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Evaluation of index-overlay methods for groundwater vulnerability and risk assessment in Kathmandu Valley, Nepal

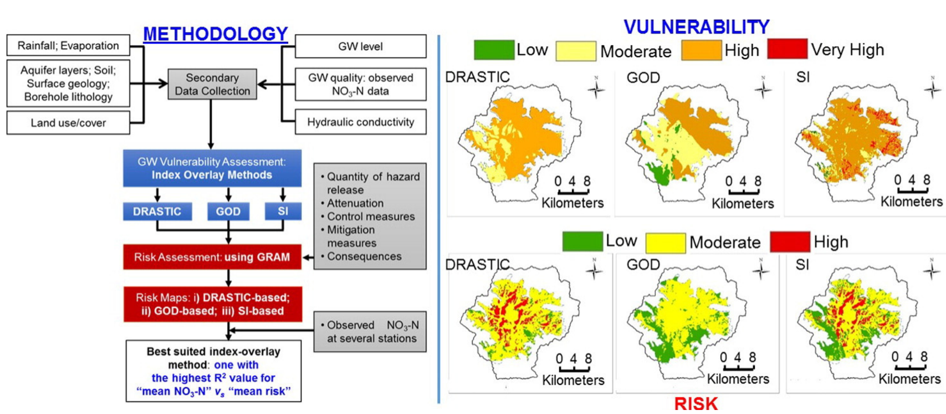
Sangam Shrestha [a,*], Ranjana Kafle [a], Vishnu Prasad Pandey [a,b]

[a] Water Engineering and Management, Asian Institute of Technology, P. O. Box 4, Klong Luang, Pathumthani 12120, Thailand
[b] Center of Research for Environment Energy and Water (CREEW), 259 Chandramukhi Galli, Baluwatar, Kathmandu-4, Nepal

HIGHLIGHTS

- Index-overlay groundwater vulnerability and risk assessment methods were evaluated.
- Sensitivity index (SI) method was found as the most-suited for Kathmandu, Nepal.
- About 15% and 58% areas are under high and moderate vulnerabilities in the area.

GRAPHICAL ABSTRACT



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ABSTRACT

This study aimed at evaluating three index-overlay methods of vulnerability assessment (i.e., DRASTIC, GOD, and SI) for estimating risk to pollution of shallow groundwater aquifer in the Kathmandu Valley, Nepal. The Groundwater Risk Assessment Model (GRAM) model was used to compute the risk to groundwater pollution. Results showed that DRASTIC and SI methods are comparable for vulnerability assessment as both methods delineate around 80% of the groundwater basin area under high vulnerable zone. From the perspective of risk to pollution results, DRASTIC and GOD methods are comparable. Nevertheless, all the three methods estimate that at least 60% of the groundwater basin is under moderate risk to NO_3-N pollution, which goes up to 75% if DRASTIC or GOD-based vulnerabilities are considered as exposure pathways. Finally, based on strength and significance of correlation between the estimated risk and observed NO_3-N concentrations, it was found that SI method is a better-suited one to assess the vulnerability and risk to groundwater pollution in the study area. Findings from this study are useful to design strategies and actions aimed to prevent nitrate pollution in groundwater of Kathmandu Valley in Nepal.

1. Introduction

Freshwater is under acute stress due to population growth, urbanization and industrial activities. At the same time, available water is

* Corresponding author.
E-mail addresses: sangam@ait.asia, sangamshrestha@gmail.com (S. Shrestha).

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contaminated by many pollutants. Groundwater is a major component of freshwater supply in many parts of the world; but it is contaminated from domestic, agricultural or other activities (Russo and Taddia, 2012). In the case of urban areas, inadequate management of wastewater and solid waste are posing significant threats to the groundwater quality and subsequently on public health.

Groundwater is vulnerable to contamination from human activities. Groundwater vulnerability is the tendency of or likelihood for, contaminants to travel and reach a specified location in the groundwater system after it is introduced at some location above the uppermost aquifer. Shallow groundwater zone is more likely to be contaminated from chemical pesticides, fertilizers and industrial wastes. When aquifers become highly polluted, contamination will stay for a long time and hard to remediate due to their large storage, longer residence times and physical inaccessibility (Foster and Chilton, 2003). Furthermore, groundwater contamination is an unnoticeable process and of irreversible nature and too expensive as well as time-consuming, which may constrain efforts aimed at improving groundwater environment (Yu et al., 2010). Groundwater can be polluted by different pollutants like nitrate, ammonia, phosphate, and microbes. Direct disposal of waste material on the river banks and other dumping sites has led to pollution of groundwater as well as surface water from nitrate and other contaminants. For example, shallow aquifer in Kathmandu Valley is contaminated with nitrate because of human-induced sources like untreated waste materials, agricultural fertilizers, and septic tanks (Shrestha et al., 2012). In some cases, naturally occurring denitrification in the aquifer environment by bacteria looking for the source of oxygen may help reduce nitrate level in groundwater (Bittner, 2000). Wisely designed management strategies could be implemented in improving groundwater quality.

