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A *priori* assessment of ecotoxicological risks linked to building a hospital

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HIGHLIGHTS

- Hospital effluents are generally discharged in sewers without treatment.
- A specific methodology have been developed to assess the ecotoxicological risks.
- A moderate risk of the studied effluent is obtained for the river concerned.
- This release contributes significantly to the global local ecotoxicological risk.

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ABSTRACT

Hospital wastewaters contain a large number of chemical pollutants such as disinfectants, detergents, and drug residues. A part of these pollutants is not eliminated by traditional urban waste water treatment plants, leading to a major risk for the aquatic ecosystems receiving these effluents. After having formulated a specific methodology in order to assessment ecotoxicological risk for such a situation, we applied it to the project to build a new hospital shared by several towns in the French Alps. This methodology is based on the ecotoxicological characterisation of the hospital wastewater using a battery of three chronic bioassays (*Pseudokirchneriella subcapitata*, *Heterocypris incongruens* and *Brachionus calyciflorus*) and of genotoxicity tests (*Ames fluctuation assay on Salmonella typhimurium*, and a *Fpg-modified comet assay on the trout liver cell line RTL-W1*). The formulated methodology highlights a moderate risk of the hospital wastewater for the organisms of the water column of the river concerned. Nevertheless, this discharge contributes significantly to the global ecotoxicological risk when taking into account all the releases of the watershed into the river. This leads to recommending the implementation of a specific treatment system in the urban WWTP, or upstream to it, in view to protecting the aquatic organisms.

1. Introduction

Hospitals use a large variety of chemical substances such as pharmaceuticals, radionuclides, disinfectants and detergents, for health care, diagnostics, disinfection and research (Kümmerer et al., 1998; Kümmerer and Helmers, 2000). After application, some of these substances and non-metabolised drugs excreted by patients are found in hospital wastewaters (Kümmerer, 2001; Langford and Thomas, 2009), which generally reach the municipal sewer network without preliminary treatment (Emmanuel et al., 2004). Pollutants from hospitals have been thus found in WWTP wastewaters (Brown et al., 2006; Langford and Thomas, 2009), and in surface water (Sprehe et al., 2001). Therefore, hospitals constitute the source of a large array of toxic substances released in aquatic ecosystems, sometimes in high concentrations. These releases could have negative effects on the biological equilibrium of natural media (Jolibois et al., 2002; Escher et al., 2011). So, though hospital activities only contribute 20–30% of discharges from care activities, they represent an important part of the problem, and it is necessary to improve their management.

The aim of this paper is to present: (i) a detailed procedure formulated for the ecological risk assessment of hospital wastewater, discharged into an urban sewer network, then in a WWTP, and

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lastly, into the natural environment, and (ii) the results of its application for the a *priori* risk assessment linked to the wastewater of a future hospital common to three towns in southeast France.

2. Specificities of hospital wastewaters

Hospitals consume large quantities of water per day. Minimal domestic water consumption is 100 L person^{-1} d^{-1}, whereas consumption in hospitals generally varies from 400 to 1200 L^{-1} bed^{-1} d^{-1} (a "bed" corresponds to a place in a hospital for a patient who is treated in the hospital). In the United States of America, average hospital water consumption is 968 L bed^{-1} d^{-1} (US-EPA, 1989; US EPA, 1989). In developing countries, this consumption seems to be on average around 500 L bed^{-1} d^{-1} (Laber, 1999). This high hospital water consumption results in large volumes of wastewater.

The main hazardous substances found in hospital wastewater are disinfectants, detergents and pharmaceuticals (Adam et al., 2006; Brown et al., 2006; Boillot et al., 2007). Hospital wastewaters often reveal the presence of organochlorine compounds in high concentrations (Gartiser et al., 1996), and up to 10 mg L^{-1} AOH was found in hospital wastewaters in Germany (Gartiser et al., 1996). The assessment of AOH shows that these non-conventional pollutants have low biodegradability (Sprehe et al., 1999). The presence of glutaraldehyde, a dialdehyde recommended for disinfecting reusable fibre-optic endoscopes, has also been found (Jolibois et al., 2002). Finally, contamination of hospital wastewater by various pharmaceuticals has been discussed in many studies (Halling-Sørensen et al., 1998; Skutlarek and Färber, 2003; Brown et al., 2006; Langford and Thomas, 2009; Chang et al., 2010; Ort et al., 2010; Escher et al., 2011; Sim et al., 2011a,b).

However, few studies have dealt with the ecological risk resulting from exposure to a such wastewater, characterised by a complex mixture of various toxic pollutants.

