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ARTICLES

From Environmental Ethics to Sustainable Decision-Making: Assessment of Potential Ecological Risk in Soils Around Abandoned Mining Areas-Case Study "Larga de Sus mine" (Romania)

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Abstract

The present study aimed at investigating the heavy metals concentrations in the soils around "Larga de Sus" abandoned mine (Zlatna, Romania), evaluating the potential ecological risk of heavy metal pollution and highlighting ethical aspects related to risk assessment, ecological restoration, and soil remediation. The results of the chemical analysis showed that the soil in the study area is highly polluted with heavy metals since the average concentrations of Pb (32.4–2318.1 mg/kg), and Ni (321.6–562.8 mg/kg) in soil exceed their corresponding threshold established by the Romanian legislation. The potential ecological risk index method developed by Hakanson was used to assess the potential risk of heavy-metal pollution. The results indicated that Pb and Ni showed severe and considerable potential ecological risk, while Cr had lightly ecological risk. In this case, remediation should be focused only on Pb or on all heavy metals even if they have lightly ecological risk? A scientific management technique cannot logically prescribe which choices should be selected. The interaction between human activity and the environment is complicated and difficult to quantify and risk management cannot and should not be based simply on risk assessment results. What is needed to make the right choice of the most appropriate alternative that fits our personality, culture, religion, and desires? The moral and ethical implications of ecological restoration and soil remediation (e.g. tolerance of uncertainty, responsibility, moral duty, etc.) have to be incorporated within the decision-making process in order to make optimum sustainable decisions and to achieve real environmental protection.

Keywords Environmental ethics · Ecological risk assessment · Heavy metals · Soil pollution · Sustainability

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Introduction

As the destructive consequence of unethical actions taken over the time, environmental contamination with heavy metals is, nowadays, a serious problem concerning not only specialists and researchers in the field of environment management but also the whole humanity (Jiang et al. 2014). Although heavy metals may occur naturally in the environment, additional contributions come from various sources including urbanization, industrialization and certainly mine activities (Zhou and Guo 2015) that were done for many years in discrepancy with the environmentally ethical values. Gandhi said, "Earth provides enough to satisfy every man's needs, but not every man's greed". Extreme greed, whether for money or for nature's resources, has disastrous consequences. The potential consequences of unethical actions taken over the time by humanity and immoral behavior in relationship with the environment have reached monumental proportions since people are not able to understand their responsibilities towards the environment. But, ethics are not about things are, but about the things should be (Taback and Ramanan 2013). However, it is still important to see how things got on this point.

Heavy metals present in tailings of former active mines can be released to surrounding soils, streams and groundwater mediated by erosion, weathering and leaching over a long duration even after the cessation of the mining activity (Huang et al. 2017a, b). Once heavy metals have reached soils, they tend to accumulate resulting in high levels of heavy metals in soils.

High levels of heavy metals in soils associated with mining activities pose potential threats and risks to local ecosystems and affect human health and safety directly through the food chain. Heavy metals are easily accumulated and absorbed by crops and their products and are persistent, bio accumulative and toxic (Huang et al. 2017a, b; Fan and Wang 2017; Huang et al. 2017a, b; Qiu 2010). In mining areas, it is evident that environmental problems are increasing rapidly day by day and human beings have been and are affected directly by these problems (Vromans et al. 2017).

Thus, ecological restoration of mining areas and remediation of soil contaminated with heavy metals is mandatory in order to reduce the associated risks for both ecosystems and human beings. According to Cairns (2003), the acid test of humankind's relationship to natural systems is the degree to which ecological damage caused by humans is repaired by humans for humans. But, in order to do this repair, it is necessary to assess, understand and realize this ecological damage produced.

In order to better understanding the long term impact of mining activities on the environment around the mining areas and to adopt a well-designed ecological restoration and soil remediation project, investigation of heavy metal content in soils and evaluation of the potential ecological risks in this mining area are of vital importance (Huang et al. 2017a, b). With regard to the investigation of heavy metal content in soils and evaluation of the potential ecological risks, technology and science are available to ensure analytical equipment, methods of analysis and evaluation methods, giving information and results based on which a well-designed ecological restoration and soil remediation project could be adopted. But, to adopt a well-designed ecological restoration and soil remediation project for mining areas, the remaining part to be considered is the ethical component. It should highlight if the ecological restoration and soil remediation is reliable according to certain ethical issues: "Does ecological restoration and soil remediation consider only human needs or also the natural system needs are considered?", "Does human dominate the ecosystem?", "Is likely to have unforeseen outcomes through the implementation of the ecosystem restoration and soil remediation project?".

The Society for Ecological Restoration (SER) has defined ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Light 2009). Looking at this current definition put forth in 2002, it seems to be too general and therefore, might not be able to do justice to the complexity of the concept.

According to Higgs (2003), recovery refers to the biogeochemical processes that allow an ecosystem to return to conditions that prevailed prior to disturbance. Thus, the act of restoration does not only aim to improve the state of a damaged area but to restore it to its previous condition, with the species richness and diversity and physical, biological and aesthetic characteristics of that site before settlement and the accompanying disturbances (Morrison 1987). Therefore, restoration projects tend to be looking into the past, looking into how the ecosystems worked prior to human intervention. Also, restoration places a high value on naturalness. But, from an ethical point of view, a dichotomy between "natural" and "human" is created. Humans cannot be distinguished as something different from nature when they are among the most significant expressions of nature. The conscious awareness, memory and deductive logic of humans do not set them apart from nature. Humans are a part of nature and therefore of ecosystems. Ecological restoration must be conducted in a way that will improve and restore the functions of both natural and human-managed ecosystems while contributing to the socioeconomic well-being of people. Nature sustains humans and fulfills their values. Moreover, the ecosystem is restored "to the future" within the context and constraints of the present. A system of environmental ethics is, in turn, a prerequisite for a culture to become cognizant of the need for social justice and intergenerational justice, that is, the importance of environment stewardship for the well-being of present and subsequent generations. A culture that accepts environmental ethics and intergenerational justice transcends the propensity for greed and has replaced it with an ethic of shared trust and caring as its underlying motivation (Clewel and Aronson 2007; Luuppala 2015).

At this moment, the definition of the concept doesn't address and states socioeconomic, ecological, ethic and cultural values involved in ecological restoration and should evolve to a wider vision that includes these approaches. From an ecological perspective, ecological restoration should represent the intentional activity that initiates or accelerates ecosystem recovery with respect to its integrity: species composition, community structure, ecological function and suitability of the physical environment to support the biota. From a socioeconomic perspective, it should recover flows of natural goods and services of economic consequence that functional ecosystems provide to society (Clewel and Aronson 2007).

From an ethical and cultural perspective, ecological restoration should represent the moral duty to recover ecosystem based on the right choices, without dominating the ecosystem and in a way that renew the human relationship to nature, as a part of it and increase the responsibility, respect and consciousness towards nature for the well-being of both present and future species living on Earth.

