

## Safe Levels for Ecological Risk Assessment of Soils Polluted by Metals: From Normative to Field (European Union Case)

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### Introduction

Over decades metals have been introduced into our ecosystems by emissions of ash and solid particles [1]. Several millions of hectares of land all over the world are continuously receiving a wide variety of contaminants [2]. Among them, metals and metalloids are permanent pollutants in our soils, because they cannot be degraded and bind strongly to soil components; representing one of the most harmful problems of our times [3]. Metals can be released from different anthropogenic activities, with mining activities being one of the most worrying sources [4]. Once in the environment, they can be involved in a series of complex chemical and biological interactions influenced mainly by properties and components of soils. The ubiquity of metals combined with the complexity of soils makes the study of metals one of the most important disciplines of soil chemistry [5].

In the European Union, the evaluation of toxic effects and environmental risk assessment (ERA) is done primarily to protect human health and terrestrial, aquatic and atmospheric ecosystems [6]. There are two distinguished approaches: a) predicting the possible effects of chemicals in the environment with the aim to prevent such effects to occur (predictive ERA) and b) assessing the actual ecological risk or damage under pollution conditions with the aim to remediate or decide on measures to reduce the risk (diagnostic ERA) [7]. The ERA of contaminated land combines the use of chemical methods, toxicological assays and ecological studies for the characterization of the risk and the associated effect [8]. However, there is an enormous disparity between the outcomes of laboratory and field studies on metal toxicity [9]. The main questions are: (1) How to establish critical metal concentrations for soil organisms? (2) How to extrapolate from short-term laboratory tests to the field conditions? and (3) how can we ensure that established metal limits protect all the involved populations and processes? [10].

The use of toxicity tests involving living organisms is essential for both predictive and diagnostic environmental risk assessment. In addition, the use of bioassays with soil organisms is a key element to assess the actual ecological risk and to support legislative regulation of contaminated soils, in order to complement the current regulations when declaring a soil as contaminated [11]. These bioassays are used to determine toxicity because they show the direct responses of organisms exposed to potentially polluting elements and thus are indicative of the actual risk of pollutants, but taking into account their real bioavailability [12].

Reference values or quality criteria for the protection of human health and/or ecosystems have been established in different countries; however, these regulations apply to different processes and show great variability among countries. Examples of different European guideline values of metal(loid)s are showed in Table 1. In the Netherlands, the Ministry of the Environment developed a set of reference values for contaminated sites based on remediation and health protection criteria [13]. In Germany, the law for the protection of contaminated sites [14] provides preventive values for investigating and intervening to protect

ecosystems against negative effects of soil contamination. This also is the case in Spain, where the central government has determined that each region has the responsibility to develop reference levels to decide on declaring a soil as polluted [15], but even today such reference values have not been established in all regions (Table 1).

In order to better applied the regulations, *in situ* polluted areas are key to optimize ecotoxicological studies as well as to check if safe environmental thresholds calculated in laboratories are effective for ecotoxicological risk assessment. For this reason, ecotoxicological assays were performed in Aznalcóllar (Andalusia region, Spain), this area suffered in 1998 the breaking of the waste dump at the pyrite mine; this accident was the largest accident reported in Europe [16]. Nowadays, after remediation actions, the area is categorized as Guadiamar Green Corridor and it is considered remediated. However last researches have showed that there is still present residual pollution, several years after the application of remediation actions [17]. In addition, were notified toxic effects by the use of living organisms even in places where soils fulfill the regulation values [18]. According to bioassay results in the affected area, there is a clear risk of contamination to living organisms but the established soil quality criteria do not reflect potential toxicity problems.

The process of ecological risk assessment (ERA) of contaminated soil represents a difficult task given the heterogeneity of the soil as well as the use and management of it. These processes are greatly influenced by differences between scientists, private and administrative interests [19]. So far, this has made the methods to be applied in the analysis of contaminated soils much less advanced than those applied to aquatic systems. Defining soil policies is not an easy task because of the high variability of soils, as well as the possible pollutants involved and the complexity of their behaviour in soils. However, the high diversity in soil quality criteria or guideline values is obviously based on the lack of consensus and the applied methodology. Therefore the development of effective soil environmental policies is, first of all, a crucial task for ERA. Defining all policies into an operational way is a joint task of all member states of the European Union. In this regard, soil environmental protection and pollution control legislation have still a long way to go.

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Soil use classification	The Netherlands [13,20]		Germany [14]			Spain-Andalusia region [21]		
	Target value (2000)	Intervention value (2009)	Industrial use	Residential use	Agricultural use	Industrial use	Urban use	Other uses
As (mg kg <sup>-1</sup> )	29	76	150	80	50	40	36	36
Pb (mg kg <sup>-1</sup> )	85	530	2,000	2,000	1,000	2,750	275	275
Zn (mg kg <sup>-1</sup> )	140	720	3,000	3,000	600	10,000	10,000	10,000
Cu (mg kg <sup>-1</sup> )	36	190	1,000	600	200	10,000	3,130	595

**Table 1:** Soil references values for the most frequent metal(loid)s released by mining activities (arsenic, lead, zinc and copper) in 3 European countries according to their current regulation. Data expressed for the total concentration (mg kg<sup>-1</sup>).

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