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A Risk Assessment Model for Water Resources: Releases of dangerous and hazardous substances

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ABSTRACT

Many dangerous and hazardous substances are used, transported and handled daily in diverse situations, from domestic use to industrial processing, and during those operations, spills or other anomalous situations may occur that can lead to contaminant releases followed by contamination of surface water or groundwater through direct or indirect pathways. When dealing with this problem, rapid, technically sound decisions are desirable, and the use of complex methods may not be able to deliver information quickly. This work describes a simple conceptual model established on multi-criteria based analysis involving a strategic appraisal for contamination risk assessment to support local authorities on rapid technical decisions. The model involves a screening for environmental risk sources, focussing on persistent, bioaccumulative and toxic (PBT) substances that may be discharged into water resources. It is a simple tool that can be used to follow-up actual accident scenarios in real time and to support daily activities, such as site-inspections.

1. Introduction

The environmental risk posed by the use of chemicals is not only the concern of the chemical industry because accidents may occur at any stage in the use of chemical substances, from domestic usage to industrial processing. At any stage, an accident or other anomalous situation may occur, leading to the release of pollutants followed by contamination of surface water or groundwater. The use of life cycle assessment tools (Ahlroth et al., 2011) reveals that the release of chemical substances to the environment may occur during any of several steps in material handling and use (European Communities, 2003) and through direct and indirect pathways between the several compartments of the environment, i.e., air, soil, water and sediments. Additionally, the risk of water body exposure depends on its vulnerabilities, i.e., the degree of susceptibility (or resistance) to the impact of the hazard and on the characteristics of the pollution source (Kappes et al., 2012).

The use of risk assessment (RA) methods associated with accidental or abnormal scenarios involving dangerous substances allows the identification of critical points during the use, transportation and handling of substances and the subsequent implementation of appropriate measures to apply in actual adverse cases. For this purpose, scientific information to support regulatory authorities in making decisions provides a rigorous, scientifically credible understanding of the complex interactions among environmental stressors, sources, relative risks and risk management alternatives (Li et al., 2012; Magnuson et al., 2002; Slater and Jones, 1999; Topuz et al., 2011; Zhao et al., 2008).

One of the most popular methods in RA is the multi-criteria decision analysis, which has emerged as a formal approach to facing available technical information and stakeholder values to support decisions in many areas, especially in the environmental field (Eliasson et al., 2003; Huang et al., 2011; Khalili and Duecker, 2013; Schuwirth et al., 2012; Topuz et al., 2011). Many approaches are based on complex mathematical models to assess pollutants fate and transport on environmental compartments or to evaluate hydrological conditions (Almasri and Kaluarachchi, 2005; Chen et al., 2010; Gutiérrez et al., 2009; Zhao et al., 2008). Although some simpler knowledge based models are being applied, e.g., to landfills (Li et al., 2012; Sizirici et al., 2011), less attention has been paid to the need for daily or urgent technical decisions. The existing risk assessment models are usually not designed to provide information quickly, and the terminology and numerical outputs are often confuse (Tristán et al., 2000). Also, the knowledge based approaches need to deal with large data sets (Chen et al., 2011; Sizirici et al., 2011).

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The destructive potential of accidental scenarios is widely recognised. Thus, the use of prompt approaches as a first assessment tool could provide rapid and helpful information to identify technical measures to mitigate immediate risks without discarding the use of intricate models to support more complex decision making requirements.

The main purpose of this work is the development of a conceptual model, established on a multi-criteria based analysis, for pollution risk assessment, which involves a screening for environmental risk sources, focussed on the persistent, bioaccumulative and toxic (PBT) substances discharged into water resources. The assessment involves the use of geographic information systems (GIS) that are a practical tool for the spatial evaluation of the hazards and for the identification of risk receptors, i.e., groundwater and surface water. On a site-specific basis, traditional ERA approaches have several spatial limitations that can be overcome using GIS (Tristán et al., 2000).

The model is based on a typical approach to calculate the total risk score for a certain scenario as a linear weighted sum of scores across several criteria (Almasri and Kaluarachchi, 2005; Huang et al., 2011; Ram and Montibeller, 2013; Schuwirth et al., 2012), using GIS to assess the risk receptors and including the use of strategic appraisal principles (Marshall and Fischer, 2005; Ram and Montibeller, 2013; Slater and Jones, 1999).