Remediation is not the same as restoration. According to Burger (2007), remediation normally refers to removing contamination. Soil remediation is expected "to ensure, as a minimum, that the relevant contaminants are removed, controlled, contained or diminished so that the contaminated land, taking account of its current use or approved future use at the time of the damage, no longer poses any significant risk of adversely affecting human health" (Telesetsky 2013).

Looking at these definitions, the term "soil remediation" is limited to removal of contamination and pollution or decreasing of its effect in order to avoid risk posed to human health. From an ethical point of view, a dichotomy between "environment" and "human" is created. The definition should evolve in order to consider the entire ecosystem and should not consider only human needs. Also, aspects regarding soil remediation as a moral obligation are not included in soil remediation definition. The environment should not be remediated only because it serves the human interest, as the present definition states. On the other side, the "minimum" level of remediation that no longer poses any risk to human health could threaten others ecosystem components.

Definition of ecological restoration and soil remediation should encompass all of these approaches and views. Only in this manner could be achieved the wholeness of the ecosystem, a good ecological restoration, and soil remediation. If ecological restoration and soil remediation do not include these approaches, it will not actually fix the problem and will not ensure that environmental degradation does not happen again. If ecological restoration and soil remediation are defined carefully, it avoids or responds to the main criticism raised against these two concepts.

Thus, as stated before a well-designed ecological restoration and soil remediation project should have a major ethical component since the future of humans and nonhuman life forms in Earth requires more than self-interest. From an ethical point of view, there is a big difference between saving nature for both present and future enlightened use by humankind (i.e. sustainable use of the planet) and saving natural systems because humankind has an ethical responsibility for the fate of the 30+ million species with which it shares the planet (Cairns 2003).

On the other hand, a well-designed ecological restoration and soil remediation project should be based on results obtained from risk assessment analysis. The term "risk" enjoys great popularity, though at the same time it comes with a variety of definitions. A definition often referred to says: the "term 'risk' denotes the likelihood that an undesirable state of reality (adverse effects) may occur as a result of natural events or human activities". A distinction is made between risk and hazard. While hazards are defined as a potential source of harm (e.g. toxicity of a chemical substance), a risk emerges when there is a likelihood that the hazard will produce harm. The technocratic understanding is an equation involving the possibility of an adverse effect and the potential damage, while the emphasis in social science, for instance, is laid on perception and decision-making. Different concepts and theories of risk have been developed. They vary from those found in cultural studies and the social sciences, which embrace a constructivist approach to nature, and the technical and natural sciences which adopt an objectivist approach. Social science theories stress ways of risk communication, risk perception (cultural theories) and subjective judgment of the extent and character of risks (psychological theory). An "environmental risk" is a product of exposition, toxicity, and sensitivity (Völker et al. 2017). The process that attempts to quantify the risk is included in risk assessment procedures.

Risk assessment procedures are methods and techniques that are used by government and sometimes industry to determine the magnitude and probability of the risk posed by hazardous chemicals or other environmental threats. Moreover, government agencies are using risk assessment procedures to set environmental standards and cleanup levels. Also, risk assessment procedures are a useful tool in cleanup decisions because the government must consider the toxicity of substances that can cause serious health and environmental problems at very low levels. This ability to measure the toxic effects of low levels of hazardous pollutants force government to ask "How clean is clean?" (Brown 1988). Risk assessment helps answer these questions because it is a tool that attempts to identify the environmental or health risks posed by pollutants at various levels.

Also, ecological risk assessment plays an important role in both theoretical support, and practical guidance for the implementation of regional sustainable development and ecological restoration in mining areas (Peng et al. 2015).

The exploitation of mineral resources from the polymetallic mining perimeters located near Zlatna town (Romania) was done for many years in discrepancy with the sustainable development causing extreme soil pollution with heavy metals (Dumitrel et al. 2013). Therefore, there is a need to develop a strategy for sustainable ecological restoration and development of this area.

Nowadays, sustainable development or sustainable use of the planet is given top priority as environmental policy in most countries. It is obvious that it is very difficult to achieve sustainable development unless environmental ethical approaches can be harmonized. It is, therefore, necessary to integrate ethical approaches into environmental policies and ecological restoration strategies in order to help in the decision-making process (Vromans et al. 2017).

Thus, investigating heavy metal content in soils, evaluating the potential ecological risk and highlight ethical aspects and issues are mandatory in order to plan a sustainable ecological restoration of the study area. Until now, some studies were conducted to identify contaminants and to determine concentrations of heavy metals in soils around mining perimeters located near Zlatna town (Romania) (Suciu et al. 2008; Keri et al. 2010, 2011) but none of these studies quantitatively evaluated potential ecological risk and embed related ethical aspects.

Therefore, the main objective of this research was to determine the concentrations of heavy metals in the soil around "Larga de Sus" abandoned mine (Zlatna town, Romania) and to assess the potential ecological risk of heavy metals in soil as a tool to help in the decision-making process. Also, the present study aims to list major ethical issues regarding ecological restoration, soil remediation, risk assessment and pollution control that human society must address to make an ethical judgment when trying to develop a sustainable ecological restoration and development in order to achieve real environmental protection.

It is necessary for people, especially environmental decision-makers and experts to harmonize and adopt ethical dimensions to scientific, technological, economic, social and legal aspects of controlling environment pollution to achieve real environmental protection (Vromans et al. 2017).

The contribution of the present study is to provide basic insights for seeking appropriate and sustainable management strategies to remediate heavy-metal polluted soil around “Larga de Sus” abandoned mine and other similar areas by considering science, technology, and ethical aspects.

Materials and Methods

Study Area

The Zlatna mining perimeter is located in South Apuseni Mountains (Romania) and comprises as the main exploitation “Larga de Sus” mine (GPS coordinates: 46°07′55.2″N 23°09′09.2″E) where the extraction of gold-silver ores and the mining of polymetallic ores took place for many years.

As shown in Fig. 1a, although the “Larga de Sus” gallery was closed in 2006, today being inactive, the mine wastewaters characterized by its strongly acid nature and significant levels of sulphate, iron and dissolved heavy metals (e.g. Zn, Mn, Cu, Pb, Cr, Cd, Ni) (Duma 2009) are flowing unimpeded on the soil (Fig. 1b) and receiving rivers, creating large imbalances in soil ecosystem.

It is obvious that these wastewaters have significant impacts on local environmental conditions, ecosystems and on economic and social welfare.

The main reason why this area became so polluted is that local authorities and the locals didn’t have the capacity and interest to prevent pollution and destruction due to the lack of available technology, cost involved and non-compliance with ethical values. They have the freedom to choose the direction they want to go in: to destroy or to protect. Freedom offers different choices.

(a) (b)

Fig. 1 Study area: **a** “Larga de Sus” mine gallery; **b** mine waters flowing from “Larga de Sus” gallery on the surface of the soil near the gallery

What is needed to make the right choice of the most appropriate alternative that fits our personality, culture, religion, and desires? Knowledge may be the answer that helps us determine between “good” or “bad”.

People have responsibilities towards nature (to guarantee the sustainability of natural resources or to try to re-establish damaged balances or rehabilitate ecosystems, etc.) towards society (humans live in society and have to consider the common interests; however, those interest should not be only human-focused) and towards future generations (Vromans et al. 2017).

