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Hydrogeochemical characterization of the main aquifer of the "Litorale Domizio-Agro Aversano NIPS" (Campania — southern Italy)

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ABSTRACT

The aim of the paper is the identification in a wide area located north of Napoli city (southern Italy) of different sectors and/or different sources of anthropogenic or natural contamination in groundwater, in order to guide more effective decontamination intervention and to establish long-term environmental measures. Local administrators and environmental agencies can follow the methods used for this first characterization and zonation of a wide region for planning more focused investigations.

The area includes a large part of the "Litorale Domizio-Agro Aversano" NIPS, recognized by the Italian State as a National Interest Priority Site, where there is a need to implement characterization and remediation activities. In this area the main aquifer is located in the Volturno river plain; the intensive agriculture and the presence of numerous dumping sites (both legal and illegal), has produced widespread contamination, with many wells showing very high nitrate concentrations and point source pollution (heavy metals, hydrocarbons, pesticides) has also been noticed.

Moreover, groundwater presents different kinds of "natural contamination" such as high fluoride concentration (almost everywhere >1.5 mg/L) and high arsenic concentration in the zones related to volcanic formations and, in some sectors, high sulphates deriving from present and/or past hydrothermal conditions. Close to the rivers, lower nitrate content is related to reducing conditions. Low sulphate contents and high Fe and Mn contents corroborate the presence of a reducing zone.

The groundwater quality in the plain is influenced mainly by groundwater subsurface flows from the carbonate aquifers and by the proximity of volcanic districts, as stressed also by the statistical analysis. Indeed, the zonation of hydrochemical facies on the basis of the statistical analysis indicates clearly the different processes occurring in the aquifer along the groundwater flow path (contaminated areas, areas with reducing conditions, areas with carbonate influence, etc.).

The main results are in the proposition of a synergic use of different kinds of data for sustainable aquifer management. Indeed, it is possible to rehabilitate wide areas by means of education, legislation and long-term environmental measures, without recourse to expensive treatment processes.

1. Introduction

Knowledge of the hydrogeochemical background of an aquifer suggests how to evaluate recent evolution and changes. Indeed, understanding natural chemical processes occurring in the aquifer is a key factor to define natural trends and hence the type and extent of real contamination.

In the last 15 years, the Italian State has identified 57 National Interest Priority Sites (NIPSs), areas where characterization and remediation activities have to be implemented, six of which are in Campania region (southern Italy), for a total surface of about 1600 km^2, with different levels and sources of pollution (Napoli Orientale, Litorale Domitio-Agro Aversano, Napoli Bagnoli Coroglio, Litorale Vesuviano, Bacino idrografico del Sarno; Aree di Pianura). Litorale Domizio-Agro Aversano NIPS, encompassing the plains of the Garigliano River and of the Volturno River and partially the Phlegrean Fields volcanic area, includes a large part of the polluted agricultural land belonging to more than 61 municipalities in the Naples and Caserta provinces. Indeed, human activities are the cause of widespread NO_3 contamination, with many wells showing NO_3 concentrations higher than 50 mg/L. Isotope techniques ($^{14}N/^{15}N$) applied at a small part of the aquifer (Acerra area in Corniello and Ducci, 2009) indicated the nitrate contamination as a cumulative result of intensive cropping and livestock, but also of leakage from the sewage network. Moreover, in this area the soil contamination is due also to legal and illegal dumping of waste, with hazardous consequences for groundwater quality (Bove et al., 2011; Grezzi et al., 2011).

Within the Litorale Domizio-Agro Aversano NIPS, attention has focused on the central and southern areas, taken up largely by the Volturno River Plain groundwater body and by a part of the Phlegrean Fields volcanic groundwater body (Fig. 1). The Garigliano

