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Development of a site-specific Ecological Risk Assessment for contaminated sites: Part II. A multi-criteria based system for the selection of bioavailability assessment tools

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Abstract

A comparison procedure based on Multi-Criteria Decision Analysis (MCDA) and expert judgment was developed in order to allow the comparison of bioavailability tests to implement the chemical Line of Evidence (LoE) within a TRIAD based site-specific Ecological Risk Assessment framework including three tires of investigation. The proposed methodology was included in the Module 1 of the Decision Support System DSS-ERAMANIA and the obtained rank supported the selection of a suitable set of available tests to be applied to the case study. A simplified application of the proposed procedure is described and results obtained by the system software are discussed.

Keywords: Bioavailability; Site-specific Ecological Risk Assessment; Contaminated sites; Decision Support System

1. Introduction

Criteria and methodologies for the assessment and rehabilitation of contaminated sites are urgently needed at international level because of the huge number of contaminated sites scattered all over the post-industrialised countries and the financial implications representing a significant constraint for the site redevelopment.

In order to address the rehabilitation of contaminated ecosystems, Ecological Risk Assessment (ERA) is the appropriate process for identifying environmental quality objectives and the ecological aspects of major concern (US-EPA, 1998; Suter et al., 2000). The application of Weight of Evidence (WOE) methods Burton et al., 2002; Chapman et al., 2002) was recently proposed within the risk characterization, to determine possible ecological impacts based on multiple lines of evidence (LOEs) (US-EPA, 1998). As one of the WOE methods, the TRIAD approach requires three major lines of evidence for comprehensive assessment of the effects of contamination: chemical contaminant characterization including literature toxicity data to estimate the effects, laboratory-based toxicity testing on surrogate organisms, and indigenous biota community characterization Long and Chapman, 1985). Each LoE in the TRIAD is

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aiming at providing information on the risk (or estimated effect) by means of appropriate measurement endpoints.

Out of the three TRIAD LoEs, the measurement endpoints related to the bioavailability concept that belongs to the chemical LoE are of concern in this paper.

Bioavailability can be regarded as a dynamic process that comprises two distinct and different steps: a physico-chemically driven desorption process and a physiologically driven uptake process. According to this distinction (Hamelink et al., 1994) the first step can be defined as the "environmental availability" (the so-called "bioaccessibility", Paustenbach et al., 1997; Ruby et al., 1999), and the second as "environmental bioavailability". The latter requires the identification of specific biotic species as target organisms. The "toxicological bioavailability", associated to redistribution within an individual organism body and to possible toxic effects, is an additional step that can be also included in the bioavailability overall process (Peijnenburg et al., 1997).

The interest in bioavailability and its inclusion into the site-specific ERA procedure stems from the fact that exposure assessment to toxic chemicals in soil requires information on the concentration that is available to the organisms in the soil (Chung and Alexander, 1998). The current approach to exposure assessment commonly relies on the total concentration, but the level that is biologically available might not be related to this number (Tang et al., 1999). In addition, the level that is biologically available may decline over time as the chemical becomes sequestered in the soil by ageing (Chung and Alexander, 1998).

Including the bioavailability concepts in the ERA procedure does not necessarily lead to a reduction of the estimated risk, but indeed it enhances the procedure accuracy.

Within the ERA-MANIA project, the Decision Support System DSS-ERAMANIA has been developed to allow incorporation, as measurement endpoints, of simple bioavailability tools to improve the ERA based on total contaminants' concentrations.

According to the Committee on Bioavailability of Contaminants in Soils and Sediments (US-NRC, 2003) several tools, demanding different efforts in terms of time and costs, and providing different types of results, have been used to evaluate bioavailability. They can be classified in four groups: physico-chemical, chemical, biomimetic and biological (US-NRC, 2003; Lanno et al., 2004) tools. The physico-chemical tools are experimental or computational procedures designed to determine the bioaccessibility of contaminants in soil; the chemical tools are analytical procedures for the speciation of contaminants thus providing an indirect measurement of bioavailability (Lanno et al., 2004); the biomimetic mimics the organism uptake from the solid particles or pore water; and finally, the biological tools determine the actual amount of chemicals taken up by the organisms.

On the basis of its own characteristics, each tool can have a specific suitability in different tiers of investigation of the TRIAD-based site-specific ERA procedure. The criteria useful to select the suitable set of tools for each tier should include both objective (e.g. cost, analysis time, applicability) and subjective (e.g. ecological relevance of the provided response) information. The variety of these heterogeneous criteria makes the tool comparison a difficult operation for the involved experts. To support the experts in this procedure (i.e. to interpret the multiple quantitative criteria), the "Comparative Tools Table for bioavailability" (i.e. BAV Table), was developed and implemented by applying Multi-Criteria Decision Analysis (MCDA).

The objective of this paper is to present the BAV Table, designed for the selection of the suitable set of bioavailability tools to be applied in each tier of the TRIAD. As presented in the companion paper (Critto et al., 2007), it is part of the first module (i.e. Module 1) of the DSS-ERAMANIA, structured in three Comparative Tables (one for each TRIAD LoE) and concerning the tests (i.e. measurement endpoints) comparison and selection within each TRIAD LoE. The two Tables concerning the comparison and selection of ecotoxicological tests and ecological observations, ETX and ECO Tables, are presented and discussed in the companion paper (Critto et al., 2007).

2. Methods

The development of the BAV Table for the comparison and selection of suitable bioavailability tools to be applied in the tiers of ERA procedure required: a) a detailed definition of the TRIAD investigation tiers (see companion paper, Critto et al., 2007); b) the identification of useful criteria for the comparison of the tools, and c) the development of a comparative procedure using Multi-Criteria Decision Analysis (MCDA).

2.1. Criteria for the comparison of bioavailability tools

According to the TRIAD tiers defined and described in the companion paper (Critto et al., 2007), each existing tool can show a specific suitability to provide insight into the bioavailability process, at subsequent investigation levels. This suitability depends on three