The heart of the matter is that the solution to these kinds of environmental problems must include an ethical dimension as well as technological, scientific, ecological, economic, cultural, and social dimensions. This is the only way to produce final, complete, sustainable and successful solutions to our environmental problems (Vromans et al. 2017).

Soil Sampling and Analysis

For this study, a total of 10 soil sampling sites were selected according to a sampling design established based on the size of the investigated mining perimeter, knowledge of the site history, land topography, visual inspections conducted on site and the position of the main source of pollution, as shown in Fig. 2. Sample points 2AL, 4AL, 6AL, and 9AL were located in the forest on the left side, upstream, right side and downstream of the “Larga de Sus” mine, respectively. Sample points 11AL, 13AL, 14AL, 15AL, and SAL were located in the industrial area of the mine. Sample point 18AL was located on a pasture at about 800 meters downstream “Larga de Sus” mine.

From every single sampling point, marked with blue on the Fig. 2, were collected one soil sample corresponding to a depth of 10–30 cm, according to methodological norms stipulated in STAS 7184/1-94.

Fig. 2 Distribution of soil sampling points

Soil samples collected from “Larga de Sus” mine perimeter were analyzed through Atomic Absorption Spectrometry (AAS) using a SHIMADZU AA-6800 spectrometer.

Prior to the AAS analysis, the moist soil collected was crumbled, dried at 95 °C for about 10 h, sieved and milled to pass through a 250 µm sieve. Then, 3 g of prepared samples were placed in a 100 ml beaker with 1 ml distilled water, 21 ml of concentrated HCl (Hydrochloric Acid) and 7 ml of concentrated HNO_3 (Nitric Acid). The glasses were covered with a glass plate and left for mineralization for 2 h (beakers containing samples were heated on a sand bath).

After cooling, mineralized samples were filtered through 0.45 µm pore size filter into a 100 ml volumetric flask, filled to the mark with distilled water and analyzed for heavy metal content through AAS. Precision and accuracy of analysis were assured through repeated analysis of samples against Standard Reference Material (standard calibrations solutions) for all the heavy metals. All the analyses were performed in duplicate on two lab replicates at 25 °C and the average values were reported. Quality control measures were taken to ensure the reliability of the data. Calibration blanks were run after every 4 determinations. All chemicals were of analytical grade or ultrapure. The water was distilled using a Technosklo water distiller and all glassware was acid washed before use.

Assessment of Potential Ecological Risk Index (RI)

Environmental risk assessment procedures specify how environmental hazards will be characterized as to the nature and magnitude of the harm posed by these hazards (Brown 1988). Risks have been classically understood as a probability of damage or a potential hazard resulting in appropriate management strategies (Völker et al. 2017).

RI was introduced to assess the ecological risk degree of heavy metals in soil or sediments, was originally proposed by Hakanson (1980) and widely used (Zhu et al. 2012; Rashki et al. 2015). The Hankanson potential ecological risk index (RI) is defined as follows (Zhou 2015):

$$RI = \sum_{i=1}^{n} E_r^i \tag{1}$$

where RI is a composite index indicating the potential ecological risk of total hey ms in soils; n is the total number of heavy metals and E_r^i. is an index of potential ecological risk of an individual element of heavy metals, which can be calculated with Eq. (2) (Zhou 2015):

$$E_r^i = T_r^i * C_r^i \tag{2}$$

where T_r^i is the toxic response factor indicating the toxic level of an individual element and the sensitivity of medium to the heavy metals. According to the report of Hakanson (1980), T_r^i of Pb, Cr, and Ni are assumed to be 5, 2 and 5 respectively (Zhou 2015; Soliman et al. 2015). C_r^i is the pollution index of an individual heavy metal, that can be calculated with the concentration of the element in soil (C^i) and the reference value (C_R^i) using Eq. (3) (Zhou 2015):

$$C_r^i = C^i / C_R^i \tag{3}$$

where the reference value is referred to natural background value of the element from the environmental quality standard for soils in Romania (Order no. 756/1997). According to Romanian standard (Order no. 756/1997), the natural background value for Ni, Pb, and Cr is 20 mg/kg dry matter, 20 mg/kg dry matter and 30 mg/kg dry matter, respectively.

The relation between evaluation indices and the pollution degree and potential ecological risk are shown in Table 1.

Before one can analyze the ethical questions embedded in risk assessment, one must first be capable of identifying those aspects of risk assessment procedures that raise ethical and/or scientific questions. Most of the current debate about risk assessment appears to be scientific rather than ethical. The number of scientific questions raised in risk assessment is numerous because of the considerable uncertainty that exists in risk assessment (Brown 1988).

Science makes probabilistic statements about the nature of the world but does not offer a course of action. Science also helps to define problems and gather information about the extent and severity of environmental change and clarifies the links between environmental change and human self-interest. The basic ethical question here becomes: Does human self-interest differ from that of ecological integrity? (Cairns 2003) and/or How it is possible to ascribe responsibilities to actions for which we are not able to oversee the consequences? To answer such questions, fundamental ethical reflection is needed next to science (Meijboom and Brom 2012).

Besides, from a proposition that a particular problem creates a particular risk, however, one can't deduce what risk is acceptable without first deciding the criteria of acceptability. Therefore, on a largely traditional view of the logic of ethics, science can't answer ethical questions all by itself (Brown 1988).

Also, these kinds of risk analyses are useful for identifying causes and predicting events with undesirable effects and therefore help decision-makers in accident management and emergency planning. These effects can cause feedback processes that might call for new decisions, or have effects on cultural and social processes. Such feedback processes can be immediate or buffered; they can be anticipated with a proactive reaction, or non-anticipated with a reactive response, and they can take place within a system as well as affecting other systems (Völker et al. 2017).

Taking feedback processes and unintended effects into account, it is important to be aware that every action associated with risk management and problem-solving

Table 1 Corresponding relationships between evaluation indices, pollution degree and potential ecological risk (Rashki et al. 2015; Zhou 2015)

E_r^i	Ecological risk level of single factor pollution	RI	General level of potential ecological risk
<40	Low	<150	Low
40–80	Moderate	150–300	Moderate
80–160	Considerable risk	300–600	High
160–320	Great risk	≥ 600	Very high
≥ 320	Very great risk		

can cause non-intended effects and risks; this is called self-referentiality. Who or what is "at risk"? From a social-ecological perspective, societies, as well as ecosystems, can be at risk, ranging from "material things", such as infrastructure, buildings, etc., to humans and non-humans, like organisms and whole ecosystems, to social-ecological systems, like the operation of a provisioning system. The causes of risks lie mostly in human activities since most bio-physical processes and natural resources are regulated by societies (Völker et al. 2017).

Another ethical issue that must be considered during taking actions associated with risk management is the fact that a decision that seems to be empirically based to some scientists may seem to be based on ethics to others—because, while some professionals judge the uncertainty of the scientific data acceptable, others judge it excessive. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made. However, they are linked—acting with an intolerance of uncertainty often demands a high tolerance for risk (Cairns 2003).

