ECOLOGICAL RISK EVALUATION OF POLLUTED SOILS FROM SASA MINERAL PROCESSING CONCENTRATOR

Boris Krstev, Blagoj Golomeov, Mirjana Golomeova, Alexandar Krstev

University “Sts Cyril & Methodius”-Skopje, Faculty of Mining & Geology-Stip, FYR Macedonia

Introduction: Soil Pollution and Ecotoxic Risk

The idea that the earth is a closed system and that soil, like other mediums, is polluted by human activities, is very recent, hardly thirty years old. The chief preoccupation has been with water pollution, a conviction that, sooner or later, all the pollutants found in water were the principal cause of the emergence of aquatic ecotoxicology. Yet, the existence of polluted soils has been cited since ancient times. Greek and Roman writers remarked that the contamination of water and air near mines had adverse effects on plants, domestic animals, and humans. But soil pollution is not as visible as water pollution, and to acknowledge that soils can be polluted goes against the belief—still very widespread—that they have an unlimited capacity to purify themselves. Perceptions have evolved: DDT pollution, the Seveso catastrophe (1976), urban pollution by pyralene electric transformers (Reims, 1985; Villeurbanne, 1986), and the nuclear fallout at Chernobyl (1986) have clearly shown that environmental pollution is general and that it affects soil as well as other mediums. Ancient practices, such as the spreading of purifying mud around farming areas, earlier considered a wasteful agricultural amendment, are now being considered again. The quality of soils is of great importance, as emphasized in the report of INSA/INRA/CRIDEAU/CNRS (I2C2, 1994):

• Soil is a living medium much more complex than air or water. It plays an essential role in the production of biomass and in the recycling of elements, and its functional characteristics can be altered by pollutants.

• Soil pollution can affect other mediums and plants, and can ultimately reach terrestrial and aquatic animal species.

• *Diffuse pollution,* affecting large land surfaces, resulting from the dispersion, probably by atmospheric means, of phytosanitary products and industrial pollutants. These situations lead to *polluted soils.*

• *Localized pollution,* much more intensive, resulting from the spilling, accidental or otherwise, of solid or liquid products, leads to *polluted sites.*

To these spatial criteria may be added some temporal criteria:

• Sites that *have been* polluted because of old mines, industrial contaminations, abandoned discharges.

• Sites that *are being* polluted by industrial, agricultural, or domestic activities. To this pollution caused by human activity is added *natural pollution* of the environment, for example the existence of significant eeochemical beds of metals.

• Sites that *will be* polluted by the presence of new chemical products, or by new industrial or agricultural activities.

The determination of quality criteria ultimately has two consequences:

• the obligation to rehabilitate very polluted soils to bring the concentrations of pollutants to acceptable levels;

• the obligation to prevent and control future pollutions for which the threshold of danger is not yet crossed.

The various strategies developed to evaluate the quality of soils and sites correspond to three possible objectives:

• to establish *references* or criteria of soil quality, on chemical and/or ecotoxicological bases (to define thresholds);

• to develop *methods of ranking* to classify polluted sites for the purpose of their decontamination (to establish a classification); and

• to develop *methods of risk evaluation,* comprehensive or simplified, to define the ecotoxic impact (to measure a risk).

It is not easy to define what exactly is understood by environment. For example, in directive 91/414 of the European Union, concerning risk evaluation for phytopharmaceutkal products before they are put on the market, the environment is defined as 'the water, air, land, wild fauna and flora, as well as all the interrelations between these various elements and all relations existing between them and every living organism.' In many cases, the pollution of a site is suspected, and must be then confirmed or disproved.

Once the elements at risk are identified, the existing scientific data can be used to work toward evaluating the modalities and extent of contact between the elements at risk and the pollutant *(characterization of exposure*), in parallel with an evaluation of the relation between the dose and the effects (toxicity) of the pollutant *(characterization of effects*). Finally, the risk is characterized by an evaluation of the extent of predicted effects and of the probability of their realization, as a function of exposure. The necessary data are obtained by various approaches: the occurrence and behaviour of products in air, water, and soil are characterized by laboratory assays, measurements made on the land or simulated by mathematical models; the estimation of toxic effects of pollutants is based on the same methods, laboratory studies on different plant or animal species, epidemiological studies of plant, animal, or human populations, or mathematical models.

