutions and municipalities) and they become influential in governing resolutions, shape planning and give a direction to the policies that are created as a result.

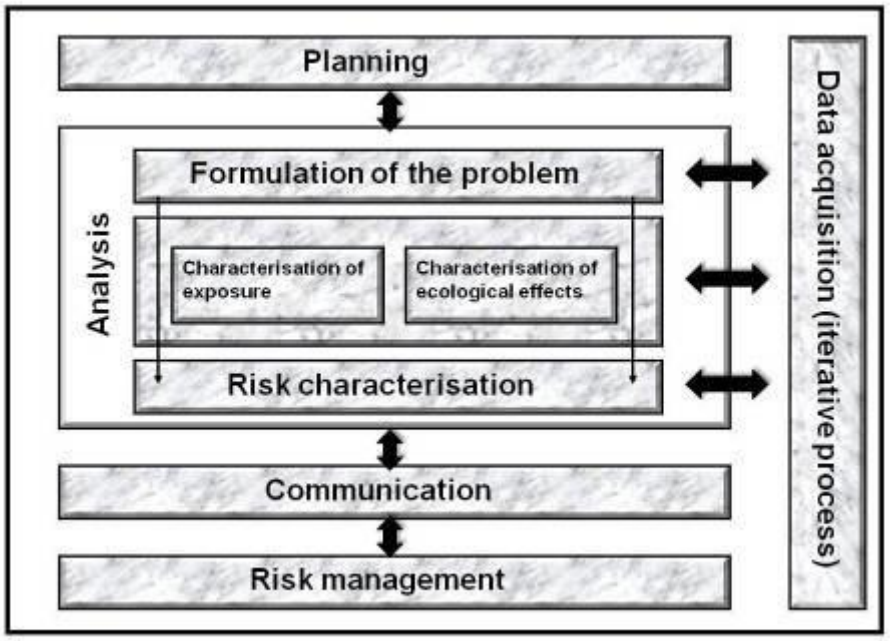


Fig.2. General diagram of ecological risk assessment (U.S. EPA, 1992)

Considering some studies that use the Ecological Risk Evaluation methodology of U.S. EPA, who focuses on chemical analysis;

In the study "Impacts of Physical Deteriorations on Water Quality and the Function of Urban Wetlands for Improving Water Quality" (US EPA 1994) performed at 8 counties at St. Paul Metropolitan district in Minneapolis, U.S.A; human-sourced physical and chemical impacts were assessed with Ecological Risk Assessment methods under the cause-effect relations over the water quality of 33 wetlands, and a conceptual model and control list was constructed.

Besides, the study "Bolsa Chica Reserve Ecological Risk Assessment" (US Fish and Wildlife Service 2003), performed in California, U.S.A, establishes the risks on land, sea and transition ecosystems and ecosystem functions caused by changes in water quality, and how these risks impact the fish population in the reserve. Data acquired in the end, aims to reduce pollutions and is included in the planning by improving the risk management process.

Regarding these studies focusing on chemical analysis, there are many examples of applications, such as those in; water basins (Bogazici University 1992, US EPA 1996, Serveiss 2002), rivers (Wenger et al. 2000), wetlands (Lemly 1997), agricultural lands, areas under intense threat of chemical wastes, areas and forests losing natural characteristics as a result of uncontrolled urbanization, (Hogsett et al. 1997), coves (Harris & Wenger 1994), valleys (US EPA 1996b), flood and overflow areas (Kooistra & Leuven 2001, Turoglu & Özdemir 2004, Özdemir 2007, Turoglu 2007, Turoglu, 2010).

As you see, there are incomplete points in EPA methodology in terms of the process of assessment for the ecological risks over natural resources with all their components. Based on these points, EU countries and some international organizations have developed their own risk assessment methodologies.

Although the ecological risk assessment methodology developed by U.S. EPA focused on chemical analysis, it has become the basis for later developed similar methodologies. With the completion of seemingly incomplete aspects and with the addition of new points of view, many different ecological risk assessment methodologies have been developed.