Results and Discussion

Heavy Metals Content of Soil from Study Area

The concentrations of Pb and Ni in soil collected from "Larga de Sus" mining perimeter is illustrated in Figs. 3 and 4. The sampling sites were demarcated as sensitive and less sensitive based on the land use category, in order to compare the results obtained with alert and intervention threshold that is stated in Romanian legislation (Order no.756/1997) as a function of land use category. Romanian regulations define sensitive land use as the one represented by the land use for residential and recreational areas, for agricultural purposes, as protected areas or restricted sanitary areas, as well as the areas of land forecasted for such uses in the future.

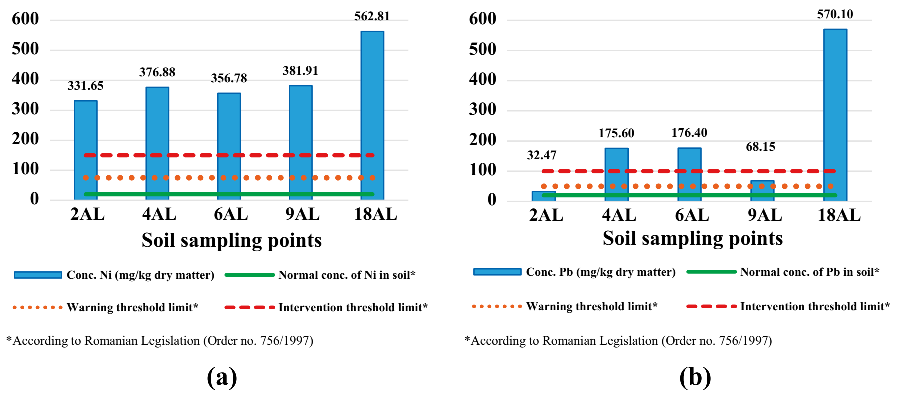

Fig. 3 The concentration of heavy metals in soil samples collected from land included in sensitive land uses category on "Larga de Sus" mining perimeter: **a** The concentration of Ni in soil samples; **b** The concentration of Pb in soil samples

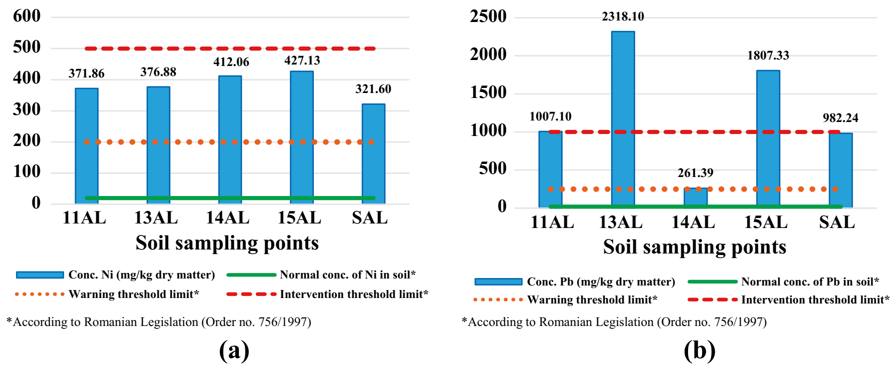

Fig. 4 The concentration of heavy metals in soil samples collected from land included in less sensitive land uses category on "Larga de Sus" mining perimeter: **a** The concentration of Ni in soil samples; **b** The concentration of Pb in soil samples

Less sensitive land use includes all existing industrial and commercial uses as well as land areas intended for such uses in the future. Therefore, according to their position, the sampling sites 2AL, 4AL, 6AL, 9AL, and 18AL were included in sensitive use category, while sampling sites 11AL, 13AL, 14AL, 15AL, and SAL were included in less sensitive use category.

The concentration of Ni and Pb in soil samples collected from land included in sensitive land uses category is presented in Fig. 3a, b, respectively.

As can be seen in Fig. 3a, the concentration of Ni exceeds more than 2 to 3.7 times the intervention thresholds limits established by Romanian legislation (Order no. 756/1997) (200 mg/kg dry matter) on all five soil samples collected from land included in sensitive land uses category on "Larga de Sus" mining perimeter.

In case of Pb (Fig. 3b), concentration found on soil samples collected from land included in sensitive land uses category exceeds more than 1–11 times the warning threshold limit (50 mg/kg dry matter) on four soil sampling points and more than 1–5 times the intervention threshold limits (100 mg/kg dry matter) on three soil sampling points, respectively.

Concentration of Cr (0.01, 8.95, 10.75, 60.9 and 28.66 mg/kg dry matter for 2AL, 4AL, 6AL, 9AL, and 18AL sampling points, respectively) found in soil samples collected from land included in sensitive land uses category from "Larga de Sus" mining perimeter exceeds only the normal concentration of Cr in soil established by the same Romanian legislation (30 mg/kg dry matter).

On the other hand, the concentration of Ni and Pb in soil samples collected from land included in less sensitive land uses category is presented in Fig. 4a, b, respectively.

With regard to the concentration of Ni found in soil samples collected from land included in less sensitive category on "Larga de Sus" mining perimeter, from Fig. 4a it is obvious that warning threshold limits (200 mg/kg dry matter) were exceeded with more than 1.6 times, but the concentration of Ni didn't exceed the intervention threshold limit (500 mg/kg dry matter). In contrast to this, the concentration of Pb exceeds intervention threshold limit (1000 mg/kg dry matter) in three soil sampling points, according to Fig. 4b.

In case of Cr, concentration found in soil samples collected from land included in less sensitive uses category (57.32, 0.01, 23.28, 59.11, and 57.32 mg/kg dry matter for 11AL, 13AL, 14AL, 15AL and SAL sampling points, respectively) didn't exceed warning (300 mg/kg dry matter) or intervention threshold limits (600 mg/kg dry matter).

The concentration of other analyzed heavy metals (Cu, Cd, Zn, As) was below the detection limit of the SHIMADZU AA-6800 spectrometer.

Thus, as a cause of human mismanagement, even if the concentration of Cr identified in collected soil samples didn't exceed threshold limits, the above results show that soil and land near "Larga de Sus" gallery is highly polluted with Ni and Pb, since concentration of Ni and Pb exceeds warning and intervention threshold limits in many considered soil sampling points, being mandatory to find a sustainable remediation strategy. The results obtained in the present study are comparable to the results obtained by Suciu et al. (2008) when studied the heavy metal content in soil in Zlatna Region. It was concluded that the Pb concentration in soil sample exceeds alert threshold limit stated in Romanian legislation, while Cr concentrations identified in soil samples exceeds only the normal concentration of Cr in soil established by the same legislation (Suciu et al. 2008).

In order to find a solution to problems involving environmental changes or manipulation of environmental problems must involve not only technical engineering decisions but also other concerns such as the economic and ethical dimensions. This can be managed only by morally developed environmental experts and decision-makers (Vromans et al. 2017).

At this stage, some ethical question may be raised. Does a morally developed environmental expert may have to choose between protecting people from heavy metal contaminated soil by leaving some contaminated soil behind the fence or requiring that all the heavy metal polluted soil to be completely removed to another location or implement a technology that could affect others systems?