The RA is traditionally based on chemical analyses of specific compounds because no method that takes into account interactions among chemicals in complex mixtures has been sufficiently developed (Baderna et al., 2011). Although the model does not

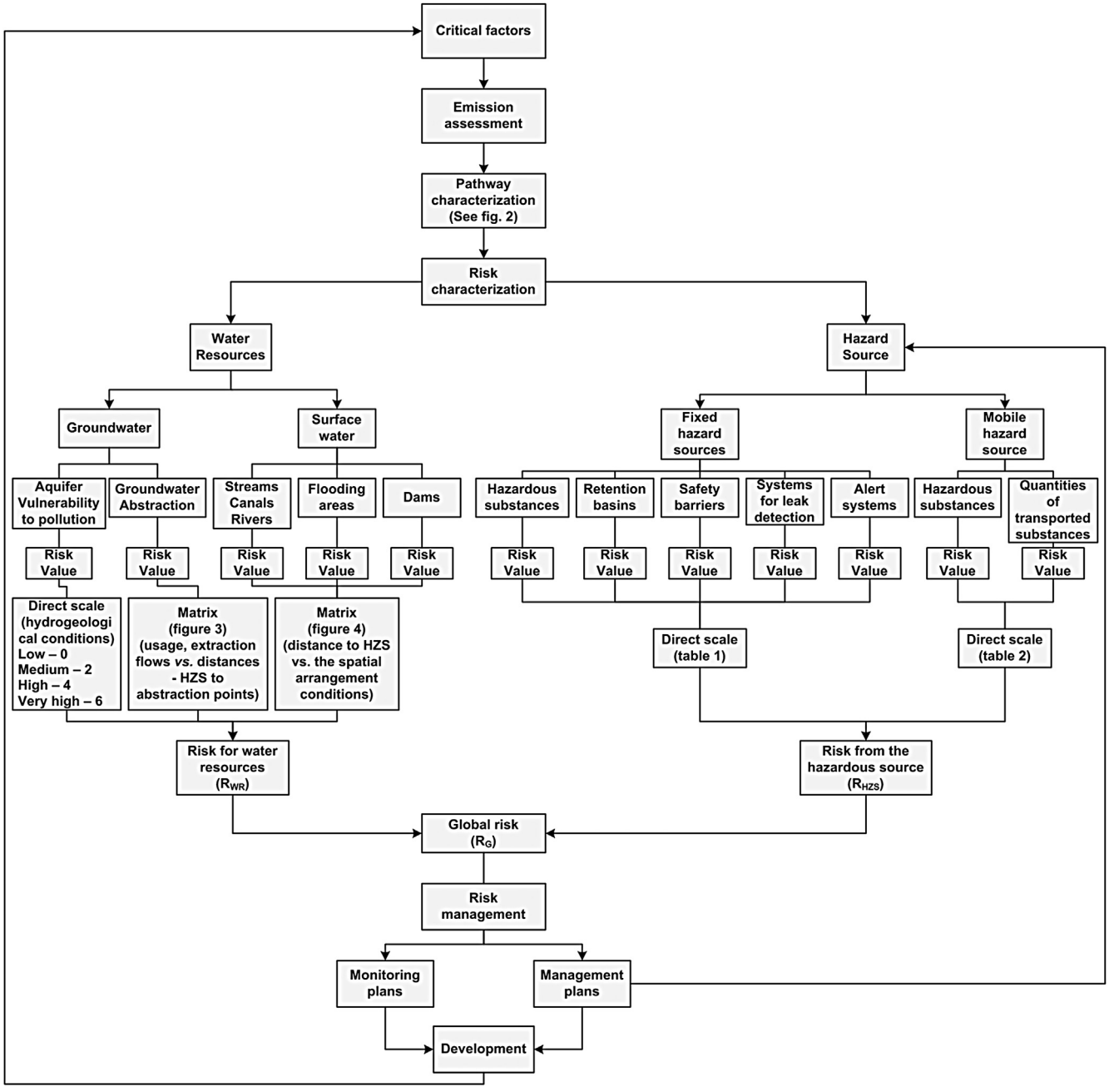

Fig. 1. Risk assessment model for water resources.