3. Methodological approach for the ecotoxicological risk assessment

The first ecological risk assessment (ERA) methodologies emerged at the beginning of the 1990s with dawning awareness of the risks liable to impact ecosystems when they are exposed to substances of anthropic origin. In 1992, the United States EPA proposed a framework for ecological risk assessment of contaminated industrial sites (US-EPA, 1992) (Fig. 1). Following a certain number of works, especially those of Suter (1993), this guide was improved to become "The Guidelines for Ecological Risk Assessment" (US EPA, 1998) which has now become the reference regarding ERA (Perrodin et al., 2011). Since then, this guide has been revised by many countries and adapted to manage polluted sites (CEAEQ, 1998; Environment Agency of United Kingdom, 2003; Liliburne and Phillips, 2011).

In addition, methodologies have been formulated to evaluate risks linked to other contamination sources. Mention can be made of the methodology drawn up by the European Union to evaluate risks relating to chemical substances placed on the market (ECB, 2003; Environment Agency of United Kingdom, 2003), and French studies on the assessment of ecotoxicological risks linked to dumping continental dredged sediments (Perrodin et al., 2006), and on the assessment of the ecocompatibility of recycled waste (Perrodin et al., 2000; ADEME, 2002).

Most ERA methods formulated at international level are implemented with four main phases: (1) the formulation of the problem, (2) the characterisation of exposures, (3) the characterisation of effects, and lastly, (4) the characterisation of the risk itself. It is noteworthy that the characterisation of exposures and that of effects are performed in parallel but are in constant interaction.

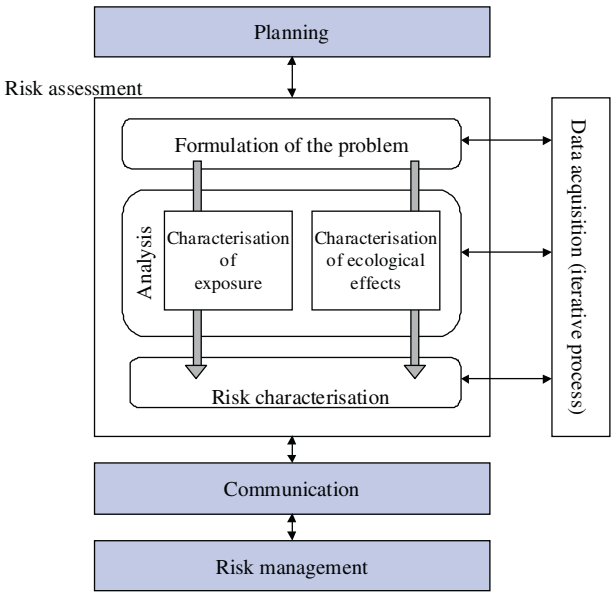

Fig. 1. General diagram of ecological risk assessment (US EPA, 1998).

3.1. The formulation of the problem

The problem formulation phase is fundamental. It comprises investigation and technical options, following which a highly precise plan of actions has to be established (identification of the data to be collected, the measurement and assessment techniques to be used, as well as the framework of interpretation) to carry out the subsequent phases of the ERA (US EPA, 1998; Perrodin et al., 2011).

3.2. The characterisation of exposures

Exposure characterisation aims at determining the spatial–temporal contact between pollutants and target populations (US EPA, 1998). It includes the analysis of sources of pollutants, the transfer of the latter from their sources, and the distribution of pollutants in the environment. This analysis can be performed by using theoretical models of pollutant transfer and/or on the basis of experimental results (Perrodin et al., 2011).

This phase concerns in the determination of one or more values characterising of exposure. In the case of a "substance-based" approach, the term Predicted Environmental Concentration (PEC) is used (as, for example, in the European Union regulation relating to chemical substances), whereas in a "matrix" approach, the notion of percentage of polluted source matrix in the environment (PEP) is more appropriate. In both cases, the parameter concerned is the concentration that can be expected in the environment following different inputs.

3.3. The characterisation of effects

This phase entails defining to what extent the organisms of the target ecosystem are significantly sensitive to the pollutants to which they are exposed (Perrodin et al., 2011). This step is mainly based on biological approaches that include batteries of bioassays. A large number of batteries of bioassays have been proposed in the literature for different fields of study and matrixes. Mention can be made of those relating to (1) substances (Radix et al., 2000; Davoren and Fogarty, 2004; Kim et al., 2007); (2) wastewaters (Naudin et al., 1995; Andrén et al., 1998; Persoone et al., 2003; Ren and Frymier, 2003); (3) sediments (Davoren et al., 2005); (4) wastes (Clément et al., 1996; Rojícková-Padrtová et al., 1998;