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GROUNDWATER VULNERABILITY ASSESSMENT TO CONTAMINATION (ERZENI BASIN, ALBANIA)

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Abstract: Groundwater quality has been recently deteriorating in different alluvial aquifers of Albania due to industrialization expansion, waste disposal, and agriculture activity. A preliminary assessment of vulnerability to groundwater contamination in Erzeni watershed area was undertaken because of enormous mining activities of river bed alluviums, the presence of the largest urban solid waste disposal site of Tirana and intensive agricultural and industrial activities at the plane part of the river course. The major geological and hydrogeological factors that affect and control groundwater contamination were incorporated into the DRASTIC model. Moreover, a Geographical Information System (Arc Gis 9.2 INFO) was used to create a groundwater vulnerability map of Erzeni river basin. Aquifer vulnerability assessment aims at predicting areas, which are more likely than others to become contaminated as a result of human activities at the land surface. As a result of the vulnerability assessment, 20% of the Erzeni basin was classified as being very highly vulnerable, 5% highly vulnerable, 15% vulnerable at moderate to low levels and, finally, around 60% of the basin has very low vulnerability.

Keywords: Albania, 2009, GIS-based evaluation, alluvial aquifer, groundwater, vulnerability.

1. Introduction

Groundwater, that represents a major source of water for domestic, industrial and agricultural uses in Albania, is recently suffering a deterioration of its quality especially in the regions with extensive demographic and industrial development, due to excessive groundwater withdrawal and introduction of different contaminants from the surface The concept of groundwater vulnerability is based on the assumption that the physical environment may provide some degree of protection to groundwater against natural impacts, especially with regard to contaminants entering the subsurface environment (Napolitano, 1995). Consequently, some land areas are more vulnerable to groundwater contamination than others. Over the past 30 years, groundwater vulnerability maps have been developed in many countries as a basis for developing land use strategies that take into consideration aspects of protection of groundwater from pollution (Fritch, 2001; Naqa et al., 2006). The final goal of vulnerability maps is the subdivision of the area into several hydrogeological units with different levels of vulnerability. These maps show the distribution of highly vulnerable areas, in which pollution is very common because contaminants can reach the groundwater within a very short time. However, such maps do not replace more detailed studies of the geological and hydrogeological conditions of particular sites for the envisaged use. The aim of this study is to assess the vulnerability of groundwater to contamination for the basin of Erzeni river which flows through Tirana and Durresi regions (Fig. 1). Groundwater vulnerability assessment was done by using a DRASTIC model (Aller *et al.*, 1987) combined with a Geographic Information System (Arc Gis 9.2 INFO). This model has been widely used in many countries because the inputs required for its application are generally available or easy to obtain.

The Erzeni Basin (Fig. 1), which is one of the most important alluvial groundwater basins in Albania (Eftimi et al., 1989; Dhima et al., 2000), consists mainly of Quaternary alluvial gravels that are 2-7.0 m thick (Puca, 2005). The groundwater flow is influenced by the recharge/discharge areas, the topography and the internal characteristics of the aquifer medium. The main recharge occurs from the south-eastern side of the area and groundwater flows to the north-western part of the basin where the groundwater is under pressure due to the impermeable clay cover layer. The yield for the most of the groundwater wells ranges from 2.0 to 5.0 l/s. The general groundwater mined from this aquifer is around 2000 l/s (Puca, 2005). From the hydrochemical point of view, the groundwater belongs to calcium – magnesium – bicarbonate type having pH, general hardness and general mineralization values of 7.3, 27.9°Gj and 850mg/L, respectively.