2.2 World Health Organization

World Health Organization (WHO) has reformed the EPA frame in terms of human health and Ecological Risk Assessment. The difference of this frame from EPA's is that the contribution of risk managers and stakeholders occur in parallel with risk assessment process. Each process performs its function within its own internal dynamics while there can be interactions, feedbacks and connections between two processes at any point (Don Maughan 1972).

In the same manner, the OECD model, which is constructed on considering socio-economical structure in parallel at Ecological Risk Assessment stage, displays a structure similar to the WHO model.

2.3 European Union

In EU countries, two approaches follow each other. Although the Ecological Risk Assessment is based on chemical analysis in the EU legislation on the Assessment of New and Existing Chemicals; the DPSIR frame, which is based on the later adopted Water Framework Directive (WFD), at river basins scale, includes other natural conditions and socio-economical structure in its risk assessment.

EU commission developed "New Chemicals Policy" for the protection of human health and environment from chemicals hazards (Kleinschmid & Wagner 1997). By replacing 40 existing laws, REACH has been developed to create a single system for all chemical articles. This system, taking year 1981 as basis, differs from the current chemical legislations in effect for substances known as "existing" and "new" chemicals. 100,106 chemical substances launched before 1981 are defined as

"existing" chemicals. Chemicals introduced after 1981 (more than 4300) are defined as "new". It is mandatory to apply very strict tests to new chemicals under current laws, while for existing chemicals, there are no such measures (ISO 2007).

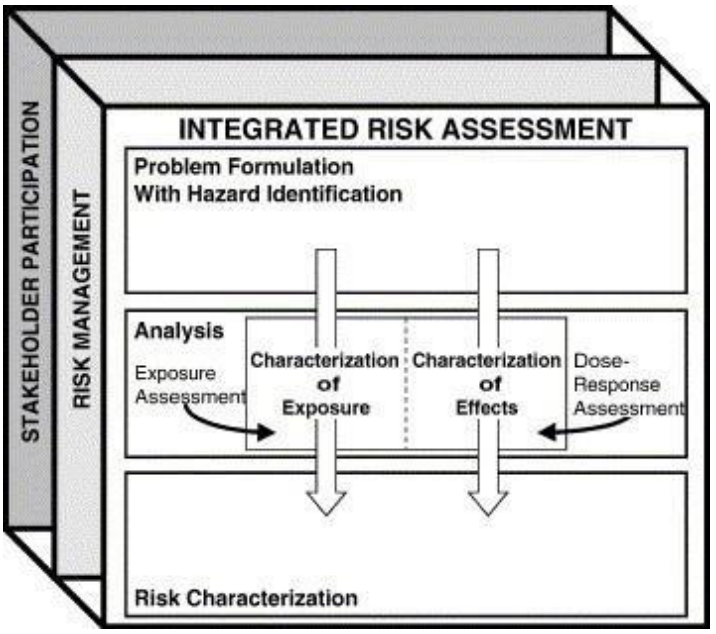


Fig. 3. A framework for the integrated assessment of human health and ecological risks (WHO 2001)

Legal legislations in EU on environment started in 1973 with EU Action. As of this date, risk management and risk assessment frame have been defined by many regulations in the European Commission (EC). At the same time, with Technical Guidance Documents (TGD), pollutant assessment criteria were defined and have been adopted by all EU member states as of 1995. U.S. National Research Council takes EU risk assessment frame as basis for "Federal Government Risk Assessment: Process Management" report, also known as the Red Book (NRC 1983). Although this framework was first prepared to assess human health, it was later adapted to the Ecological Risk Assessment (Barnthouse & Suter 1986, US EPA 1992). Technical Guidance Documents define scientific, political and social parameters as important parts of the general assessment process.

Exposure status may vary greatly in different countries due to differences such as topography and climatology, etc. (Toope 2003). At this point, standards have been developed for EU countries by considering average environmental characteristics and possible exposures. These standards can be revised specifically for the study area by appropriate measurable data and area-specific emission values.

