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Assessment of zones vulnerable to pollution caused by nitrate and seawater intrusion: The case of Apulia Region

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Introduction

The study area is situated in Apulia region (Italy), along the Taranto's ionic arc and it comprises the territory of 'Palagiano' (Fig. 1). The climate is typically Mediterranean: hot and dry. The precipitation is scarce and takes place only in the period between October and March and summer droughts are frequent. As the study zone is within the Apulia region, it is then characterized by a limited superficial hydrographic network, whereas the groundwater resources are abundant and over-exploited for the civil and agriculture uses. Because of the bad management of the groundwater, this resource becomes to be threatened particularly by the sea water intrusion and by the anthropic pollution mainly caused by the use of huge amounts of nitrogen fertilizers for intensive agriculture.

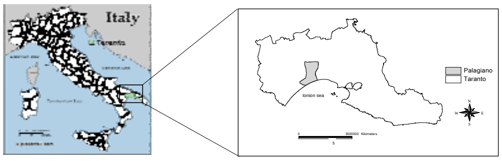

Fig 1. Location of the study area

Problems

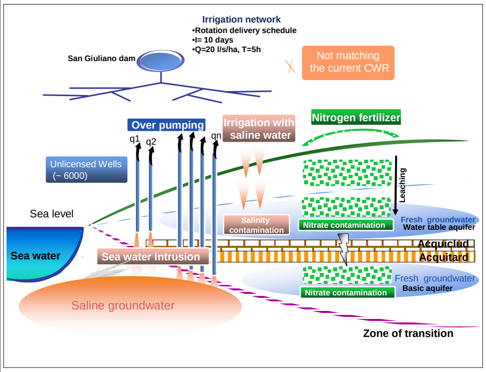

Fig 2. Shematic presentation of the problems in the study area

➢ Due to hot and dry climatic conditions and to the poor distribution of seasonal rainfall the agriculture in the area of Palagiano depends strongly on irrigation. Nevertheless the irrigation network in this area is too restrictive and not timely matching the current crop water requirements. Consequently during the last 10 years a large number of farmers have started developing their "private water sources" by drilling their own wells . Nearly 6000 unlicensed wells are estimated in the area (Fig. 2).

➢ This has led to an over-pumping from groundwater (which especially occurs during the peak water demand periods) causing the withdrawal of saline water and we have so the sea water intrusion phenomenon. The irrigation with this saline water will in turn cause the salinization of the water table aquifer and increase the process of salt build-up in the soils.

➢ On the other hand the overuse of nitrogen fertilizer has led to nitrogen leaching into the water table causing the nitrate contamination of this aquifer. In the presence of fracture this contamination can reach the deep aquifer.

Methods

➢ First DRASTIC methodology within GIS was used to assess the vulnerability to potential contamination of groundwater. The seven variables from which the DRASTIC model name is derived are depth-to-water table (D), net recharge (R), aquifer media (A), soil media (S), topography (T), impact of vadose zone (I) and hydraulic conductivity (C). The above parameters are used to define the hydrogeologic setting of an area. These parameters are further sub-divided into ranges or zones, representing various hydrogeologic settings and are assigned different ratings in a scale of 1–10. The rating assigned to each of these ranges or zones indicates their relative importance within each parameter, in contributing to aquifer vulnerability. The linear additive combination of the above variables with the ratings (r) and weights (w) was used to calculate the DRASTIC Intrinsic Vulnerability Index (DIVI) as fellow (Aller et al., 1987):

$$DIVI = D_r \times D_w + R_r \times R_w + A_r \times A_w + S_r \times S_w + T_r \times T_w + I_r \times I_w + C_r \times C_w$$

➢ Spatial and temporal variability of the salinity and nitrate concentrations was studied using on one hand available analysis (for the year 1998) of these elements in some deep and shallow wells of the zone. On the other hand to assess the current chemical state of the groundwater in the area of Palagiano and to understand the inter-annual trend of salt and nitrate concentrations, analyses were done on 32 samples taken from shallow wells in both winter and summer seasons.