2. Materials and Methods

For the assessment of the Erzeni groundwater vulnerability to contamination the DRASTIC (Aller *et al.*, 1987) model and a geographic information system (ArcGIS) (Napolitano, 1995) were used to

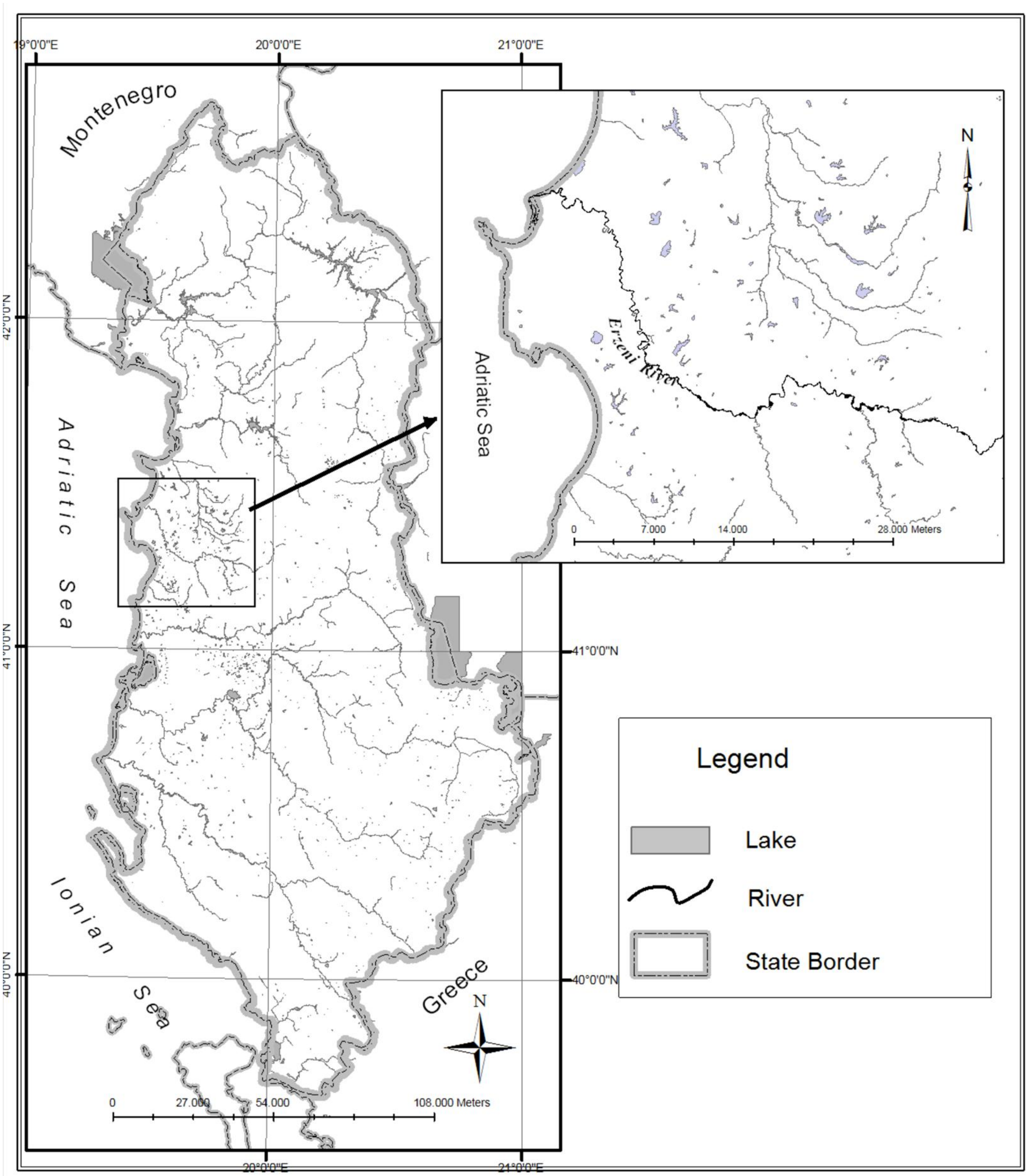

Fig. 1. Hydrographic map of Albania (Erzeni basin is shown on the right).

produce the vulnerability map for groundwater contamination. This involved: (i) data (hydro-geological, geological and pedological) collection, (ii) scanning of toposheets and digitizing (raster to vector) source data, (iii) creating the attribute table, (iv) analyzing the DRASTIC factors for evaluation of Drastic Index, (v) rating these areas as to their vulnerability to contamination and deriving a Graduated Map.