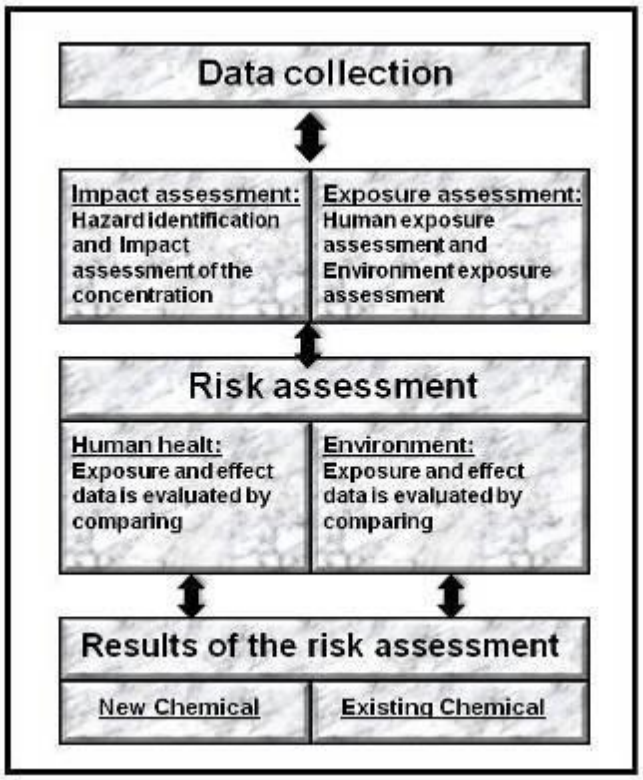


Fig. 4. New and existing chemicals risk assessment process of the European Union (EEA 1999)

Table 1 Existing and new chemicals regulation of the European Union (EC 1996)

	New Chemicals	**Existing Chemicals**
Identification of New and Existing Chemicals	Since 1981 the European Union are not included in the previous 10 years	Located in the European Commercial Chemical Substances
Basic Regulation	Directive 92/32/EC (EC, 1992)	Council Regulation (EC), 793/93 (EC, 1993c)
Risk Assessment Legislation	Directive 93/67/EC (EC, 1993b)	Commission Regulation (EC), 1488/94 (EC, 1994b)
Technical Guidance Document for Risk Assessment Legislation	EC, 1993b, and Technical Guidance Document Together (EC, 1996)	EC, 1994 and the Technical Guidance Document Together (EC, 1996)

WFD (2000/60/EC) is the basic EU legislation that establishes the Environmental Quality Standards (EQSs) for chemicals and creating risks for aquatic ecosystems, covering risk management issues on river basins scale. Over Europe; WFD was formed within the framework of integrated river basin management (IRBM) paradigm (Kirby et al. 1994).

According to WFD, EU countries shall bring the environmental quality standards of their water surfaces up to a certain standard until 2015 and accomplish improvement. Quality of water sources are

affected by many different pressure elements. These are; point-source discharges, non-point sourced common sourced discharges, water abstractions, flow formations, morphologic deteriorations.

3 risk classes are defined according to WFD:

1. water surface not under risk (if WFD quality standards are met according to pressure/impact analysis),

2. water surface under potential risk (if there is no sufficient data),

3. water surface under risk (if WFD quality standards are not met according to pressure/impact analysis),

All these pressures and the impacts they cause are grouped in four risk categories:

1. Organic pollution

2. Hazardous substances

3. Nutrients

4.Hydromorphological alterations / deteriorations

DPSIR (driving forces, pressures, state, impacts, responses) framework, which is based on the WFD and which defines application areas and method, was developed by European Environment Agency (EEA 1999). In the first stage of DPSIR framework, the driving force and pressures are defined and the potential impacts they cause (hazards) are established. To this end; socioeconomic data, trends, environmental data, current water quality data and sensitive regions are defined. In the second stage, current chemical water quality data are evaluated within the framework of Environmental Quality Standards. In stage three, impacts and causal relations are revealed and assessed. Various quality data (biological, physiochemical, chemical and hydro-morphological data) are integrated. At last stage, responses are evaluated. Technical measures and policies are set to improve or protect the water quality.