1. DEFINITIONS

1.1 Danger, Risk and Risk Evaluation

There are several definitions of risk evaluation, and they enable us to specify the nature and the impact of this operation. Risk evaluation is 'an operation that assigns levels and probabilities to adverse effects of human activities and natural catastrophes' (Surer, 1993a). For Covello and Merkhofer (1993), risk is a concept 'at least two-dimensional, implying (a) the possibility of an adverse effect and (b) an uncertainty about the appearance, chronology, and gravity of this adverse effect. If one of these characteristics does not exist, there is no risk. Volmer et al. (1988) define risk evaluation as 'methods designed to estimate the significance and probability of adverse effects of anthropogenic substances on the environment. These various definitions do not always specifically refer to a particular type of risk, health or ecological. According to Norton et al. (1992), the evaluation of ecological risk is 'an operation that evaluates the likelihood of adverse ecological effects produced as a result of exposure to stresses."

The most recent definition is that of Rodricks (1994): 'risk evaluation ... is a systematic means of organizing available information and knowledge and specifying the level of scientific certainty, in relation to the facts, models, and necessary hypotheses; the objective is to draw conclusions from these about health risks, of whatever nature.' This definition is very interesting because it brings to light the essential elements of the operation of risk evaluation: research and organization of existing information; use of different approaches and methods; specification of an uncertainty attached to a result.

The necessity of making a risk evaluation, even summarily, lies in a double observation: One cannot eliminate the possibility of unpredictable adverse effects of human activity (one cannot foresee everything); Some decisions must be taken, even on the basis of necessarily incomplete information (one cannot wait).
Risk evaluation is founded on the fundamental distinction between *danger* and *risk.* In the case of chemical products, the danger is linked to the existence of dangerous substances, that is, those that have the *potential to exercise adverse effects on the environment and living species, if they come into contact with them.*
Dangerous products are distinguished from others by their capacity to cause toxic effects in the short term {mortality) or in the Jong term (occurrence of cancers, reproductive problems, etc.). Moreover, this definition must be accompanied by a notion of *dose.* The classic examples of fluoride and selenium show that the notion of dangerous product falls within sometimes very narrow limits. The *danger* arises from the substance itself or from the substance and environmental components that are closely mixed with it (matrix). The fumes of incinerators, the mud from waste treatment plants industrial effluents, automobile emissions, and a badly polluted medium (for example, the soil in a site containing significant quantities of potentially toxic pollutants) are *dangerous objects.*
The risk is the *probability of occurrence of toxic effects after exposure of the organism to a dangerous object.* The notion of risk takes into account the existence of a possible exposure to dangerous objects. It is important to distinguish between *pollutant* and *toxin:* a very dangerous product kept confined in a laboratory, in small quantities, is a toxin, but not a pollutant. Conversely, a pollutant is not always a very toxic product, but the capacity of a chemical substance to disperse through the environment in large quantities classes it automatically as a pollutant, that is, a product presenting a potential risk for that environment. It is this that the European Union implicitly recognized when it demanded a large number of ecotoxicity tests when the quantity of a dangerous substance produced rises, in direct proportion to the probability of dispersal in the environment
In the text *pollutant* is defined as *a dangerous object of presenting a. risk to environments and living organisms.* A *polluted site* is *geographic zone in which pollutants are found. Pollution* is defined as *the actual or supposed presence of pollutants in the environment.* The terms *pollutant* and *contaminant* are synonymous most of the time, and in the following text, we use the two interchangeably.
Chemical substances are not the only environmental dangers: climatic changes, modifications of rural areas, etc., are threats to existing ecosystems. The present trend is to group all these potential dangers under the general term of *stresses.* In the same manner, individuals, environments, or ecosystems susceptible to stressful effects are designated under the general term of *elements at risk* or *receptors.*