(i) The seven parameters that are involved in arriving at the Drastic Index have been collected from the following sources: Geological Survey of Albania, Institute of Soils and Institute of Topography for the Depth to water, Aquifer media, Hydraulic conductivity and Net recharge, Soil media, Impact of Vadose Zone and Topography, respectively.

(ii)The toposheets were scanned for generating raster images TIF format (Tagged image file) which are then exported to CADD for converting them into a vector format through the digitization process; finally the topographic map was georeferenced.

(iii) the attribute table, that was created in Excel, contains the following data: number and X, Y coordinates of the hydrogeological well, weights and ratings of Drastic parameters, values of Drastic Index. The data of attribute table were imported from Exel to GIS 9.2 through Access.

(iv) Drastic Index formula DR*DW +RR*RW + AR*AW + SR*SW + TR*TW + IR*IW + CR*CW was entered in the calculator (Excel) table where product of ranks and weights of each parameter was summed up and the final output (Drastic Index), as a whole number which assigns the vulnerability, was calculated.

(v) The Graduated Map for each parameter and for the Drastic Index (vulnerability map) was created in Arc Gis 9.2 INFO by using Spatial Analyses.

3. Results and discussion

Vulnerability refers to the sensitivity of groundwater to contamination, and is determined by intrinsic characteristics of the aquifer. It is distinct from pollution risk, which depends not only on vulnerability but also on the existence of significant pollutant loading. In this study, the DRASTIC model and a geographic information system (Arc Gis 9.2 INFO) were used to produce the vulnerability map for groundwater contamination in the Erzeni basin. Different models can be applied to mapping of groundwater vulnerability, but the most commonly used model in assessing groundwater vulnerability in porous aquifers seems to be the DRASTIC model (Aller *et al.* 1985; Aller *et al.*, 1987; Deichert and Hamlet, 1992,).

DRASTIC, that is a methodology for identifying vulnerability to groundwater pollution, was originally developed by the U.S. Environmental Protection Agency. The DRASTIC acronym stands for the seven hydrogeological parameters: Depth to water, net Recharge, Aquifer media, Soil media, Topography (slope), Impact on the vadose zone media, and hydraulic Conductivity of the aquifer. The DRASTIC model has four assumptions (Aller *et al.* 1985; Aller *et al.*, 1987):

1) the contaminant is present on the ground surface;

2) the contaminant is flushed into the groundwater by precipitation;

3) the contaminant has the mobility of water;

4) the area being evaluated by DRASTIC is 0.4 km^2 or larger.

For the determination of the DRASTIC index number (pollution potential) each factor rating was multiplied by its weight and the resulting values were added together:

$$\text{DRASTIC Index} = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \quad (*)$$

where r = rating for area being evaluated (1–10), and w = importance weight for the factor (1–5). Importance weights are found in a generic DRASTIC table (Table 1) that lists weights for factors having greater applicability (Aller *et al.*, 1987) while factor ratings are derived from data on each factor (Table 2-8). Finally, the Drastic Index values are calculated by using the above (*) equation (Table 9). Higher sum values, i.e. higher DRASTIC index, represent a greater potential for pollution or a greater vulnerability of the aquifer to contamination. The DRASTIC index was further divided into five categories: very low, low, moderate, high, and very high. The sites with high and very high categories are more vulnerable to contamination.

Table 1. Assigned weights for DRASTIC parameters.

Feature	Drastic Weights
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of Vadose Zone	5

Table 2. Ranges and rating for the depth to water.

Depth to water (m)	
Range	Rating
0-2.0	10
2.0-5.0	9
5.0-10.0	7
10.0-15.0	5
15.0-30.0	3

Table 3. Ranges and rating for the net recharge.

