HUMAN RISK ASSESSMENT METHODOLOGY DUE TO EXPOSURE TO POTENTIAL ENVIRONMENTAL POLLUTANTS: A CASE STUDY FOR HEAVY METALS IN SOIL

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ABSTRACT: *The paper present the assessing the health risk potential by exposing to heavy metals traces (Pb, Ni, Zn, Cd) in the soil adjacent to the synergistic sources of pollution: Jilț lignite quarry, Turceni power plant and Ceplea slag and ash deposit. Samples were prepared and analyzed using the GFAAS analytical technique. The average concentrations in soil samples (mg.Kg^{-1}) for Pb (43.71) and Ni (64, 14) exceed the normal value, and the soil index (Cn) on the four cardinal directions, show values supraunitare, that indicates a high level of pollution. Based on the average concentrations determined in soil, other parameters used for dose exposure evaluation the individual risk for heavy metals can be calculate, based on the USEPA model. Individual risk order: Pb (10^{-7}); Ni (10^{-6}); Cd (10^{-6}), compared to the reference value according to WHO (10^{-6}), means a cancer case in over one million people exposed.*

ABSTRACT: health risk assessment; soil pollution; heavy metals; ndividual risk exposure

1.Introduction

The risk assessment for the population is an extremely significant tool for the decision-makers for an adequate management of the contaminated soil, which according to the identified level of pollution, the use of the land is in accordance with the selected purpose (agricultural, residential, recreational, commercial, industrial etc.).

The first methodology for human risk assessment due to exposure to contaminated soils was developed in the 1980s by the United States Environmental Protection Agency (USEPA) [1], followed by a number of other national methodologies based on USEPA principles: CSOIL (Netherlands), RBECA (Italy), CLEA (United Kingdom), etc.

According to the legal provisions in Romania [2], the environmental protection authority decides whether the contaminated sites need to be remediated, as well as the best technology to be used for remediation, based on the geological environment pollution research and assessment studies and risk assessments (art. 24, 25 HG 1408/2007). At the same time, the legislation envisages that these studies must be carried out in accordance with a framework methodology and content developed by the Ministry of Environment and Forests [3].

The presence of metals in the environment both naturally and through anthropogenic forms has an impact on plants, microorganisms, aquatic organisms and life support functions, such as immobilization, mineralization and nitrification and, in this way, human health and ecosystem health is negatively affected [4].

Heavy metals represent an important category of stable toxic pollutants, persist in storage compartments (soil, sediments) for a long time. The absorption and accumulation of heavy metals in plants are the result of the influence of external factors such as: heavy metal concentration in soil, composition and intensity of atmospheric deposition, precipitation and plant growth stage [5].The presence of high concentrations of toxic metals in organic systems, in particular, agricultural ones, can cause serious health issues. Thus, it has been demonstrated that the presence of heavy metals in soil is associated with the quality of agricultural products in rural areas [6]. Chronic exposure to heavy metals has been implicated in several degenerative diseases of the human body and may have been proved to increase the risk of cancers [7].

2. HUMAN EXPOSURE AND HEALTH RISK ASSESSMENT METHODOLOGY

The mathematical model was mainly based on the methodology developed by the Environmental Protection Agency of the United States - Superfund Risk Assessment Guide: Volume I - Human Health Assessment Manual [1], were analysed and read from the perspective of the particularities in Romania which sometimes are significantly different to other developed countries, such as those considered as reference: food ingestion rate, the type of consumed food of vegetal or animal origin, etc.

The mathematical model developed by the US EPA 97 [8] is based on the general scheme for risk assessment, shown in Figure 1.

