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Index-based groundwater vulnerability mapping models using hydrogeological settings: A critical evaluation

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ABSTRACT

Groundwater vulnerability maps are useful for decision making in land use planning and water resource management. This paper reviews the various groundwater vulnerability assessment models developed across the world. Each model has been evaluated in terms of its pros and cons and the environmental conditions of its application. The paper further discusses the validation techniques used for the generated vulnerability maps by various models. Implicit challenges associated with the development of the groundwater vulnerability assessment models have also been identified with scientific considerations to the parameter relations and their selections.

Contents

1. Introduction

Groundwater is a valuable resource for the existence of mankind as people across the globe use it for various activities like consumption, irrigation and industrial use. Its contamination has always been a big concern for such activities and has aroused curiosity among the researchers, government agencies and environmental organisations in the recent years. The long term exposure of toxic contaminants present in groundwater has adverse effects on human health in the form of various grievous diseases like skin lesion, skin cancer, neurological effect, hypertension, cardiovascular diseases, pulmonary diseases and diabetes mellitus (Hendryx, 2009; Kile and Christiani, 2008; Saha et al., 1999; Smith et al., 1992; Smith et al., 2000; Tseng et al., 2003). Groundwater contaminants are naturally occurring inorganic pollutants such as arsenic, aluminium, lead, mercury, fluoride, iron, and nitrate and manmade organic pollutants such as pesticides, plasticizers, and chlorinated solvents (Ghosh and Singh,

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2009; US Geological Survey, 2014) which are widely spread in air, water, soil, rocks, plants and animals in different ratios. Inorganic contaminants are released in the environment via chemical and physical breakdown of rocks and subsequent leaching and runoff, volcanoes, microorganisms and human activities such as mining and excavation. Organic contaminants are released in the environment through various agricultural activities. These contaminants get into groundwater and finally enter into human bodies through food chain.

Groundwater is relatively less vulnerable to contamination in comparison to surface water. However, urbanisation and industrialization have caused a serious threat to the water resources because the natural purification rate has been subdued by the rate of waste/industrial effluent discharge into the environment. Also, the panoptic use of tube-wells has caused serious groundwater intoxication over the years. Many government agencies have come up with their reports on groundwater quality assessment models. Some of the severely affected countries are: Bangladesh (Elahi et al., 2012; Hossain et al., 2007; Islam and Islam, 2007; McArthur et al., 2001; Smith et al., 2000), India (CGWB, 2014; Ckakraborty et al., 2007; Ghosh and Singh, 2009; Gorai and Kumar, 2013; Lalwani et al., 2004; Umar et al., 2009), China (Cheng et al., 2011; Cuihua et al., 2007; Dong et al., 2009; Mohamed, 2013; Rodríguez-Lado et al., 2013; Shuaijun et al., 2011; Su et al., 2009; Wang et al., 2010; Wu et al., 2011; Yang et al., 2011), U.S.A. (Klug, 2009; Ruopu and Lin, 2011; USEPA, 2014; USGS, 2000), etc. (CGWB, 2014; Islam and Islam, 2007; Rodríguez-Lado et al., 2013; USEPA, 2014).

In order to monitor and assess the quality of water from the regions where the primary source of drinking water is groundwater wells, several groundwater vulnerability and risk mapping models have been developed. These models estimate the sensitivity of groundwater to contamination and it is expressed in the form of vulnerability map. The vulnerability map segregates the particular region into several hydrogeological sub-regions with different levels of severity from the contamination point of view (Naqa et al., 2006). There are mainly three kinds of techniques used in the creation of vulnerability assessment maps, viz. statistical techniques (Burkart et al., 1999; National Research Council, 1993; Teso et al., 1996; Troiano et al., 1997), process-based simulation techniques (Jury and Ghodrati, 1987; Pineros Garcet et al., 2006; Rao et al., 1985; Tiktak et al., 2006; Wu and Babcock, 1999) and index-based techniques (Aller et al., 1987; Civita, 1994; Daly et al., 2002; Doerfliger et al., 1999; Foster, 1987; Margane, 2003; Robins et al., 1994; Stempvoort et al., 1993; Vrba and Zaporozec, 1994) as shown in Fig. 1. Statistical techniques find the mapping between the spatial variables and the presence of contaminants in the groundwater. Statistical techniques are not generic in nature as they are mostly used in the assessment of groundwater where similar contaminants are present. Process-based techniques employ simulation models to forecast pollutant movement in groundwater. However, they have shortcomings in the form of unavailability of adequate data but they are more elaborated than simple index-based techniques. Index-based techniques have the advantages over the rest of the two as it resolves their limitations. Index-based techniques are not encumbered by computational complexities and data shortage. This is the reason that index-based techniques are the most preferred for the groundwater vulnerability assessment.