Net recharge (mm/Year)	
Range	Rating
0-5.0	1
6.0-10.0	3
10.1-16.0	6
16.1-25.0	8
>25.0	9

Table 4. Ranges and rating for the aquifer media.

Aquifer Media	
Range	Rating
Coarse-grain gravel	8
Medium-grain gravel	7
Fine-grain gravel	6
Medium-grain sand	5
Fine-grain sand	4

Table 5. Ranges and ratings for soil media.

Soil Media	
Range	Rating
Silty clay	3
Silty sand	4
Loam	5
Sandy loam	6
Sand	9
Gravel	10

Table 6. Range and rating for topography.

Topography (Percentage slope)	
Range	Rating
0-2.0	10
2.0-4.0	9
4.0-6.0	5
6.0-8.0	3
>8.0	1

Table 7. Ranges and ratings for impact of the vadose zone media.

Vadose Zone Media	
Range	Rating
Sandy gravel	8
Silty sand	6
Silt	4
Sandy silt	3
Sandy clay	2
Clay	1

Table 8. Ranges and ratings for hydraulic conductivity.

Hydraulic Conductivity (m/day)	
Range	Rating
0-5.0	1
5.0-10.0	2
15.0-25.0	3
25.0-50.0	6
50.0-100.0	8
>100.0	10

The Arc Gis 9.2 INFO was used to compile the geospatial data and to generate the final vulnerability maps. The DRASTIC index map (Fig.2) was prepared to determine the vulnerability to groundwater contamination (*i.e.*, pollution potential). This map shows that the vulnerability of the Erzeni alluvial aquifer to contamination ranges from very low (DI=65) to very high (DI=200). The most vulnerable areas of the aquifer to groundwater contamination – showed by the highest DRASTIC indexes – are located in the southeast area of the basin where the soil cover and/or vadose zone are absent or very thin and aquifer media consists mainly of gravel and pebbles (Table 10). On the contrary, along the northwestern sectors of the Erzeni basin, where a thick (20-30m) vadose zone with a well developed soil cover are present, the lowest vulnerable areas of the aquifer to groundwater conta-

Table 9. Calculation of Drastic Index values.

D factor	R factor	A factor	S factor	T factor	I factor	C factor	Di number
DrDw	RrRw	ArAw	SrSw	TrTw	IrIw	CrCw	ID
45	36	27	20	3	40	27	199
45	36	27	20	3	40	27	200
45	36	27	20	3	40	27	198
45	36	27	20	3	40	27	198
45	36	27	20	3	40	27	198
45	36	27	20	3	40	27	198
45	36	27	20	3	40	27	198
45	36	27	20	3	40	27	198
10	8	15	6	10	15	12	76
10	8	15	8	10	15	12	78
10	8	15	6	10	15	12	76
50	28	24	10	5	30	24	171
50	28	24	10	5	30	24	171
50	28	24	10	5	30	24	171
50	28	24	10	5	30	24	171
50	28	24	10	5	30	24	171
50	28	24	10	5	30	24	171
50	32	21	18	5	40	24	190
50	28	21	12	5	40	24	180
50	36	21	12	5	40	24	188
50	36	21	12	5	40	27	191
25	28	21	10	5	30	27	146
35	24	24	12	5	30	27	157
25	20	21	12	5	30	27	140
25	20	21	12	5	30	27	140
25	20	21	12	5	30	27	140
15	20	21	12	5	25	27	125
15	20	21	12	5	25	27	125
15	20	21	12	5	25	27	125
15	20	21	12	5	25	27	125
15	20	21	12	5	25	27	125
15	20	21	12	5	25	27	125
15	12	18	12	6	15	15	93
15	12	18	12	6	15	15	93
15	12	18	12	6	15	15	93
15	12	18	12	6	15	15	93
15	12	18	12	7	15	15	94
15	12	18	12	7	15	15	94
10	12	15	6	7	15	15	80
10	12	15	6	7	15	12	77
10	12	15	6	7	15	12	77
10	12	15	6	7	15	12	77
10	12	15	6	7	15	12	77
10	12	15	6	7	15	15	80
10	12	15	6	7	15	15	80
10	12	15	6	7	15	15	80
5	8	15	8	9	10	12	67
5	8	15	8	9	10	12	67
5	8	15	8	9	10	12	67
5	8	15	6	9	10	12	65
5	8	15	6	9	10	12	65
5	8	15	6	9	10	12	65
5	8	15	6	9	10	12	65
5	8	15	6	9	10	12	65
15	8	15	8	10	15	12	83
15	8	15	8	10	15	12	83
15	8	15	6	10	15	12	81