This kind of question cannot be answered by science alone because it is essentially ethical or political. If for instance, a risk assessment determines that heavy metals from contaminated soil nearby "Larga de Sus" mine pose a risk on human health, the first decision that an environmental expert may think about is taking measures to protect locals nearby "Larga de Sus" mine from the risk posed. One alternative would include diminishing risk posed to locals nearby "Larga de Sus" mine by taking remediation measures that will not assure a complete and effective soil remediation due to the lack of available 100% efficient remediation technology (every soil remediation technology leave a residual or secondary product). In this situation, some heavy metal polluted wastes should be left somewhere. Moral integrity requires environmental experts to ensure that environmental degradation does not happen again. The moral development of environmental experts means that environmental experts form their own ethical framework to live in harmony with nature by assessing the consequences of their relationships with nature. A moral developed environmental expert should choose not leaving this waste behind the fence where the others parts of the ecosystem and other locals as well could be affected and should be aware that remediation should not benefit and be addressed only to the needs of locals nearby "Larga de Sus" mine. People are a part of nature and should be not seen as something outside nature. Remediation of soils nearby "Larga de Sus" mine must improve both ecological and humans' health. An important way of delivering a sustainable solution to the bigger picture of the environmental crisis identified on mining sites is by scrutinizing the moral realm of locals, administrations and authorities, and the human relationship with nature. If local administrations, authorities, and community located in mining sites, do not acknowledge its dependence on ecological life support systems, it will lose the chance to survive and develop in that area. Another alternative that could be taken into account for restoration of mining sites might refer to completely remove the heavy metal polluted soil to another location, where people might not be at risk or to choose to implement a remediation technology that has unforeseen negative effects on other systems. In these situations, the same ethical issues besides uncertainty will appear that will make decision-making difficult as it could cause bigger ecological damage to another habitat or ecosystem than the total initial ecological repair. Every action taken would have an impact on the entire ecosystem. It is important to choose the alternative that has a positive impact and an improvement in ecological and human health or life quality, for both present and future generations.

Ethics clearly plays a role in these decisions, because such complex assessments or scenarios include a number of value assumptions and use concepts such as risk, safety, health, and welfare that all ask for more than mere technical competence. As a result, a scientific management technique cannot logically prescribe which choices should be selected for mining areas if a management technique refrains from taking a position on these ethical issues. Also, taking a position on these ethical issues can be just as difficult. In some circumstances, one may take comfort in the high probability that the restored ecosystem or remediated soil from mining areas will almost always be ecologically superior to the damaged ecosystem or soil. Furthermore, a healthy environment will certainly go to provide more services to a society near mining areas and to the entire ecosystem.

Ecological Risk Assessment

The potential ecological risk indexes for every metal identified on soil samples collected from "Larga de Sus" mining perimeter is presented in Table 2.

As can be seen in Table 2, indexes of potential ecological risk range between 80.4–140.7, 8.1–579.5 and 0.001–4.06 for Ni, Pb and Cr, respectively. The values of potential ecological risk indexes obtained are comparable to the results obtained by Huang et al. (2017a, b) that found that the potential ecological risk index ranges from 163.9 to 385.05 when studied the potential ecological risk of heavy metals in soils of a Pb–Zn mining area in Huan Provence (China). Estimated values of potential ecological risk of an individual element show that investigated heavy metals were ranked in the order of Pb > Ni > Cr indicating that Pb pose a very high risk to the local ecosystem and should be preferentially controlled. On the other hand, the

Table 2 The indexes of potential ecological risk of heavy metals in soil samples

Element	Sample ID	Ni	Pb	Cr	RI
T_r^i	–	5	5	2	–
E_r^1	2AL	82.913	8.118	0.001	91.031
E_r^2	4AL	94.220	43.900	0.597	138.717
E_r^3	6AL	89.195	44.100	0.717	134.012
E_r^4	9AL	95.478	17.038	4.060	116.575
E_r^5	18AL	140.703	142.525	1.911	285.138
E_r^6	11AL	92.965	251.775	3.821	348.561
E_r^7	13AL	94.220	579.525	0.001	673.746
E_r^8	14AL	103.015	65.348	1.552	169.915
E_r^9	15AL	106.783	451.833	3.941	562.556
E_r^{10}	SAL	80.400	245.560	3.821	329.781

potential ecological risk index results indicated that Pb and Ni showed very high and considerable potential ecological risk, while Cr had lightly ecological risk.

Based on above risk assessment analysis, an environmental specialist could plan a remediation strategy that will be focused on lowering the level of Pb from the polluted soil near "Larga de Sus" mining perimeter to an acceptable risk level.

In this case, risk management decisions that simply declare that cleanup procedures at a superfund site will leave pollutants at a level that pose an acceptable risk may hide important ethical questions. The term "acceptable risk" includes a normative dimension that is usually not defended in the public policy debate (Brown 1988).

According to Fig. 5 that indicates potential ecological risk degree of a single sampling point by heavy metal, sampling sites 4AL, 6AL and 14AL (located in the forest near the studied gallery) were at moderate risk, while sampling sites 18AL (located on a pasture at about 800 meters away from the gallery), 11AL, SAL and 13Al and 15AL (sampling points located right next to the gallery) were at considerable, great and very great risk in case of Pb. Contrariwise, in the case of Ni and Cr, all considered sampling sites were at considerable risk and low risk, respectively.

Considering total potential ecological risk index of all investigated heavy metals, sampling sites 2AL, 4AL, 6Al, 9AL and 18AL, 11AL, 14AL were at low risk and moderate risk, respectively. On the other hand, sampling points 15AL and

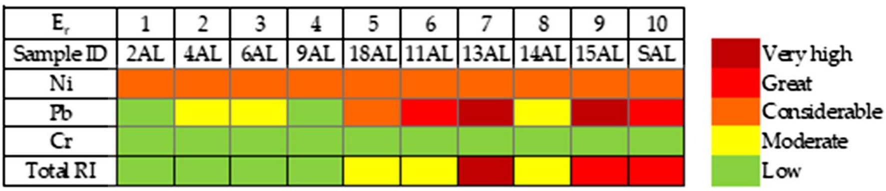

Fig. 5 Ecological risk degree of the heavy metals in soil based on corresponding relationships between evaluation indices, pollution degree, and potential ecological risk

SAL were at great risk while 13AL sampling point was at very great risk, indicating that heavy metals in 13AL (sampling point located right next to the gallery) sampling point pose very great ecological risk to the local ecological system and human health and should give serious concern.

Thus, appropriate engineering measures, ecological measures and ecological restoration of the area could start with the "red" points were very great risk was identified and with the heavy metal that pose a very high risk to the local ecosystem (Pb). But, risk management decisions may mask certain considerations when a risk manager, under the pressure of scientific uncertainty, bases a risk management decision on liberal assumptions because could not prove that more conservative assumptions represent the actual risk. Who has the burden of proof to show that a new technology or substance is safe, or that the risk is acceptable is an important ethical consideration. Also, "How it is possible to ascribe responsibilities to actions for which we are not able to oversee the consequences?" is another ethical question raised in this stage.

