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"AMORE" Decision Support System for probabilistic Ecological Risk Assessment - Part II: Effect assessment of the case study on cyanide

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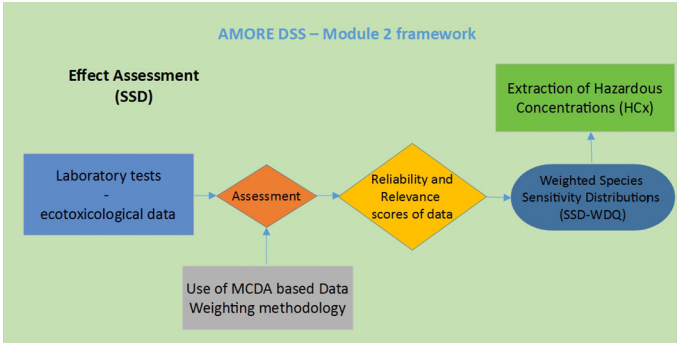
HIGHLIGHTS

- Production of Weighted by Data Quality Species Sensitivity Distributions (SSD-WDQ)
- Estimation of Hazardous Concentrations. Example of cyanide to aquatic organisms
- Estimation of Environmental Quality Criteria. Example of cyanide in a river basin
- AMORE Decision Support System for probabilistic Ecological Risk Assessment
- Applied case study: assessment of cyanide effects to organisms in a river in France

GRAPHICAL ABSTRACT



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ABSTRACT

Ecotoxicological data are highly important for risk assessment processes and are used for deriving environmental quality criteria, which are enacted for assuring the good quality of waters, soils or sediments and achieving desirable environmental quality objectives. Therefore, it is of significant importance the evaluation of the reliability and relevance of available data for analysing their possible use in the aforementioned processes. In this context, a new methodology which has been developed based on Multi-Criteria Decision Analysis (MCDA) techniques, is being used, demonstrated and tested for analysing the reliability and relevance of ecotoxicological data of cyanide (which are produced through laboratory biotests for individual effects). The proposed methodology is also used for the production of Weighted by Data Quality Species Sensitivity Distributions (SSD-WDQ), as a component of the Ecological Risk Assessment of chemicals in aquatic systems. The SSD-WDQ production resulted in the estimation of environmental quality criteria (hazard concentration affecting 5% and 50% of the species). The proposed work is part of the development of the AMORE Decision Support System (DSS) for the application of probabilistic Ecological Risk Assessment (ERA), presented in the companion paper (Isigonis et al., 2019). The DSS has been tested through a case study on ERA of cyanide in the watershed of river Selune in France. The paper presents the 'Effect Assessment' of cyanide, based on the aforementioned methodologies. The main results presented in the paper are the probabilistic analysis of the estimated species sensitivity on cyanide (Effect Assessment) and the calculation of Hazardous Concentration (HCx) of the same contaminant in the Selune river area, based on the functionalities of the DSS. The results are described and discussed in detail, with the use of various graphs and indices. The indices are calculated for all the available ecotoxicological data, as well as for the data on trophic levels or taxonomic groups separately. An effect comparison is presented between the innovative methodologies included in the DSS and the currently existing methodologies.

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1. Introduction

Ecological Risk Assessment (ERA) is defined as the estimation of both the magnitude and the probability of environmental harm caused by human activities (Barnthouse and Suter II, 1986). ERA can be divided in two main tiers: Screening ERA and site-specific ERA (Critto and Suter II, 2009). The definition of Environmental Quality Criteria (EQC) is included in the context of screening ERA. EQC (or standards) are threshold numerical values that indicate a level beyond which there is a significant risk that the associated environmental quality objective has not been achieved and for which the assessors should adopt actions for the preservation of the ecosystems, including the development of a site-specific risk assessment (EPA, 2005).

The EQC can be derived either through deterministic or probabilistic approaches, with the latter being preferred in the recent advances in the sector as they allow to take into consideration species variability and uncertainty in sensitivity towards chemicals (Gottschalk and Nowack, 2013). The most widely adopted probabilistic approach used for this purpose is the Species Sensitivity Distribution (SSD).

A complete description of SSD is presented in Posthuma et al. (2002) and a detailed critique of SSD is presented in Forbes and Callow (2002) in which the most significant assumptions made in SSD-theory are reported and appraised. Specifically, Forbes and Callow (2002) raised a number of questions regarding the effect of intraspecies variation, proportion of data between the different taxonomic groups and adopted statistical methods in SSD. To tackle these considerations, Duboudin et al. (2004) have introduced the concept of Species Sensitivity Weighted Distributions (SSWD) in which various statistical methods, as well as weights for the ecotoxicological data, are used in the production of SSDs.

In their study, Duboudin et al. (2004) have proposed a weighting coefficient combining two different criteria that allow taking into account: (1) the intraspecies variation in effect response and (2) the taxonomic groups' abundance. Though, this weighting coefficient is neither related with the quality of the assessed data nor with their reliability and relevance for the ecosystem of concern, elements which are considered highly important for the derivation of robust and reliable EQC/S (Duboudin et al., 2004).