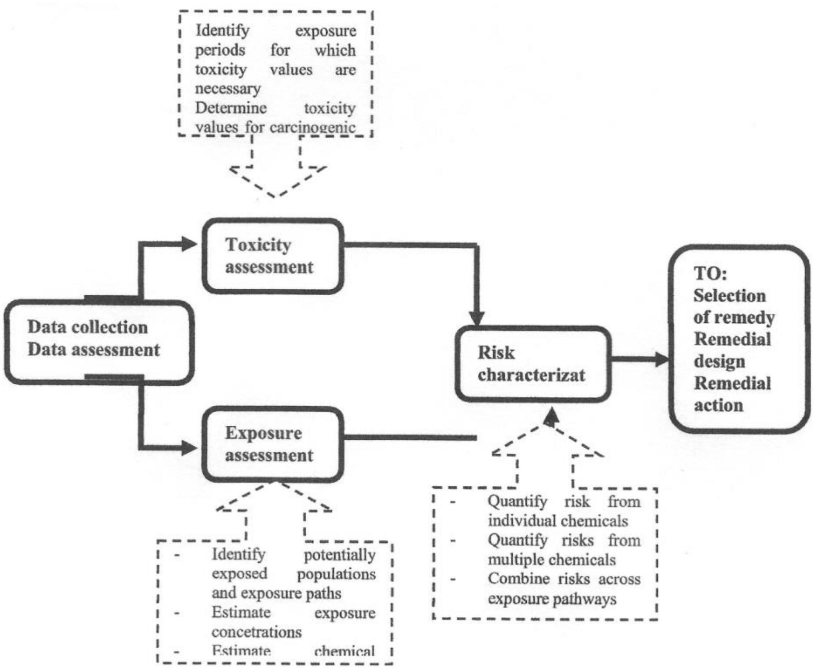

Figure 1. General scheme for risk assessment [8] (Adaptation)

Health risk assessment models were developed basically in Europe [9] and in the United States [1, 10]. The European model is still under development and is not as straightforward as the American model. This model has been developed in all details and is fully available through Risk Assessment Information System (RAIS) (http://rais.ornl.gov/) and is supported by the Toxicological profiles developed and gathered by the USEPA Integrated Risk Information System (IRIS) (http://cfpub.epa.gov/ncea/iris/index.cfm) and by the US Agency for Toxic Substances and Disease Registry – Toxicological profiles (ATSDR) (http://www.atsdr.cdc.gov/toxfaq.html).

The risk assessment is a multi-step procedure that comprise: i) data collection (gathering and analyzing the site data relevant to human health), ii) exposure assessment (estimation of the magnitude of actual and/or potential human exposures), iii) toxicity assessment (determination of adverse health effects associated with exposure to different chemicals) and iv) risk characterization (summarizes and combines the outputs of the calculations of exposure and toxicity assessments).

3. CASE STUDY

The purpose of this case study cas is to evaluate the risks determined by the impact of the soil contaminated with heavy metals on the environment and the population's health for a site located in the south-western part of Romania, an impact zone bordering a power plant that uses lignite as a fuel. This was also the subject of various research projects, finalized with public reports, [11, 12].

The area of interest for the analysis of heavy metals in the soil addressed in this study is located on the north-east direction of the Jiu River, comprising three fixed points with synergic emission potential of pollutants in the environment: exploitation of lignite Jilţ Quarry; Turceni thermal power plant, Ceplea ash and slag deposit.

The obtained samples extracts were analyzed by atomic absorption spectrometry, a method recommended for multicomponent analysis of heavy metals in the environment[3], using Thermo Electron Model S Series AA SOLAR software platform.

3.1. HEAVY METALS LEVEL

The data obtained for the analyzed samples were statistically processed using Microsoft Office Excel 2007, the average, average and point values obtained were analyzed in relation to the national reference values [3] and similar research in the literature. The statistical results obtained for the four analyzed metals are presented in table 1.

Table 1. Heavy metal concentrations in soil (mean values, total forms).

Sample	Zn(mg. Kg^{-1})		Pb(mg. Kg^{-1})		Ni(mg. Kg^{-1})		Cd(mg. Kg^{-1})	
	c	Sd	c	Sd	c	Sd	c	Sd
Soil field blanks	63.46	0.80	42.3	0.62	63.5	0.71	0.72	0.67
Soil adjacent area	87.85	24.74	43.71	3.69	64.14	11.24	0.85	0.12
NV (soil)	100		20		20		1	
AT (soil)[a]	300		100		100		3	

[a] Sensitive soils, Source: Order nr.756/1997; NV: Normal values;AT: Alert thresholds

Heavy metals content in the perimeter of the questioned surface (mean values) (mg.Kg -1): Zn (87.34 ± 61.4), Pb (43.71 ± 3.69), Ni (64.14 ± 11, 24), Cd (0.82 ± 0.12) relative to the national norms [3] exceeds the normal values for lead and nickel (20 mg Kg^{-1}), while zinc and cadmium are close to normal.