Individuals or institutions can take responsibility regarding their actions related to ecological restoration of mining sites by using their capacity of practical reasoning to reflect on the perceptions, options for actions and moral beliefs. But, how future consequences of present actions and decisions can be seen? Everything we do for ecological restoration of mining sites is in some way chosen. Even not choosing or, put differently, if we do nothing for the restoration of mining sites, has just as strong a consequence as any active choice we may make. There is no way to avoiding this challenge. Thus, remains the challenge to develop some practical tools that enable us to take a forward-looking responsibility and make informed choices. How can such tools be obtained? We cannot develop tools to predict the future in detail and uncertainty is present in any active or passive choice and decision. So, it is unlikely that it will find a "crystal ball" to inform us about the long-term consequences of our contemporary choices (Waelbers 2011). The only reference we have is the consequences of our past decisions and actions. Nevertheless, if we want to take a forward-looking responsibility or if we want to make well-balanced decisions we should at least try to imagine what the possible social and moral impacts of ecological restoration of mining sites can be.

The main issue is that administrations and authorities carry out risk management options based on risk analyses results and the defined acceptable risk levels. In the case studied in the present paper, an environmental specialist or authority that will not consider all socioeconomic, ethical and cultural values involved in remediation, could plan a remediation strategy that will be focused on lowering the level of Pb from the polluted soil and "red" points near "Larga de Sus" mining perimeter to an acceptable risk level. Acceptable risk is an emotive term used to represent a level which society believes is 'good enough' (Gough 1988). But, everyone has personal views on what is an acceptable level, which may be different from that of society as a whole (risk perception).

The judgment, choices, and decision that must be taken in the risk management process, ecological restoration and soil remediation should be in accordance with socioeconomic, ecological, ethic and cultural values. Some ethical issues involved in ecological restoration, soil remediation and risk assessment are suggested in Table 3, together with some solutions to them.

In order to provide a foundation to the ethical issues, questions and solutions included in below table, a literature review was undertaken on various academic papers and books spanned on ethical debates on ecological restoration and remediation. The literature review functions as the background upon which the rest of the research is subsequently based, and allows connections to be made between material in the readings and the "Larga de Sus" mining site. Moreover, site visits that were conducted for more than 4 years allowed enhanced understanding of the history of the area as well as greater ease connecting with locals who had an in-depth understanding of political, social, technical and cultural aspects involved in ecological impact of the site and human-nature interactions. In order to analyze the information gathered from the above research methods, identify issues reflected on the studied area, and to propose solutions, some viewpoints regarding ecological restoration suggested by Higgs (2003), Light (2009) and Cairns (2003) were used.

The proposed solutions and questions addressed to the ethical issues presented in Table 3 are relevant for "Larga de Sus" mine. For example, in order to avoid subjective decision regarding wrong or bad or acceptable and unacceptable when a soil remediation technology needs to be implemented for remediation of soil polluted with heavy metals around "Larga de Sus" mine, an ethical standard for good practices indicating the best alternatives for soil remediation that could be implemented in this mining area should be created. This ethical standard should provide an overview of principles and procedures to be applied for identifying whether one land is an unacceptable risk for human health and environment. Moreover, it should evaluate each soil remediation technology from socioeconomic, ecologic, ethical and cultural viewpoints and its implications in these dimensions. Two examples of standards that however needs to be changed in order to consider all these viewpoints are National Strategy and National Plan for Managing Contaminated Sites from Romania and The Governmental Program for the closing and greening process of mining sites 2007–2020 (Decision no. 683/2015). In these national policies, there is no clear and precise methodology for the remediation of soil and socioeconomic, ecological, ethical and cultural aspects involved in the remediation process are not considered. Effective restoration and remediation, for example, establishes and maintains an ecosystem's values. This principle should be reinforced by a series of guidelines that give specification to the principle, including avoiding harm, reestablishing ecosystems, structure, function, and composition, enhancing resilience, restoring connectivity, encouraging and reestablishing traditional cultural values and practices, and ensuring research and monitoring. These must be further supported by best practices, recommended processes for practice, and case studies. Romanian national policies should cover all these aspects raised in every contaminated site, including "Larga de Sus" mine and initially, should be modified in accordance with Principles of World Commission on Protected Areas-SER Ecological Restoration for Protected Areas and International Standards for the Practice of Ecological Restoration (Higgs et al. 2018). As principles articulate guidance with greater generality, ranging over a larger set of possible applications, they require more careful interpretation by practitioners for application in particular situations.

Table 3 Ethical issues involved in ecological restoration, soil remediation and risk assessment (Cairns 2003; Martin 2017; Brown 1988; Luuppala 2015; Bell et al. 2006; Clewel and Aronson 2007)

Ethical issues	Overview	Questions addressed	Solutions
Uncertainty of outcome	The ecological restoration and soil remediation will have unforeseen outcomes, even when carried by the most skilled professionals and important variables may be omitted	Is likely to have unforeseen outcomes through the implementation of the ecosystem restoration and soil remediation project?	One may take comfort in the high probability that the restored ecosystem or remediated soil will almost always be ecologically superior to the damaged ecosystem or soil. Furthermore, a healthy environment will certainly go to provide more services to society and to the entire ecosystem
The decision regarding wrong or bad and acceptable or unacceptable	Deciding when or what is wrong or bad or acceptable or unacceptable could be subjected to a subjective judgment in the ecological restoration or soil remediation	How can be decided when or what is wrong or bad or acceptable or unacceptable? Who is accepting what, in which way, and when?	Create criteria that help differentiate right from wrong or acceptable from unacceptable (ethical standards)
Ego or Eco?	The position of humans in the ecosystem, the relationship between humans and nature and perception of nature	The relation between human and nature is considered in ecological restoration and soil remediation? Do ecological restoration and soil remediation consider human self-interest or natural systems interest? Does human dominate the ecosystem? The worth of nature is recognized?	Determining whether this relationship, as it now exists in the ecosystem, would permit to live a quality life or relations needs to be improved/changed
Remediation and ecological restoration goals	Awareness of the importance of the restoration process, the means by which to restore, and the product of the restoration and remediation. The ideal states and conditions that an ecological restoration effort attempts to achieve consider all social, ecological, ethic and cultural values	Why are remediation and ecological restoration important? Goals are meant to be in the best interest of society, nature or personal interest? What goals should be driving restoration and remediation?	Clear establishment of remediation and ecological restoration goals in the project phase considering social, ecological, ethical and cultural views. Social, ecological, moral and cultural values provide guidance and should play a vital role when choosing a certain goal over another

Table 3 (continued)

Ethical issues	Overview	Questions addressed	Solutions
Judgment by the magnitude, extent, and character of risks	Choices in soil remediation and ecological restoration are values judgments, matters of morality, and social and political judgments, not technically dictated	A technically dictated solution should be implemented for soil remediation? Soil remediation should be focused on risk assessment results: spots where the highest risk level was identified and the heavy metal that pose the highest risk to the environment? The risk posed to the environment should be removed or reduced to an acceptable risk level?	In order to achieve sustainable soil remediation, it is needed to consider all the results of the risk assessment analysis and aspects involved (social, economic, ethical and cultural). The risk posed to the environment (entire ecosystem) should be reduced to as maximum as possible within the context and constraints of the present