➢ To visualize the spatial distribution of the salinity and nitrate concentrations the previous analysis results were interpolated using SURFER program into outstanding contour map.

➢ Finally in order to make a prediction of every possible effect on ground water quality, simulations of the groundwater flow and contaminant transport were generated using MODFLOW.

Results

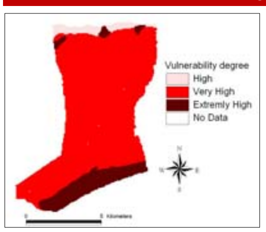

Fig 3. Aquifer vulnerability map

➢ The aquifer vulnerability map (Fig. 3) shows very high and extremely high degree of vulnerability.

➢ Through the distribution of the salinity in Figs. 4 and 5, we can note that the distribution of the salinity in the basic aquifer is function of the distance from the coast. The greater salinity contents are found in vicinity of the sea and vary around 4.3 dS/m. While going towards north, the salinity values decrease but they remain always greater than 1.6 dS/m.

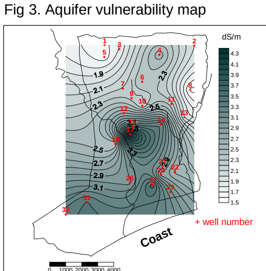

Fig4. Salinity distribution in the deep aquifer

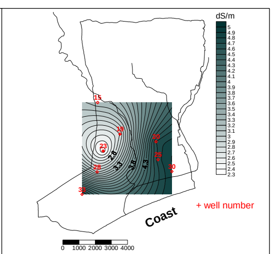

Fig5. Salinity distribution in the upper aquifer

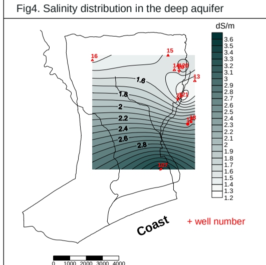

Fig 6. Salinity distribution in winter

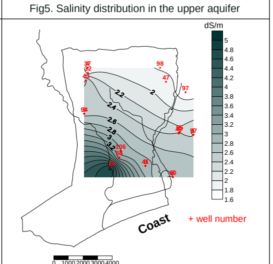

Fig 7. Salinity distribution in summer

Results

➢ Comparing to the deep aquifer, the superficial one presents high values of salinity that can reach 4.8 dS/m. In this case, the distribution of the salinity is not only caused by the sea water intrusion phenomenon but above all is in relation with the intensive irrigation practices. In fact the withdrawal of saline water from the deep aquifer and its use for irrigation and the application of fertilizers result in the accumulation of the salts in the soil. These salts will then be leached to the upper aquifer.

➢ The Figs. 6 and 7 show that the salinity is in increase from winter to summer. In fact, in winter the salinity is between 1.2 and 3.6 dS/m while it can reach in summer 4.8 dS/m. This increase is due to the high exploitation of the groundwater in the period of peak demand which extends from May to August.

➢ In the upper aquifer the nitrate pollution is above all related to agriculture practices. The maximum concentration is found in the well number 28 (214 mg/L) (Fig. 8).

➢ In the deep aquifer the distribution of nitrate is heterogeneous. We note that the high concentrations are located between the "Lenne" and the "Lama di Vite" rivers with a peack of 82 mg/L found in the well numver 17 and in the South Western part of Palagiano. We can explain the anomaly found in the well number 17 by the mix of the upper and deep aquifer caused by an inadequate isolation of the two aquifers in its proximity (Fig. 9).

