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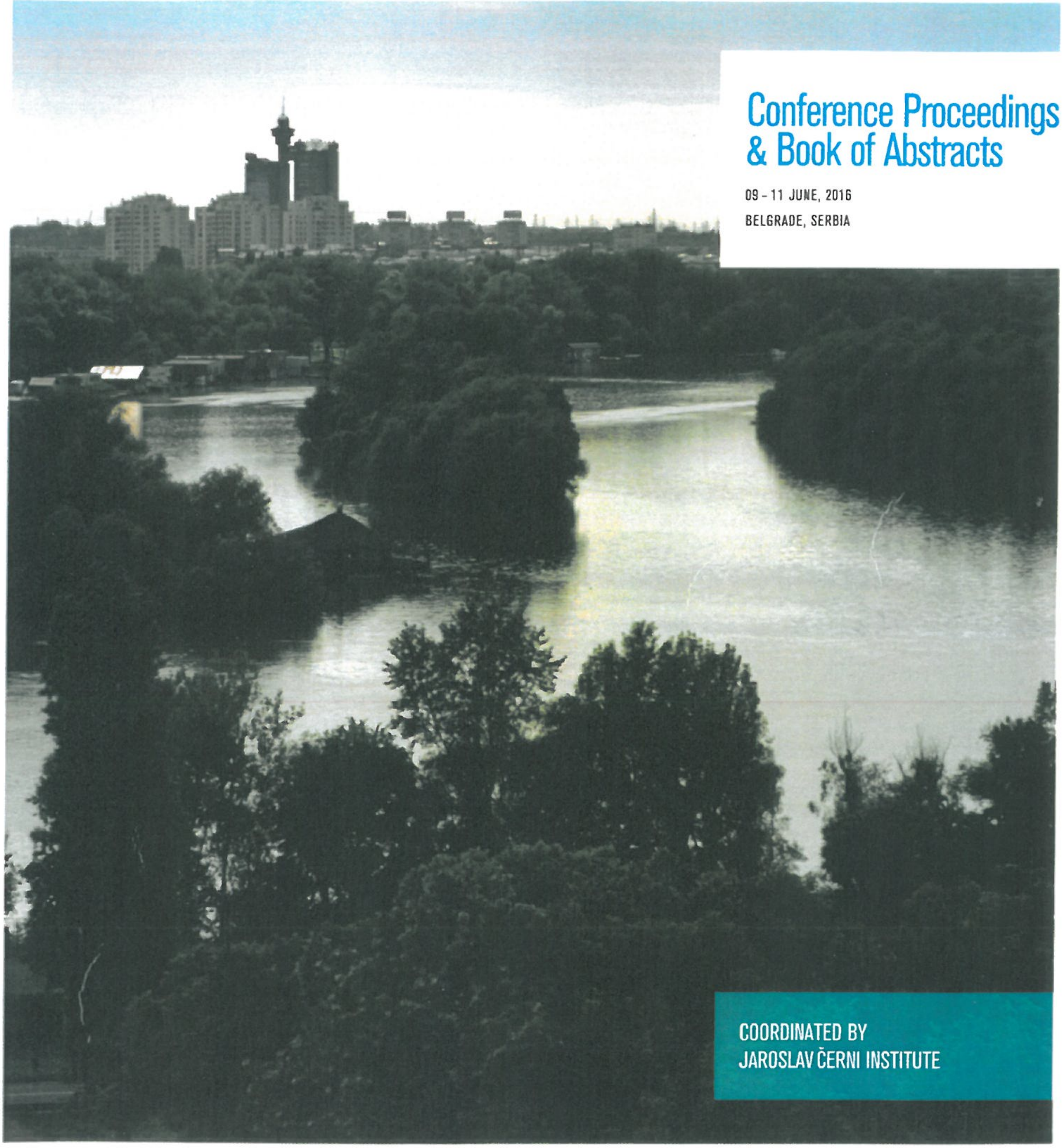

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AND

BOOK OF ABSTRACTS

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VULNERABILITY OF GROUNDWATER TO POLLUTION USING VLDA MODEL IN HALABJA SAIDSADIQ BASIN, IRAQ

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Abstract: Groundwater considered being the most vital source of water in several regions in the world. Specifically in the Halabja-Saidsadiq Basin, groundwater plays an important role as one of the essential source of water supplies. Therefore, it needs to be taken care of. In this study, VLDA method applied to model a map of groundwater vulnerability to contamination. The VLDA model classified the area into four categories with different coverage area: low (2%), moderate (44%), high (53%) and very high (1%). After constructing every vulnerability maps, it required to be confirm in order to estimate the validity of the theoretical sympathetic of current hydrogeological conditions. In this study, nitrate concentration analysis was selected as a contamination indicator to validate the result. The nitrate concentration between two different seasons (dry and wet) was analyzed from (30) water wells, considerable variations in nitrate concentration from dry to wet seasons had been noted. Consequently, it point toward that groundwater in the HSB are capable to receive the contaminant due to suitability of overlies strata in terms of geological and hydrogeological conditions. Based on this confirmation, the result exemplify that the degree and distribution of vulnerability classes acquired using VLDA model are more sensible.