The derivation of robust and reliable EQC/S mainly depends on the availability and quality of relevant ecotoxicological data. Ecotoxicological data can be obtained through many different approaches and conditions (e.g., the protocol can be standardised or not; time duration can vary among experiments, leading to chronic or acute data), different physiological endpoints can be observed (e.g. mortality, growth, reproduction and more), statistics used for interpreting data can differ, leading to e.g. NOEC or ECx and more. It is therefore of high interest the analysis of their reliability and relevance that will allow the derivation of more significant and relevant EQ criteria to be adopted in screening ERA, as well as more reliable site-specific ERA.

Several frameworks have been proposed in order to address the issue of the relevance of ecotoxicological data for use in risk assessment processes (Roth and Ciffroy, 2016). Isigonis et al. (2015) have analysed the most important frameworks for the assessment of ecotoxicological data and presented a novel framework, which is based on a Multi-Criteria Decision Analysis (MCDA) - Weight of Evidence (WoE) approach.

This paper aims at presenting and verifying the innovative 'Effect Assessment' module of the newly developed software (AMORE DSS) for probabilistic Ecological Risk Assessment. The complete functionalities, architecture and framework of the AMORE DSS are presented in detail in the companion paper (Isigonis et al., 2019). The presented module allows the use of state-of-the-art methodologies for the systematic assessment of quality of ecotoxicological data, the production of reliable weighted data quality SSD graphs (SSD-WDQ) and the estimation of Hazardous Concentrations, in a robust and effective quantitative way, by using derived expert knowledge and modern computerised capabilities. These results are used further in the complete Ecological Risk Assessment process, for the estimation of risk indices of pollutants in aquatic environments, which is presented in the companion paper (Isigonis et al., 2019).

2. Material and methods

2.1. AMORE DSS

The AMORE Decision Support System has been developed as part of the AMORE research project (French National Research Agency project) and consists of three modules which aim in assisting environmental researchers and experts in assessing environmental risks of chemicals in aquatic systems. To this end, it provides a set of tools for analysing and integrating both exposure and effect information (i.e. modelling as well as experimental data). The complexity of the topic outlines the necessity of the development of a DSS that surpasses the single analysing capabilities of humans.

The AMORE DSS consists of three modules, namely the 'Exposure Assessment', the 'Effect Assessment' and the 'Risk Assessment' modules, which are interactive and complete each other. A complete overview of the DSS functionalities is presented in the companion paper (Isigonis et al., 2019). The second module of the DSS (Effect Assessment) incorporates a novel methodology (Isigonis et al., 2015), which has been developed for the assessment of ecotoxicological data, in a quantitative and systematic way (see Section 2.2 for a summary). The assessment framework, on which the methodology was based and designed, has been built upon the review of the state-of-the-art in the field of ecotoxicological assessment frameworks for the analysis of the quality of ecotoxicological data but at the same time, it has been expanded to provide the possibility of exploring ecotoxicological data in a thorough way (Isigonis et al., 2015).

The methodology is based on the use of Multi-Criteria Decision Analysis and Fuzzy Logic methods, can handle heterogeneous criteria and integrates the evaluation provided by different experts through a solid participatory process. A short reference to the MCDA methodology (Isigonis et al., 2015) is presented in Section 2.2, while the 'Effect Assessment' module, where the methodology is incorporated in the DSS architecture, is described below. The methodology has been applied and tested, as part of the case study to assess the toxicity of cyanide to aquatic organisms. The used ecotoxicological data is presented in Section 2.3 and the results of the case study for the 'Effect Assessment' of cyanide to aquatic organisms in Section 3.

2.1.1. AMORE DSS – module 2: effect assessment (Species Sensitivity Weighted Distribution – SSWD)

Species Sensitivity Distributions (SSDs) can be used in the well-known 'forward' and 'inverse' ways (Van Straalen and Denneman, 1989). The forward use is mainly utilised for performing risk assessment, whereas, in the inverse way the SSDs can be used for the derivation of EQC. In the proposed study, we mainly use the 'inverse' way for the extraction of EQC and the production of SSD-WDQ graphs, which are presented for comparison with the conventional SSWD graphs. The SSD-WDQ graphs are further used in the 'forward' way in our risk assessment case study and the validation of the "AMORE" Decision Support System, presented in the companion paper (Isigonis et al., 2019).

The "Effect Assessment" module allows the creation of Weighted by Data Quality Species Sensitivity Distributions (SSD-WDQ), with the use of the MCDA-based methodology for the assessment of the reliability and relevance of ecotoxicological data (Isigonis et al., 2015), that makes use of quality criteria for the construction of the graphs.

The developed methodology uses an "Experts' knowledge base", which has been created through the 'Questionnaire for expert consultation', as described in Isigonis et al. (2015), for the needs of the applied case study and allows the assessment of ecotoxicological data, based on the elicitation of expert knowledge in the field of ecotoxicology.

For the assessment of each ecotoxicological datum, the user has to compile the response sheet of the methodology (Isigonis et al., 2015),

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