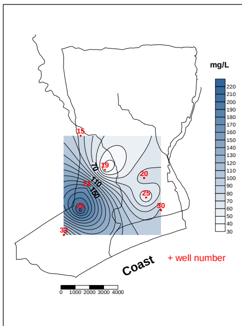

Fig 8. Nitrate distribution in the upper aquifer

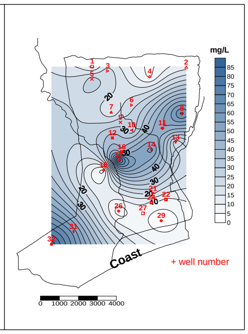

Fig 9. Nitrate distribution in the deep aquifer

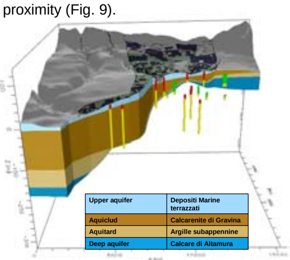

Fig 10. Cross section of the model domain

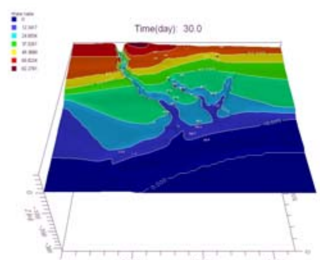

Fig. 11 Water table contour map (time = 30 days)

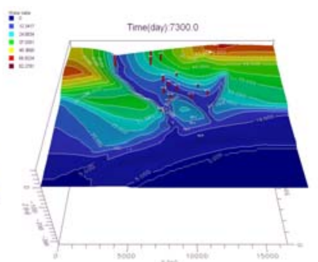

Fig.12 Water table contour map (time = 7300 days)

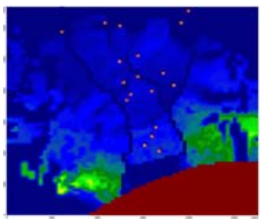

Fig 13. Concentration color map (time = 730 days)

Legend

Value (mg/L)	Color
135	
113	
90	
76	
52	
42	
21	
0	

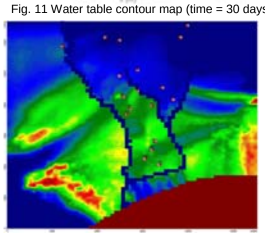

Fig 14. Concentration color map (time = 7300 days)

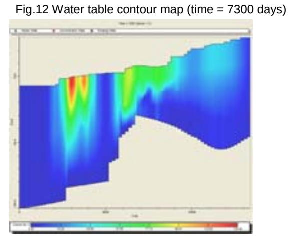

Fig 15. Contaminant plume in a cross section (time = 7300 days)

➢ The shape of the hydraulic head surface in the water table (Fig. 11) follows the general slope of the land surface . In fact since this aquifer is in direct contact with the atmosphere then the pressure head is neglected and consequently the hydraulic head is equal to the water table elevation

➢ In another part, according to the water table contours maps (Figs. 11 and 12) for the different time steps, we can note a remarkable decrease of the water table particularly in the proximity of the rivers. This can be due to the fact that the rivers are functioning like a drain for the phreatic aquifer.

➢ The concentration color maps (Figs. 13 and 14) display the results of nitrate distribution in the water table aquifer for the Output times 730 days and 7300 days. These times correspond to 2 and 20 years from the start simulation time (1 September 1998). We can notice the increase of the nitrate concentration during the simulation period and the extend of the nitrate contamination to the all area.

➢ To better understand the behavior of the contaminant plume it's possible to visualize it in a cross section as shows Fig. 15. After 20 years it is clear that the plume has migrated to all the units.

Conclusion

➢ Vulnerability assessment using the DRASTIC index model has been recognized for its ability to delineate areas that are more likely than other to become contaminated as a result of anthropogenic activities. This reduce considerably the cost of monitoring. In fact, once identified only these area were targeted by intensive monitoring .

➢ The prediction of the possible effects on groundwater quality specially its contamination with nitrates was performed using Visual MODFLOW program. The simulations of the nitrate transport show that after 20 years the contaminated zones would cover almost all the area. To avoid this situation remediation activities should be done in this area.

Literature cited:
Aller L., Bennett T., Lehr J.H., Pretty R.J and Hackett G. (1987).
DRASTIC: A standardized system for for evaluating ground water pollution potential using hydrogeologic setting. US environmental protection agency, Ada, Oklahoma (EPA-600/2-87-035).