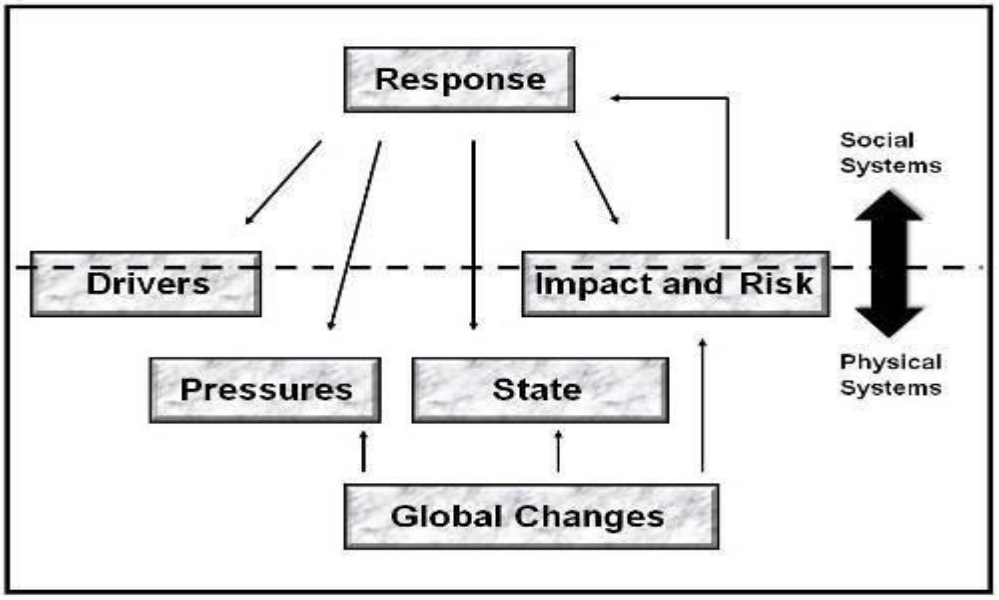


Fig. 5. DPSIR framework (ISO 2007)

At this stage, when countries are generally considered in terms of Ecological Risk Assessment methodology; Holland's risk management approach (Program for Environmental Management of the Dutch Government) was first developed between 1986 and 1990, by using Germany's Environmental Management Program. According to this concept, in addition to source-based approach in risk management (emission standards), importance of impact-based approach (environmental quality standards and impact standards) was emphasized. Previous risk evaluations were based on only chemical analysis (Jorgensen 1991).

2.4 Other Countries

UK and Canada have formed their own ecological risk assessment models (CCME 1997). UK's Ecological Risk Assessment model is based on assessing lands under potential pollution risk together with legal legislations (Wood & Jones 1997).

Canadian model shows the exact opposite of the approach in the American risk evaluation model, which is based on the idea stated by NRC committee as "Although risk assessment and risk management process are analytically independent from each other, they are and must be in interaction in practice. If they progress independently and separately from each other, it will be hard for risk manager to take correct decisions in time." (NRC 1983). In Canadian model, risk assessment and management processes are regulated separately. At the same time, Canadian model is contrary to U.S. and EU models in terms of process sequence. Canadian model has risk management as the first step, and then makes the risk assessment. In U.S. and EU models, risk assessment is the first step.

Australia applies a versatile, combined approach method. Besides chemical analysis, it assesses natural source analysis together, according to data status.