Keywords: Vulnerability, VLDA, Nitrate concentration, Halabja Saidsadiq Basin (HSB).

INTRODUCTION

Groundwater considers being an important water sources in various region. Halabja and Saidsadiq Basin(HSB) that is located in the northeastern part of Iraq (figure 1), is one real example as a source for drinking, industrial and agricultural activities. This area in the past was destructed by army attacks by chemical weapons. After 2003, the area is experiencing considerable economic development and enhanced security. In view of these changes, there is an increase in the numbers of people heading to live in this basin and its surrounding regions. This is imposing a growing demand for water which has placed substantial pressures on groundwater resources. While, the studies of the groundwater resources and its potential pollution in the area has not been taken into account yet in the area.

Groundwater vulnerability is a measure of how easy or how hard it is for pollution at the land surface to reach a productive aquifer. The vulnerability studies can provide valuable information for stakeholder working on preventing further deterioration of the environment (Mendoza & Barmen, 2006). To simplify the identification of the groundwater state and to resist the pollutants in the reservoirs, several methods were recommended such as DRASTIC, VLDA, COP, GOD, SINTACS, etc. These different methods are offered under the form of numerical excerpt systems based on the negotiation of the different factors affecting the hydrogeological system (Attoui and Bousnoubra 2012). Therefore, the objective of this study is to model the groundwater vulnerability map using VLDA method as the first attempt to protect the groundwater from contamination.

Study Area

Geographically, Halabja Saidsadiq Basin is located in the northeastern part of Iraq between the latitude 35" 00 00" and 35" 36' 00" N and the longitude 45" 36' 00" and 46" 12' 00" E (figure 1). Ali (2007) divided this basin into two sub-basins including Halabja- Khurmal and Said Sadiq sub-basins. The whole area of both sub-basins is about 1278 square kilometers with population of about 190,727 in the early 2015. About 57% of the studied area is an arable area due to its suitability for agriculture (Statistical Dtectorate,2014). Consequently, the use of fertilizers and pesticides are common practices, so it affects the groundwater quality (Huang et al, 2012).

Geology and Hydrogeological Setting

Geologically, the studied area is located within Western Zagros Fold-Thrust Belt. Structurally, located within the High Folded zone, Imbricate and Thrust Zones (Jassim and Goff, 2006). The age of the exposed rocks in the area is from Jurassic to the recent. In addition, the area is characterized by at least four different hydrogeological aquifers due to presence of different geological units. The characteristic features of the aquifers and all exposed rocks in the basin are tabulated in the table (1).