All restoration attempts aim for a successful outcome. Nevertheless, the uncertainty of outcomes is present in every ecosystem restoration and soil remediation project. For example, if a soil phytoremediation technology that uses exotic plant species (e.g. Indian mustard “Brassica juncea”) will be implemented for remediation of soil polluted with heavy metals nearby “Larga de Sus” mine, the indigenous species present at “Larga de Sus” mine could be as threatened by invasive exotic species as by stress posed by heavy metal pollution or even worse. In these conditions, total ecological destruction exceeds total ecological repair. Moreover, ecological restoration efforts might eliminate those species that had initially colonized at “Larga de Sus” mine and were able to tolerate anthropogenic stress (e.g. Robinia pseudoacacia). It is distressing to think that species that are removed as landscapes from “Larga de Sus” mine are restored might actually turn out to be quite desirable someday. The same issue of ecological restoration was identified by Cairns (2003) besides others ethical problems associated with ecological restoration: the resource/commodity trap, mitigative destruction of ecosystems, displacement of species best able to tolerate anthropogenic stress, etc.

Due to the uncertainty of outcome involved, choices in soil remediation and ecological restoration are values judgments, matters of morality, social and political judgments. Cairns (2003) stated that “considerable ethical judgment will be necessary in making these decisions about recolonizing species, and, inevitably, the decisions will not be the same from one site to another. These issues must be discussed and evaluated before the restoration is ever started so that the risk to the species sources are explicitly stated and the probability of success is related to the risks of doing further damage.”

But, in some situations, one may take comfort in the high probability that the restored ecosystem or remediated soil will almost always be ecologically superior to the damaged ecosystem or soil. Furthermore, a healthy environment will certainly go to provide more services to society and to the entire ecosystem. Berger stated that ‘If the species are not the same, then assuredly we do not have perfect structural (species) restoration, but we may have a restoration of certain if not many important species and some ecosystem functions’ (Cairns 2003).

In the case studied on the present paper, the following question was raised: “The risk posed to the environment by heavy metals pollution of soil nearby “Larga de Sus” mine should be removed or reduced to an acceptable risk level?”. Reducing risk to an acceptable risk level could not be generalized since, everyone has personal views on what is an acceptable level, which may be different from that of society as a whole. Thus, considering the actual development and the possibilities of the studied area, the lack of available remediation technology and clear standards and the involvement of administrations, authorities, and locals, the answer is simple: the risk posed to the environment (entire ecosystem) should be reduced to a maximum as possible within the context and constraints of the present.

Although it is admittedly important to continue to enhance our analytical ability to make mathematical estimates of risk, it is also critically important to develop the ability and procedures to identify the many values questions that are often central to making a risk management decision but that are sometimes hidden in the risk assessment jargon. Failure to identify the ethical positions that are necessarily embedded in most risk assessment procedures leads to the following problems: failure of democratic institutions, inability to analyze risk management decisions, the propensity of costs to influence risk assessment and risk management procedures and the propensity to clean up to acceptable levels only (Brown 1988).

Conclusions

The results of this study provide valuable information about heavy metal contamination of soils in "Larga de Sus" mining perimeter (Zlatna, Romania) and risk posed by heavy metal pollution of soils to the local ecosystem.

The detected levels of Pb and Ni in the soil around "Larga de Sus" abandoned mining perimeter exceeds the national thresholds limits, indicating the impending need to fully investigate and assess the ecological impact on the local ecosystem. The most heavily contaminated areas appear in the vicinity of the mine and at about 800 meters far away the mine in case of Pb and Ni, respectively.

Ecological risk assessment results show that the total potential ecological risk was moderate to very great on more than half of the samples collected. Pb was the key influence factor to cause the potential ecological risk (its value achieve 579.5) since heavy metals (Ni, Pb, and Cr) in soil were ranked by severity of ecological risk as Pb > Ni > Cr.

The overall risk indexes caused by the heavy metals in soil samples were 673.74 corresponding to very high risk. Great to very great ecological risk has been estimated to exist in the area right next to "Larga de Sus" gallery, while at the region a bit farther from the gallery, there exist low to moderate ecological risk.

Thus, sustainable ecological restoration of the studied area should be focused first on the results of the ecological risk assessment conducted in this study, but environmental decisions must be viewed primarily as ethical choices rather than as technically dictated conclusions.

In other words, risk assessment procedures and decision-making process regarding ecological restoration and soil remediation, must be amended to assure that ethical issues listed by the present study (uncertainty of outcome, tolerance of uncertainty, responsibility, moral duty, relation between humans and nature, judgment involved etc.) are identified to avoid systematic distortion of values questions. Experts, decision-makers and citizens must pay specific attention to ethical values in order to safeguard restoration and remediation projects from turning into malicious restoration or remediation.

In the case studied on the present paper, the following question was addressed besides other important ethical questions: "The risk posed to the environment by heavy metals pollution of soil nearby "Larga de Sus" mine should be removed or reduced to an acceptable risk level?". Everyone has personal views on what is an acceptable level, which may be different from that of society as a whole. Thus, considering the actual development and the possibilities of the studied area, the lack of available remediation technology and clear standards and the involvement of administrations, authorities, and locals, the answer is simple: the risk posed to the environment (entire ecosystem) should be reduced to a maximum as possible within the context and constraints of the present.

Therefore, it is not easy to achieve sustainable ecological restoration, soil remediation or development unless environmental ethical approaches can be harmonized. The task would be a lot easier if ecologists understood the philosophical and ethical grounding of their work and why they are aiming to restore in the first place and if philosophers understood how ecology works, how ecosystems came about and what the suitable role for humans would be in all of this. Sustainable decision-making process must find an optimum between people, profit, planet, and ethical views.

Besides ethical issues regarding ecological restoration, soil remediation and risk assessment listed in the present study, other important ethical include determining when to discontinue a restoration, remediation or risk assessment effort and determining if ecological repair equal the rate of ecological destruction.

Nature is the measure to judge the ethical rightness of our judgments, actions, and behavior, and we must ensure that we comprehend and understand the full context of our actions.

References

Bell, R., Glade, T., & Danscheid, M. (2006). Challenges in defining acceptable risk levels. In W. J. Ammann, S. Dannenmann, & L. Vulliet (Eds.), *RISK 21-coping with risks due to natural hazards in the 21st century: Proceedings of the RISK21 workshop* (pp. 87–98). Ascona: crc Press.

Brown, D. A. (1988). Superfund cleanups, ethics and environmental risk assessment. *Boston College Environmental Affairs Law Review, 16,* 181–198.

Burger, J. (2007). The effect on ecological systems of remediation to protect human health. *American Journal of Public Health, 97,* 1572–1578.

Cairns, J. (2003). Ethical issues in ecological restoration. *Ethics in science and Environmental Politics ESEP, 3,* 50–61.

Clewell, A. F., & Aronson, J. (2007). *Ecological restoration. Principles, values, and structure of an emerging profession*. Washington, DC: IslandPress.