3. RESULTS AND DISCUSSION

U.S. EPA's Ecological Risk Evaluation process handles risk management and technical evaluation processes separately. Following the risk assessment, which is fully a technical evaluation, it allows discussions with stakeholders (industrial institutions, NGOs and public institutions) at risk management stage. In other frameworks, such as; revised NRC framework, EU Risk Assessment Framework for New and Existing Chemicals, risk assessment and management frameworks of FAO / WHO for food additives (WHO 2001), risk managers and stakeholder requests play a greater and more important role in risk assessment. If risk managers and stakeholders are closely involved in the process, they can have an effective role in the selection of scenarios, models and parameters. On the other hand, if they are not involved in the process, there can be critically wrong decisions in risk assessment processes.

Other than the level of interaction between risk management and stakeholders; all risk evaluation paradigms basically follow the same logic. There is a terminological difference in the basis between human health and Ecological Risk Assessment processes. A significant difference is seen in hazard identification process. "Hazard" identification is used by NRC (NRC 1983) in the stage of evaluating problem formulation data evaluation and impact resource selection; it is used in other frameworks in stages where impacts and impact causing capacities are assessed within the characterization of effects - effects assessment (WHO 2001).

A great improvement is seen risk evaluations performed for environmental problems caused by point-pollution sources. It becomes important to take non-point pollution sources under control for environmental improvement. To solve pollution and habitat deterioration problems, basin approach must be adopted instead of assessing each water source or pollutant one by one. The Watershed Approach Framework establishes the interaction between natural resources (geographical data) and public/private sector activities (human impacts on surface and underground water systems, etc.).

Many states in U.S.A. have developed a strategy in accordance with Clean Water Action Plan, and are rehabilitating their basins. Not only one environment (water, air etc.) is evaluated in this basin-based approach; relations between these environments are also assessed. In the same manner, the application area of Water Framework Directive, the legal legislation that is the basis for water management European Union countries, is shifting from local scale to basin scale.

Various pressures (pollution, morphologic pressures, climate changes, regional and global economic structure, etc) impact various ecosystems in various manners. Therefore, risk analysis models, using ecosystems that have complex structures as an object, cannot be applied for all times, situations and locations as a constant pattern. Every place-time duo has varieties according to their specific pressure situations and must have flexible structure open for innovations.

4. CONCLUSIONS

According to some authors who approach critically to Ecological Risk Assessment (Power & Mccarthy 1997) Ecological Risk Assessment has many uncertainties due to the incomplete understanding of the operation of ecosystems, due to the inability to establish regular relations between parameters of this mechanism, and due to discussions on which of the legal, technical or socioeconomic contexts will have a higher priority in assessments.

Also, in another study (Power & Adams 1997) the authors discussed the differences of U.S. Environmental Protection Agency's Ecological Risk Assessment framework, which is based on chemical analysis and treats risk management as a secondary process in order to have a scientific approach, from the Canadian framework, which puts risk management to the core of risk assessment process.

According to another author (Tal 1997), risk assessment was developed by risk assessors as a part of risk management to overcome the adversities in environmental actions. Environmentalists believe that risk assessment cannot be sufficient to fully establish the characteristics of environmental damages and hazards over humans and ecosystems. According to environmentalists, risk assessment is an effort only to quantify and sort risks instead of removing them. They also believe that risk assessment uncertainties cannot be successfully eliminated and that risk assessments can be manipulated according to point of view of the assessor. Despite this, the author adds that some environmentalist groups leave this approach and accept risk assessment approach.

Despite this negative point of view of environmentalist movement against risk assessment, Ecological Risk Assessment has been adopted by many countries and successfully applied although there are approach, priority and methodology differences.

There are methodology differences between U.S. – EPA framework, which focuses on chemical analysis, and Canadian framework, which focuses risk management, and EU- WDF framework, which includes natural circumstances and socioeconomic structure. The approach to be chosen must be decided according to the Ecological Risk Assessment research area.

When the above criticisms are evaluated; the inability to fully understand the mechanism of ecosystems does not mean that causality relations cannot be established between the subcomponents that form this mechanism. Despite however complex is the cluster of relations between subcomponents, it is possible to measure, quantify and assess the impact levels of these relations. It is a matter of time, facilities and technology to make uncertainties become measurable and assessable.

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