mination are located. Even the very high vulnerable area represents only 20% of the basin, it has a strong impact on aquifer vulnerability because it represents the recharge area of the basin. After entering the aquifer in this area the contaminant can be distributed in other parts downward the aquifer flow.

Table 10. Indicative values of hydraulic conductivity and vadose zone thickness.

Well No.	10	19	14	2-Φεβ	2-Ιαν
Drastic index	198	171	140	94	67
K (m/day)	110	75	15,5	12,3	8,5
Thickness of Vadose zone (m)	1	4	18	20	36

Table11. Representative data of qualitative monitoring.

Well No.	10	19	14	2-Φεβ	2-Ιαν
Drastic index	198	171	140	94	67
NO_3 (mg/l)	2,8	1,8	1,3	1	0
PO_4 (mg/l)	1,8	1,1	0,9	0,9	0,8
NH_4 (mg/l)	0,1	0,05	Trace	0	0

The above configuration of the vulnerability to groundwater contamination fit very well with the data of the qualitative monitoring. This later has detected different levels of ammonium ions, nitrites, nitrates, phosphates, etc, in the groundwater of the southeastern sectors (Table 11) of the aquifer as it could be expected from the vulnerability map.

4. Conclusions

The DRASTIC model and a geographic information system (Arc Gis 9.2 INFO) were used for the assessment of the groundwater vulnerability to contamination in the Erzeni basin. This assessment along with a continuous qualitative monitoring are indispensable for this aquifer because its groundwater represents an important water source for potable, industrial and agricultural needs of the Tirana – Durresi region where Erzeni river flows. According to values of the DRASTIC index, five categories of aquifer vulnerability to contamination are distinguished: very low, low, moderate, high, and very high which fit very well with the data of the qualitative monitoring. The areas with high and very high categories, i.e. the more vulnerable areas to contamination are located in the southeastern part of the basin, whereas the lowest vulnerable areas of the aquifer to groundwater contamination are located along its northwestern sectors.

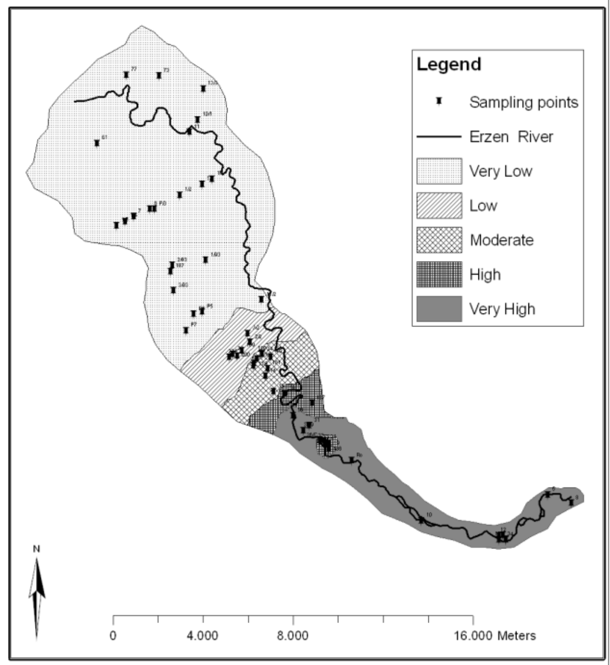

Fig.2. Vulnerability map based on DRASTIC Index.

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