In order to facilitate the interpretation of the degree of loading of potential pollutants and to compare the contamination intensities of each pollutant, an excessively high normal content Cn for each individual element [13] was calculated. The values of the Cn coefficient on the 8 cardinal directions, according to the stated meanings, reflect the fact that the metals Pb and Ni are for all directions above the value 1, shows a high level of pollution, while Zn has predominantly higher than one values in the NE-SE direction (airflow propagation direction), Cd being constantly subunit except for the thermal plant.

3.2. Individual risk for exposure

The potential human health risk from heavy metals in the site was assessed taking into account all levels of concentrations identified in the analyzed area [8]. For every exposure pathway, doses were estimated using the following expressions:

• Exposure through dermal contact

$$I1 = [CS \times CF \times SA \times AF \times ABS \times EF \times ED] / [BW \times AT] \quad (1)$$

The exposure through dermal contact I1 has been calculated taking into account the chemical concentration in soil (CS), the conversion factor (CF), the skin surface area available for contact (SA), the absorption factor (ABS), the exposure frequency (EF), the exposure duration (ED), the body weight (BW) and the mean time (AT).

• Soil ingestion $I2 = [CS \times CF \times IR \times FI / BW] \times [EF \times ED / AT]$ (2)

For the characterization of potential carcinogenic effects, the probability that an individual develops cancer during the exposure period, beginning from the daily intake or dosage calculated within the previous stage and information concerning the specific dosage – response for each chemical element, is estimated.

$$Risk = I * SF \quad (3)$$

Where:
I-chronic daily intake (mg/kg-day) and
SF- slope factor (mg/kg/day).

In case the risk is determined by several pollutants, the risk is calculated as the sum of the risk generated by each pollutant for each exposure pathway.

For the calculation of the exposure through soil ingestion I2, date related to the ingestion rate (IR) and fraction ingested from contaminated source (FI) were considered.

Due to the fact that heavy metals are a category of indestructible persistent pollutants with toxic effects on living organisms when they exceed a certain concentration, monitoring of these metals is important for assessing environmental safety and human health, especially [14, 15]. Based on the average concentrations determined in soil (h = 0.25m): Table 1, expressions (1) and (2) other parameters used for dose exposure evaluation are listed in Table 1, suggested by the US Environmental Protection Agency for this type of assessment [16, 8], the individual risk for Ni, Cd, Pb can be calculated taking into account the following: the concentration due to the direct deposition of contaminants is zero and the concentration due to the transfer in grains is based on the absorption factor (UF) and the soil metal concentration (Cs); it is considered that 100% of the territory is devoted to the cultivation of crops (wheat); 10% of wheat is used in the contaminated area. The general data needed to calculate the individual risk factor for the three heavy metals with toxic potential Pb, Ni, Cd are shown in Table 2.

Table 2. Estimating the order of magnitude of individual risk.

Heavy metals	Comcentration in soil mg/kgd.w Average values	Slope factor (mg/kg/day)[a]	Individual risk order Ir
Pb	43.73	8.50×10^{-3}	10^{-7}
Ni	64.14	9.10×10^{-1}	10^{-6}
Cd	0.85	4.20×10^{-1}	10^{-6}

Although the determined Pb and Ni concentrations exceed the normal soil traces of approx. 50% and 60%, the excess of the normal content (Cn) being double to Cd (Table 1), the highest individual risk index was obtained for Cd and Ni (10^{-6}). This is highlighted in two recent researches: Cocârtă et al.(2016), which highlights the high level of Cd (10^{-4}) against Pb (10^{-6} and Ni 10^{-5}) [15] and by Ye et al. (2015), which highlights the high risk [17]. The reference limit for the WHO individual risk index level 10^{-6} set by the WHO and quoted by Dumitrescu et al. [16], means a cancer case in over one million people exposed.

5. CONCLUSIONS

Energy installations, especially coal-fired power plants, can influence the environment, sometimes even affecting the ecological balance in the areas where they are located, with a complex impact on all environmental factors in the surrounding area (atmosphere, water, soil, flora and fauna, food and housing). Combustion products dispersed from the lignite matrix, fly ash discharged through the chimneys, ash and slag from the waste deposits, coal dust from the coal deposits or its transport and preparation together constitute a trace source of heavy metals with potentially toxic for the area of the site. As persistent, indestructible pollutants and toxic effects on living organisms when they exceed a certain concentration, monitoring of these metals is important for assessing individual risks, environmental safety and human health in particular

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