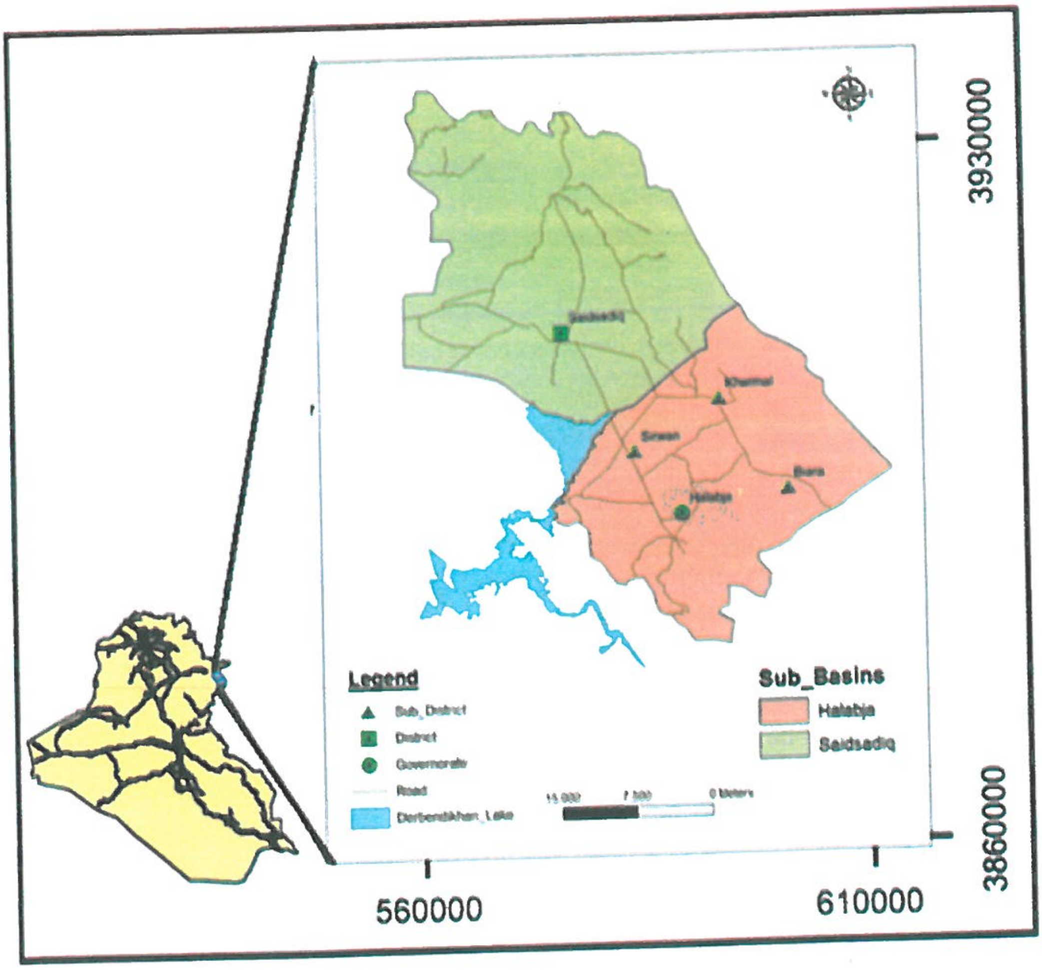

Figure 1: Location map of study basin.

Aquifer type	Geological formation	Thickness (m)	References
Intergranular Aquifer	Quaternary deposits	more than 300	Abdullah 2015 a
Fissured Aquifer	Balambo Kometan	250	Ali,2007
Fissured-Karstic Aquifer	Avroman Jurassic formation	200 From 80 to 200	Jassim and Goff,2006
Non-Aquifer (Aquitard)	Qulqula Shiranish Tanjero	more than 500 225 2000	Jassim and Goff,2006

Table 1. Type of aquifers in the study basin.

The data used for groundwater vulnerability mapping using VLDA method were collected from the field and officially from archives of all related offices. Features were used to create the shape files with GIS (Arc Map 10) software. On the basis of the DRASTIC model for assessing groundwater vulnerability and in accordance with certain principle, VLDA model is proposed by (Zhou et al, 2012). VLDA principally reflects lithology of vadose zone (V), pattern of land use (L), groundwater depth (D). and aquifer characteristics (A). In addition, consistent weight can be assigned to each of the four indexes depending on its impact on groundwater vulnerability.

The vulnerability comprehensive assessment index (DI) is the sum of the above-mentioned weighted four indexes, as computed conferring to the following formula:

$$DI = \sum_{j=1}^{4} (W_{ij} R_{ij}) \qquad (7) \quad \text{(Zhou et al, 2012)}$$

Where DI is the comprehensive assessment index of the i^{th} sub-system of the groundwater vulnerability system in the HSB. W_{ij} is the weight of the j^{th} comprehensive assessment index of the ith sub-system, and $\sum_{j=1}^{4} W_{ij} = 1$, R_{ij} is the value of the j^{th} assessment index of the ith subsystem; 4 is the quantity of indexes.

The slighter the DI signifier to the lower vulnerability of the groundwater system and the better the stability will be. For evaluating the groundwater vulnerability, different weights were proposed by different researchers. As a result, on the basis of the arithmetic averages from previously applied normalized weights, the weight value for VLDA proposed to be 0.286, 0.251, 0.191 and 0.271 respectively. While, for this study, the new corresponding weights in HSB were proposed using sensitivity analysis method (Abdullah 2015 b). According to the result of sensitivity analysis, the proposed weights used for VLDA model measured as 8.2, 4.8, 5.2 and 4.8, and after normalization, the weight is 0.357, 0.209, 0.226 and 0.209, respectively, (table 2).

Calculation of indexes	Lithology of vadose zone (V)	Pattern of land use (L)	Groundwater depth (D)	Aquifer characteristics (A)
Weights-Sensitivity analysis	0.357	0.209	0.226	0.209
Weights-previously proposed	0.286	0.251	0.191	0.271

Table 2. Weights of indexes in VLDA model

RESULT AND CONCLUSIONS

The vulnerability outcome (figure 2), reveals that a total of four ranges of vulnerability indexes had been noted ranging from low to very high with vulnerability indexes (2.133-4, >4-6, >6-8 and > 8). The area of low vulnerability with vulnerability index (2.133-4) occupy an area of (26 Km^2) or (2%) of the whole area and located in the south west of the basin. While very high vulnerability class covered the central part of the basin with index value of (>8) and an area of (1%) or (13) Km^2. This area is characterized by high water table level and presence of several springs with fractured limestone, it means such area where (V, D and A) have the highest value. The High vulnerability class occupied the most of mountains area that surrounding the basin and the central part of HSB. This vulnerability zone covered an area of (677) Km^2 or (53%). Finally, medium vulnerability zone cover an area of (562) Km^2 or (44%) of all studied area and positioned southeast and northwest of the basin. The last two vulnerability classes (high and moderate) that occupied most of the studied basin refer to the exhaustive human activities, good water yield property of the aquifers and fissured limestone and coarse-grain aquifers as vadose zone type.