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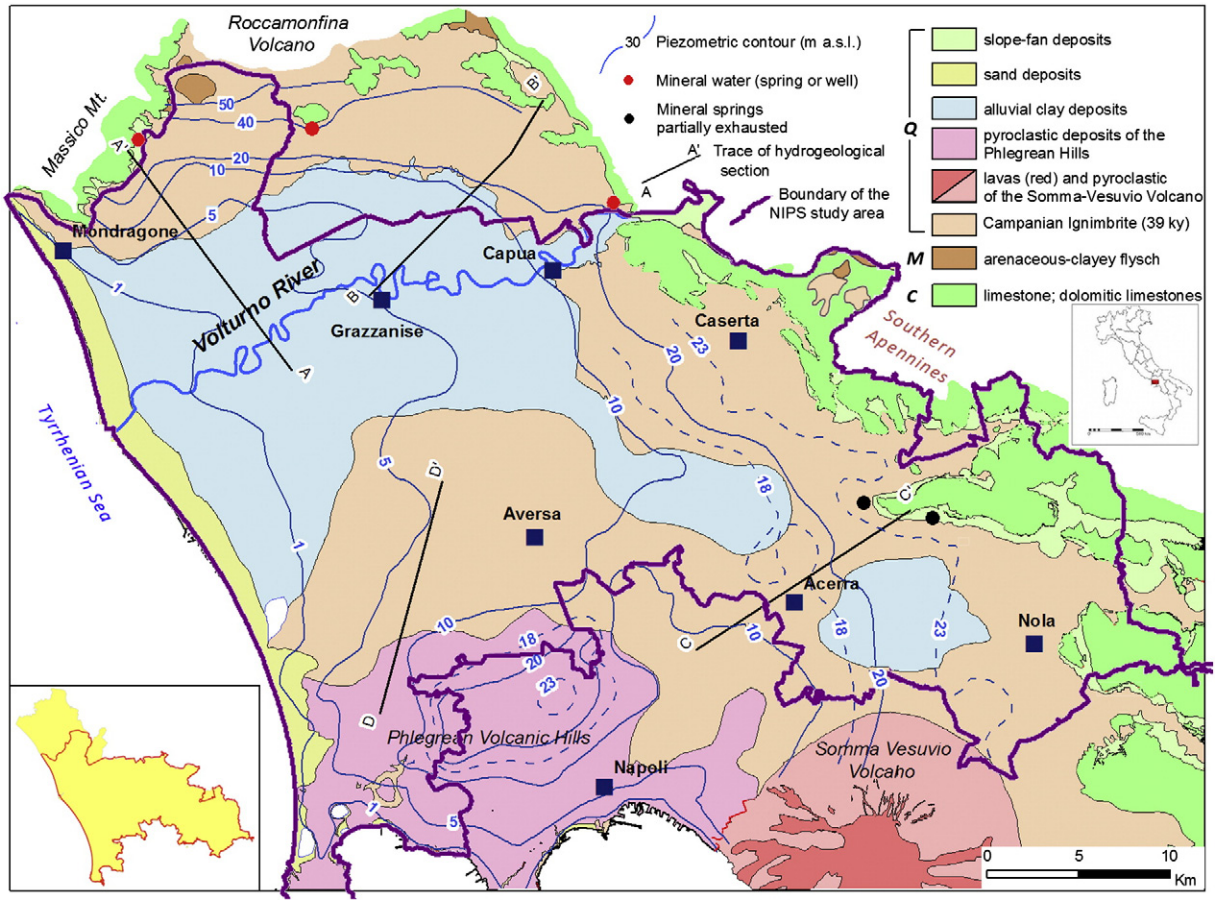

Fig. 1. Hydrogeological map showing the hydrogeological units (C = Cretaceous; M = Miocene; Q = Quaternary), the piezometric surface of the main aquifer in m a.s.l. (blue line) and the traces of the hydrogeological cross sections of Fig. 2 (black line). In the lower left corner the studied main aquifer is surrounded by a red line, and the NIPS area is in yellow.

plain is a separate groundwater body, with different features and lower anthropogenic pressure (Corniello et al., 2010b); for these reasons this paper does not deal with this plain and the southern border of Mt. Massico represents the northern limit of the study area.

In the Volturno River Plain the aquifer is located in the alluvial, pyroclastic and marine porous sediments underlying the "Campanian Ignimbrite" tuffs. Rainwater infiltration and subsurface flow from carbonate and volcanic aquifers contribute to recharging the aquifers of the plain. Nearby, hot springs diffuse degassing areas and thermal areas testify to the occurrence of hydrothermal systems, which strongly influence the groundwater features (Ducci and Sellerino, 2012). Furthermore, widespread settlements, with population densities exceeding 1000 inhabitants/km^2 in municipalities near Naples, interact strongly with the aquifers.

Therefore, the aim of the study is to discriminate areas where groundwater is affected by natural contamination from areas where there is man-made contamination, on the basis of the detailed definition of the geological and hydrogeological settings of the NIPS area, using a large amount of stratigraphical, piezometric and hydrochemical data. These last were also processed by descriptive and multivariate statistical analysis, whose advantages in hydrochemistry are deeply argued in Güler et al. (2002). The statistical classification of hydrogeochemical data by hierarchical cluster analysis (HCA) and the differentiation between different chemical environments by principal component analysis (PCA) have been widely applied to group groundwater into hydrochemical facies (Irawan et al., 2009; Mrklas et al., 2006; Tallini et al., 2013).

This example of the first characterization and zonation of a wide region is useful for local administrators and environmental agencies that can easily use this approach for planning more focused investigations.

2. Hydrogeological setting

The NIPS area is located in a NW–SE elongated structural depression bounded to the north-east by the Southern Apennines chain and to the southwest by the Tyrrhenian Sea. From the Early Pleistocene, this area was affected by a NE–SW extension and volcanism developed within the plain in the last 0.3–0.5 Myr. Hot springs, diffuse degassing areas and thermal anomalies affect the volcanoes and their sea sectors, and testify to the occurrence of hydrothermal systems (Milano et al., 2004).

On the basis of the hydrogeological peculiarities the study area can be divided into two interconnected groundwater bodies: the Volturno river plain and the Phlegrean Fields pyroclastic hills.

The large plain of the Volturno river (1340 km^2) is surrounded by the Mesozoic limestone mountains of the Southern Apennines (N and E), by the Roccamonfina volcano (N), by the Somma-Vesuvius volcano (SE), the Phlegrean Fields pyroclastic hills (SW) and the Tyrrhenian Sea (S and W).

The elevation of the wider part of the plain ranges between 0 and 100 m a.s.l. The plain is made up of Quaternary alluvial-pyroclastic and pyroclastic porous deposits (in light blue and light orange in Fig. 1). Campanian Ignimbrite is a large-volume trachytic tuff which erupted from the Phlegrean Fields (37–39 ky BP) and consisted of a fall-out deposit overlain by ignimbrite (De Vivo et al., 2001). The ignimbrite extends over an area of about 30,000 km^2 including the Volturno river