Groundwater management encompasses a broad range of activities including prevention of groundwater contamination. Vulnerability and pollution risk assessments to identify risk zones are the very first important steps to generate useful information for devising strategies aimed at groundwater protection to contamination. Delineating vulnerable zones helps water resource managers to divert groundwater development activities to other safer areas and hence can minimize cost of water treatment. There are different methods for groundwater

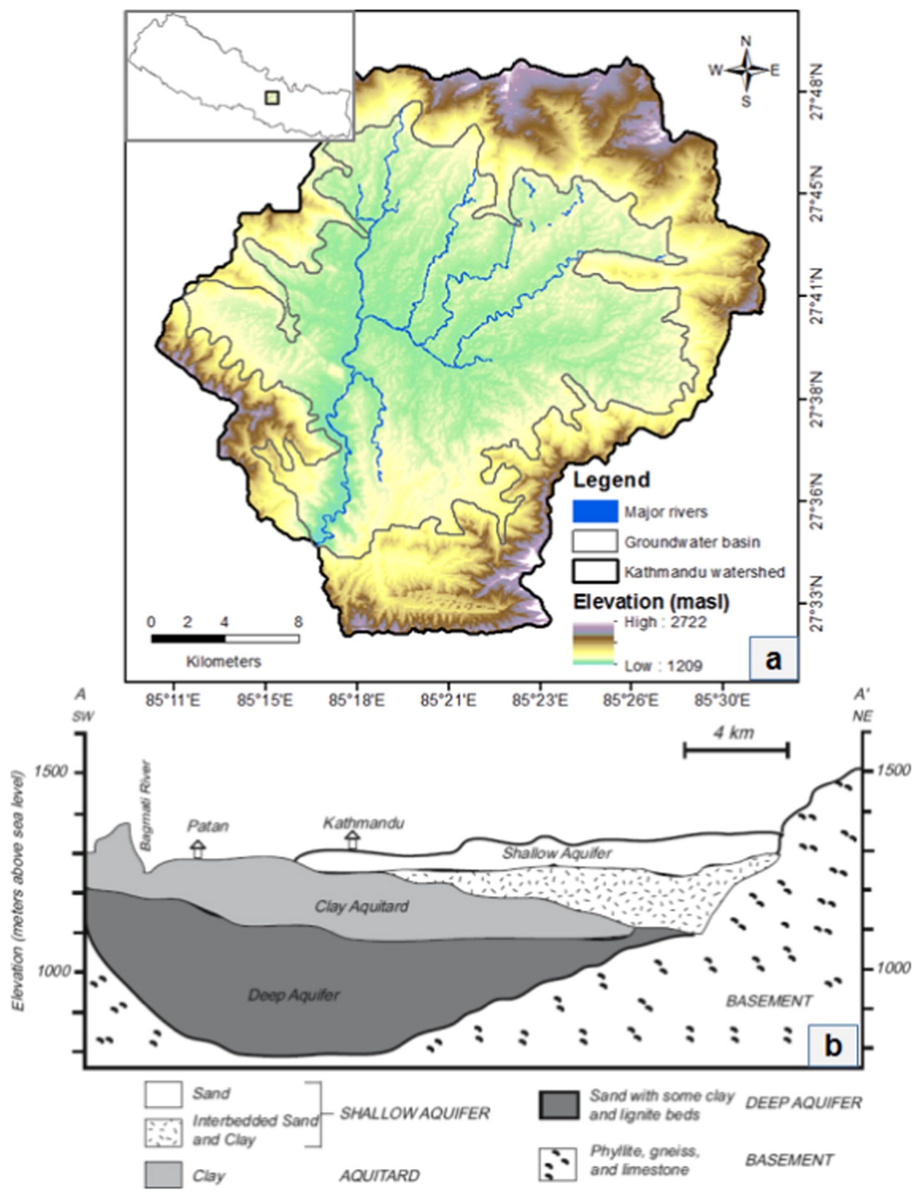

Fig. 1. Location of study area: a) location and topographic details; b) aquifer layers as shown in Warner et al. (2008).