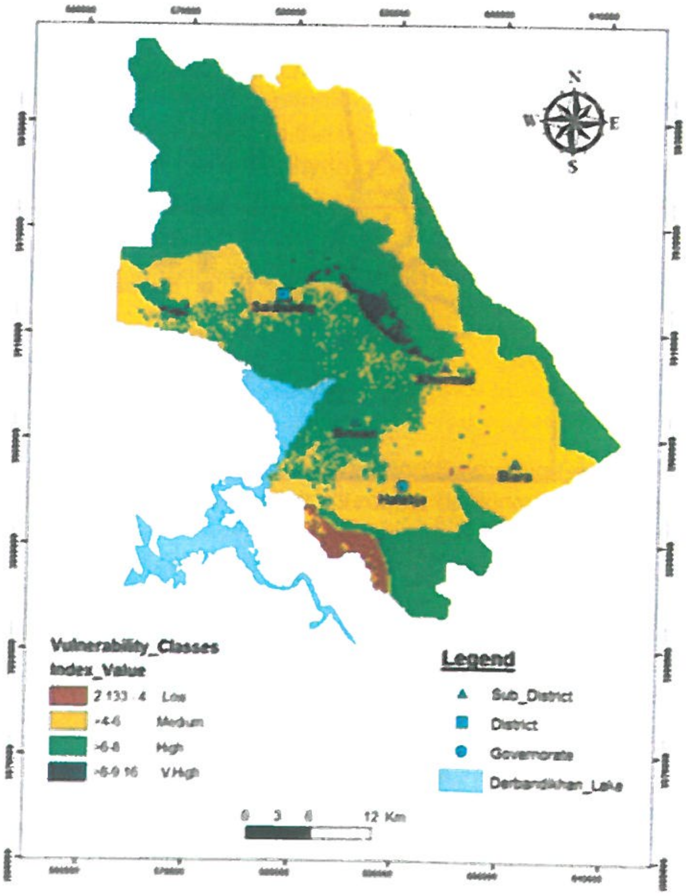

Figure 2: VLDA Vulnerability index Map of HSB

VALIDATION OF THE RESULT

Each vulnerability maps should be confirming after constructing in order to estimate the validity of the theoretical sympathetic of current hydrogeological conditions (Bruy`ere et al,2001and Perrin et al, 2004). In order to validate both applied models at HSB, nitrate concentration analysis has been selected. In the particular studied case, the nitrate concentration differences between two following seasons (dry and wet) were analyzed from (30) water wells. The selected wells for nitrate concentration measurement located nearly in all vulnerability zones at each models. The average of nitrate concentration in dry season were (>10) mg/l for both classes respectively. Whereas, for the wet season the concentration were considerably risen up (>30) mg/l for each class. Therefore, these considerable variations in nitrate concentration from dry to wet seasons, figure (3), verify the sensibility of the degree and distribution of vulnerability levels acquired using the VLDA model.

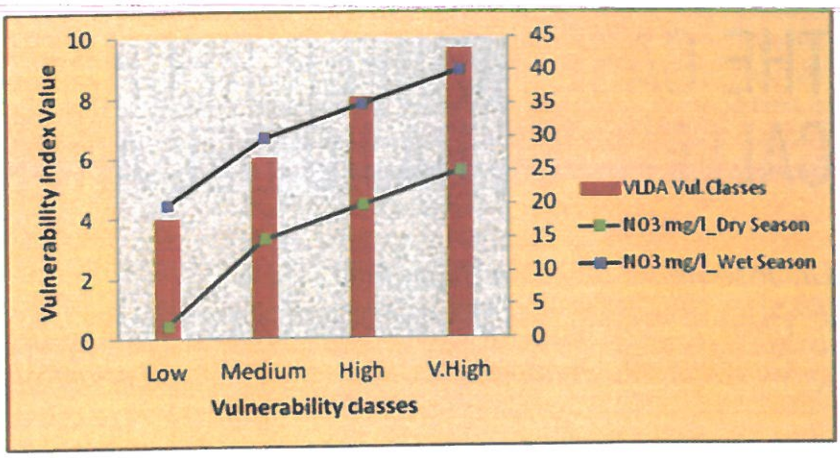

Figure 3. Comparison of Both model with nitrate concentration.

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