The aim of the current study is to review and evaluate the recent progress made in the area of vulnerability assessment of groundwater contamination in the form of discussion of various index-based vulnerability assessment models. This paper discusses the pros and cons of various index-based vulnerability assessment models and their applications in

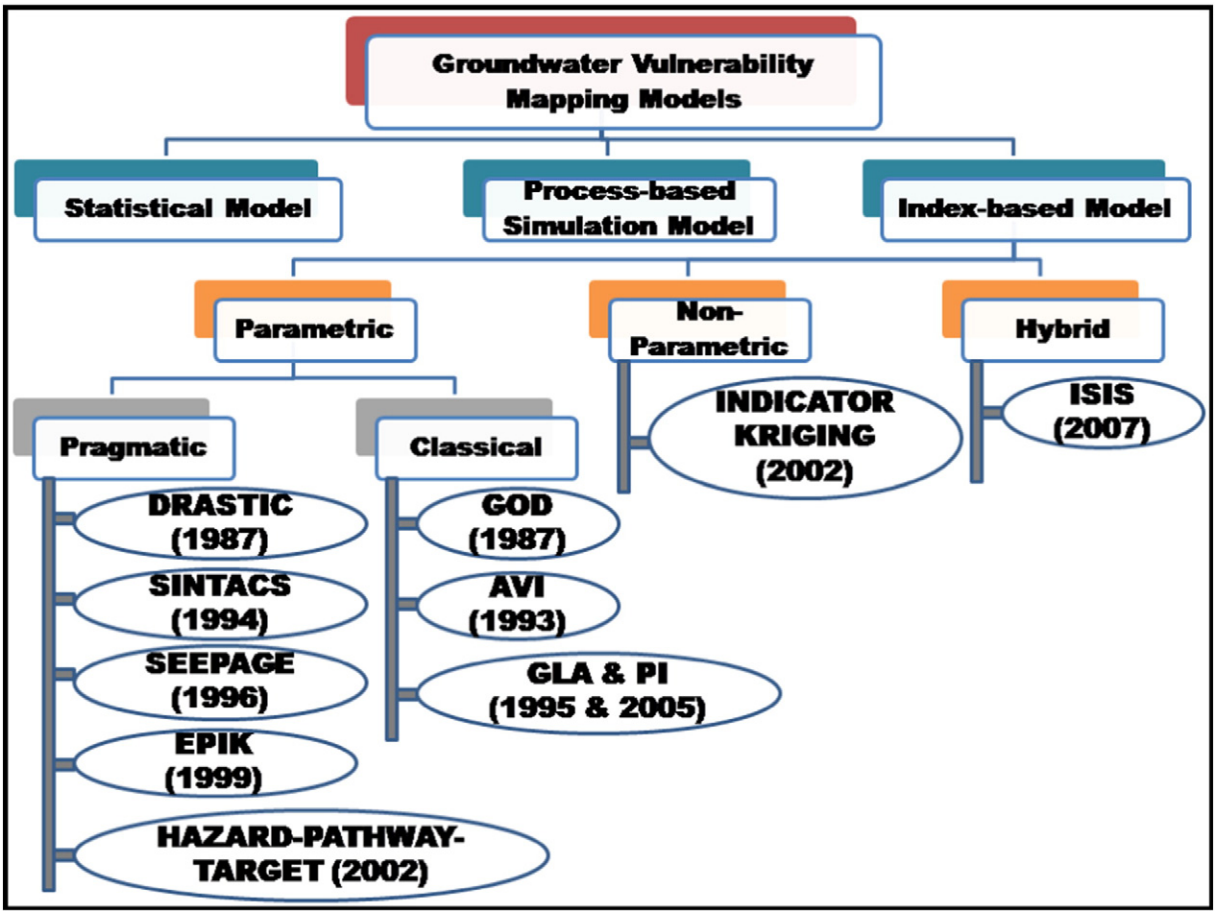

Fig. 1. Index-based groundwater vulnerability mapping models.