Decision no. 683/2015 regarding National Strategy and National Plan for Managing Contaminated Sites from Romania, Official Gazette no. 683 of 31/08/2015 (**in Romanian**).

Duma, S. (2009). The impact of mining activity upon the aquatic environment in the Southern Apuseni Mountains. *Romanian Review of Regional Studies, V,* 51–66.

Dumitrel, G.-A., Popa, M., Glevitzky, M., Vica, M., & Todoran, A. (2013). Evaluation of soil heavy metal pollution in the Zlatna region. *Journal of Environmental Protection and Ecology, 14,* 1569–1576.

Fan, S., & Wang, X. (2017). Analysis and assessment of heavy metals pollution in soils around a Pb and Zn smelter in Baoji City, Northwest China. *Human and Ecological Risk Assessment: An International J.*. https://doi.org/10.1080/10807039.2017.1300857.

Gough, J. (1988). Risk and uncertainty. Information Paper No. 10. Resource document. Centre for Resource Management University of Canterbury and Lincoln College. https://researcharchive.lincoln.ac.nz/bitstream/handle/10182/1376/crm_ip_10.pdf;sequence=1. Accessed 16 December 2018.

Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Research*, *14*, 975–1001.

Higgs, E. (2003). *Nature by design*. Cambridge, MA: MIT Press.

Higgs, E., Harris, J., Murphy, S., Bowers, K., Hobbs, R., Jenkins, W., et al. (2018). On principles and standards in ecological restoration. *Restoration Ecology, 26,* 399–403.

Huang, S. H., Li, Q., Yang, Y., Yuan, C. Y., Ouyang, K., & You, P. (2017a). Risk assessment of heavy metals in soils of a lead–zinc mining area in Hunan Province (China). *Kemija u Industriji*. https://doi.org/10.15255/KUI.2016.049KUI-15/2017.

Huang, S., Yuan, C., Li, Q., Yang, Y., Tang, C., Ouyang, K., et al. (2017b). Distribution and risk assessment of heavy metals in soils from a typical Pb–Zn mining area. *Polish Journal of Environmental Studies*. https://doi.org/10.15244/pjoes/68424.

Jiang, X., Lu, W. X., Zhao, H. Q., Yang, Q. C., & Yang, Z. P. (2014). Potential ecological risk assessment and prediction of soil heavy-metal pollution around coal gangue dump. *Natural Hazards and Earth Systems Sciences*. https://doi.org/10.5194/nhess-14-1599-2014.

Keri, A. A., Avram, S., & Rusu, T. (2010). Characteristics regarding the geomorphological change of land at the Larga de Sus Mine, the Zlatna Mining Perimeter, the County of Alba. *ProEnvironment, 3,* 318–321.

Keri, A. A., Melenti, I. L., & Rusu, T. (2011). Complex recovery possibilities of the sterile deposited at the mine Larga de Sus (County of Alba). *ProEnvironment, 4,* 217–223.

Light, A. (2009). Ecological restoration: From functional descriptions to normative prescriptions. In U. Krohs & P. Kroes (Eds.), *Functions in biological and artificial worlds: comparative philosophical perspectives* (pp. 147–161). Cambridge: MIT Press.

Luuppala, S. L. (2015). Ecological restoration: Conceptual analysis and ethical implications https://helda.helsinki.fi/bitstream/handle/10138/170046/ecologic.pdf?sequence=1. Accessed 15 December 2018.

Martin, D. M. (2017). Ecological restoration should be redefined for the twenty-first century. *Restoration Ecology, 25,* 668–673.

Meijboom, F. L. B., & Brom, F. W. A. (2012). Ethics and sustainability: Guest or guide? On sustainability as a moral ideal. *Journal of Agricultural and Environmental Ethics, 25,* 117–121.

Morrison, D. (1987). Landscape restoration in response to previous disturbance. In M. G. Turner (Ed.), *Landscape heterogeneity and disturbance* (pp. 159–172). New York: Springer.

Order no. 756 of 11.03.1997 approving the regulations on environmental pollution assessment, Official Gazette no. 303 of 11/06/1997 (**in Romanian**).

Peng, J., Zong, M., Hu, Y., Liu, Y., & Wu, J. (2015). Assessing landscape ecological risk in a mining city: A case study in Liaoyuan City, China. *Sustainability*. https://doi.org/10.3390/su7078312.

Qiu, H. (2010). Studies on the potential ecological risk and homology correlation of heavy metal in the surface soil. *Journal of Agricultural Science*. https://doi.org/10.5539/jas.v2n2p194.

Rashki, G. O., Sayadi, M. H., & Rezaei, M. R. (2015). Potential ecological risk assessment of heavy metals in sediments of water reservoir case study: Chah Nimeh of Sistan. *Proceedings of the International Academy of Ecology and Environmental Sciences, 5,* 89–96.

Soliman, N. F., Nasr, S. M., & Okbah, M. A. (2015). Potential ecological risk of heavy metals in sediments from the Mediterranean coast. *Egypt. Journal of Environmental Health Science & Engineering*. https://doi.org/10.1186/s40201-015-0223-x.

STAS 7184/1–84 Soils. Sampling for soil and agrochemical studies (**in Romanian**).

Suciu, I., Cosma, C., Todica, M., Bolboaca, S. D., & Jantschi, L. (2008). Analysis of soil heavy metal pollution and pattern in Central Transylvania. *International Journal of Molecular Sciences, 9,* 434–453.

Taback, H., & Ramanan, R. (2013). *Environmental ethics and sustainability: A casebook for environmental professionals*. New York: CRC Press.

Telesetsky, A. (2013). Ecoscapes: The future of place-based ecological restoration laws. *Vermont Journal of Environmental Law, 14,* 493–548.

Völker, C., Kramm, J., Keber, H., Schramm, E., Winker, M., & Zimmermann, M. (2017). More than a potential hazard-aproaching risk from a social-ecological perspective. *Sustainability*. https://doi.org/10.3390/su9071039.

Vromans, K., Istldar, G. Y., Paslack, R., Simon, J., & Vrind, R. (2017). *Environmental ethics—An introduction and learning guide*. New York: Routledge.

Waelbers, K. (2011). *Doing good with technologies. Taking responsibility for the social role of emerging technologies*. New York: Springer.

Zhou, Z. (2015). Content of heavy metals in BioChars and assessment of ecological risk on their application to soil. *Energy, Environmental & Sustainable Ecosystem Development: International Conference on Energy, Environmental & Sustainable Ecosystem Development (EESED2015)*. https://doi.org/10.1142/9789814723008_0017.

Zhou, H., & Guo, X. (2015). Soil heavy metal pollution evaluation around mine area with traditional and ecological assessment methods. *Journal of Geoscience and Environment Protection*. https://doi.org/10.4236/gep.2015.310005.

Zhu, H., Yuan, X., Zeng, G., Jiang, M., Liang, J., Zhang, C., et al. (2012). Ecological risk assessment of heavy metals in sediments of Xiawan Port based on modified potential ecological risk index. *Transactions of the Nonferrous Metals Society of China*. https://doi.org/10.1016/S1003-6326(11)61343-5.

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