1.2. Ecotoxicology and Risk Evaluation

In the absence of universal agreement, *ecotoxicology* is defined here as the *study of the occurrence of pollutants and their effects on the environment and humans, that is, abiotic mediums and the biotic components that populate them.* This definition is very wide, since it includes the occurrence and effects of pollutants under the same term; also, it takes into account the direct effects of pollutants on living organisms and the direct effects on environments {for example, the greenhouse effect on the ozone layer) and the indirect repercussions on biocenoses.
This definition does not specify the level of organization of biological system: one of the characteristics of ecotoxicology often emphasized is to consider ecosystems and not just individuals, but sometimes a 'toxicology' of the individual has been opposed—wrongly—to an 'eco' toxicology that takes only ecosystems into account. According to Barbault (1993), 'as a basic science, ecology has as its objective the study of the organization, functioning, and

evolution of biological systems corresponding at an equal or higher level of integration to that of the individual.' The definition proposed by Barbault is very wide, since it takes into account not only the level of ecosystems, but also that of communities, of populations (biol-ogy of populations), and of individuals (ecophysiology).

The different applications of ecology have been pointed out by Barbault (1993): regulations of pest or exploited populations, preservation and use of genetic diversity, agricultural practices (biocontrol, for example), management of territory,, and conservation of fauna and flora. The principal application of ecotoxicology is *the evaluation of the risk posed by chemical products to the environment and to humans.*

The difference between ecotoxicology and risk evaluation is important. A very eloquent analogy can be found in the example of climate: on the one hand, a fundamental science, climatology, enables us to understand and explain climatic phenomena, and on the other, an applied science, meteorology, provides the climatic predictions necessary for human activities.

1.3. Development of Risk Evaluation Strategies

Risk evaluation arose when people recognized that they use toxic products for their vital needs. It became necessary to manage the use and handling of such products, at first informally, through advice, advertisements, and recommendations, and then by the more stringent means of regulations and sanctions. The need to develop a rational strategy for decision making (regulatory or relating to regulation) and define environmental management practices *from existing scientific data* has led to the rise of risk evaluation as a scientific discipline, with its own vocabulary and methods." The methods of risk evaluation were developed principally in the United States, in order to satisfy the requirements of numerous laws promulgated in the 1970s and 1980s, which reflect the environmental preoccupations of that country (for example, CERCLA, FIFRA, SARA, and TSCA). In the 1980s, several commissions formed out of the National Academy of Sciences drew up methodological bases of risk evaluation: these are now used by numerous federal agencies: the EPA or FDA.

A specialized commission (the Risk Assessment and Management Commission) was created with the mission of evaluating the current standards and methods of risk evaluation and making recommendations on the best use of available information. The evaluation of ecotoxic risks is a recent and complex scientific field, with a significant conceptual base that does not have a fixed and unanimously accepted vocabulary. The reader will find a comparative analysis of modes of operation in the 1950s and today, as well as recommendations for the future, in an article by the renowned toxicoiogist John Douil (Doull, 1996). CERCLA, Comprehensive Environmental Response Compensation and Liability Act; FIFRA, Federal Insecticide, Fungicide and Rodenticide Act; SARA, Superfund Amendment and Reauthorization Act; TSCA, Toxic Substance Control Act. EPA, Environmental Protection Agency; FDA, Food and Drug Administration.

1.4. From Human Risk to Ecological Risk

We have earlier seen that evaluation of ecotoxic risk can be subdivided into two principal branches, the evaluation of *risk to human health* (health risk) and the evaluation of *ecological risk* (risk to the physical environment and plant and animal organisms other than human). Some examples show the poverty of this argument (Suter, 1993a):

• DDT and its metabolites have had adverse effects on some bird populations, without parallel with the effects so far observed in humans.

• PCDD/PCDF are much more toxic to several animal species than to humans: the pollution of the Love Canal (USA) had pronounced toxic effects on rodent populations (sterility and precocious mortality) and some bird populations suffered from the pollution of the Great Lakes (embryo mortality and teratogenesis). The evaluation of health risk and the evaluation of risk to other animal species are based on identical principles, but it was quickly recognized that the diagrams that were developed in the first case are not well adapted to the second. According to Suter (1993a), the divergences occur on the following points:

- Animals are exposed by avenues that are unique to them, for example, the grooming of fur in small mammals.
- Given the very large number of animal species, the probability of finding one or several species more sensitive than humans is mathematically not negligible. The cause of these interspecific differences is not always known. The large-scale phenomena of the ecosystem do not have a human equivalent, for example, the eutrophication of a lake or its acidification by acid rain." Species other than humans are subject to stronger exposure, for example, because of monophagous diets (a heron consumes only fish, while a human has a varied diet) or because of closer contact with the ambient medium (immersion in water for fish, close contact with the earth for small mammals and earthworms).
- Most birds and mammals are smaller than humans, and their energy metabolism more intense, which means that these species consume more contaminated food, drink more contaminated water, and breath larger volumes of polluted air (in relation to their unit of mass).
- Certain products are specially designed to fight pest species and inherently present a significant risk to neighbouring species on the phyllogenic plain (a herbicide presents higher risk to plants than a neurotoxic insecticide). Animal species are more closely allied to their environment than humans, who can always, at least theoretically, avoid certain dangers by varying their diet, eliminating certain foods, or changing their domicile. The different points of divergence between human risk and ecological risk pointed out by Suter do not all have the same weight. The existence of different levels or avenues of exposure does not justify different strategies in risk evaluation. For Lipton et al. (1993), the ecological risk differs from human risk on four essential points:
- The identity of receptors is unknown. The evaluation of human risk, since the beginning, has been focussed on the human, while the elements at risk are much more difficult to define in an evaluation of ecological risk. For example, the effects of DDT on invertebrates
- The receptors are located at different levels of biological organization. Health risk considers individual humans, while the evaluation of ecological risk must include populations, ecosystems, and eventually ecocomplexes.
- The number of species: a single species in the case of health risk, millions of species in the case of ecological risk.
- The level of biological organization: health risk is concerned essentially with the risk for some individuals and populations at risk; the evaluation of ecological risk is supposed to encompass the effects at the higher levels of biological organization, communities and ecosystems.

Table 1. Results from investigations

POSITION	FLOW M3/s	PH	REDOX Potential mV	Conduct. µS/cm	Average values (µg/lit)				
					Fe	Mn	Pb	Zn	Cd
Surface water (1)	0,5	8,22	-139	421	124	255	0,1	230	0,1
Surface water (1)	-	8,92	-180	248	30	20	3,5	7,5	0,1
Surface water (1)	0,25	7,87	-118	442	10	150	8,0	0,7	0,0
Surface water (1)	3,8	8,37	-85	560	60	15	8,0	5,0	0,5
Underground water	-	-	-	-	0,08	0,005	0,001	0,15	0,003
Sediments(mg/kg)	-	-	-	-	4	0,5	3320	4910	28
Soils(mg/kg)	-	-	-	-	4	0,2	1600	2550	20
Air(mg/m²/month	-	-	-	-	2	2,5	0,5	5,0	0,05

Table 2. Results from investigations

POSITION	FLOW M3/s	PH	REDOX Potential mV	Conduct. µS/cm	Average values (µg/lit)				
					Amonium	Nitrites	Nitrates	Sulphates	Chlorides
Surface water (1)	0,5	8,22	-139	421	0,1	0,003	0,25	120	
Surface water (1)	-	8,92	-180	248	0,05	0,006	0,25	50	
Surface water (1)	0,25	7,87	-118	442	0,15	0,100	1,60	50	
Surface water (1)	3,8	8,37	-85	560	0,05	0,050	2,50	70	
Underground water	-	-	-	-	0	0,003	3,00	50	7
Sediments(mg/kg)	-	-	-	-	0,02	0,800	55	3,25%S	-
Soils(mg/kg)	-	-	-	-	0,06	0,700	80	0,85%S	-
Air(mg/m²/month	-	-	-	-	-	-	20	400	400

REFERENCES

1. *Jean-louis Riviere*, Ecological Risk Evaluation of Polluted Soil, *A.A. BALKEMA, Rotterdam, Brookfield, 2000*
2. *Suter GW,* Ecological Risk assessment, *Lewis Publishers, Chelsea, 538 pp, 1993*
3. *Suter GW,* Weighing the Ecological Risk of Hazardous Waste Sites: the Oak Ridge case, *Environmental Science Technology, 1992*
4. *Volmr PD,* A proposed method for calculating taxonomic-group-specific variances for use in ecological risk assessment, *Chemosphere 1988*
5. *Urban DJ,* Hazard Evaluation, standard evaluation procedure, ecological risk assessment, EPA, *Washington DC, 1986*