Correlation between hydrochemical facies and depositional environments in a salinized lowland coastal aquifer (Ferrara, IT).

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INTRODUCTION

The increasing demand of freshwater in coastal areas has intensified the research on saltwater intrusion in coastal aquifers (Custodio, 2010; Post and Abarca, 2009). However, land-use activities can lead to a relevant deterioration of coastal water resources and ecosystems (Lambrakis and Kallergis, 2001; Antonellini et al., 2008). In addition, in lowland sedimentary areas the problem of saltwater intrusion is greatly enhanced by land reclamation which forces seawater to intrude the coastal aquifers (Gattacceca et al., 2009). In order to understand the hydrogeochemical processes occurring within a groundwater system is also necessary to define the contribution of water-sediment interaction (Gaofeng et al. 2010) and to relate the groundwater quality to the sediment through which it passes. Thus, in this study we compared the depositional environments and the groundwater hydrofacies to delineate possible water/sediments interaction mechanisms.

STUDY AREA

The study area is the coastal aquifer of Comacchio (Ferrara, Italy), in the southeaster part of the Po River Plain. The Holocene geomorphic evolution of the area has been controlled by continental (Würmian) and marine deposition (post Würmian transgression) in a coastal environment of the Po Plain (Amorosi et al., 1999; Bondesan et al., 1995). Above the Pleistocene alluvional-plain deposits, the Flandrian transgressive phase (18–5.5 kyear) deposited back-barrier fine-grained deposits and transgressive barrier sands. Today the alternation of highs and lows in the topography corresponds to different coastlines and to different stages in the evolution of the Po Delta.

In this coastal aquifer four piezometers located along a flow line were selected to monitor the groundwater quality. These four piezometers are part of the regional monitoring network of the coastal aquifer, developed by the Geological Survey of the Emilia Romagna Region (Bonzi et al., 2010). The selected piezometers are aligned along fore-stepping direction of Holocene Po Delta system. The sedimentary sequence is characterized by transgressive bay and barrier deposits at the base and prograding sandy deltaic lobes and strand plains at the top; locally, coastal plain fine deposits overlay sand bodies making the aquifer semi-confined.

MATERIAL AND METHODS

All piezometers of the regional monitoring network have 5 cm inner diameter and are fully screened. In two boreholes, P33 and P34, core samples were collected every meter or when a change in stratigraphy was recognized. Samples were stored in a cool box at 4 °C and immediately transported in laboratory for sediment analysis.

Groundwater samples were collected every meter from the four piezometers, by using an 800L straddle packers system (Solinst, Canada). The samples were collected via low-flow technique using an inertial pump, after measuring the groundwater static level and purging the well. Then, the collected groundwater samples were filtered through 0.22 • m Dionex polypropylene filters, stored in a cool box at 4 °C and immediately transported in laboratory for analysis. Major anions and cations in groundwater were analysed using an isocratic dual pump ion chromatography ICS-1000 Dionex.

RESULTS AND DISCUSSION

The results from groundwater characterization show that the salinization is very high, with most of the samples exceeding the actual Adriatic sea salinity (• 35-38‰) with peaks of 60-70‰. These brines have been found within fine sediment layers associated with back barrier, salt-marsh and lagoonal environments. In fact, in this kind of environments salinity can be increased by evaporation processes. Once these sediments are covered by other layers and become

saturated with water, the salt can be leached by dissolution processes. This is well testified for P33. Moreover, the large amount of organic matter that can accumulate in lagoonal, marsh and swamp environments, as well as in distal delta fronts and prodelta deposits lead to very reduced conditions, with sulphate reduction within the aquifer, here represented along the transect by piezometer P33 and P34. These piezometers are also characterized by a clayey plug on the top of the sedimentary sequence.

On the other hand, outcropping dune ridges and beaches correspond to recharge areas, with lower salinity with respect to the previous environments. The chronic deficit of organic carbon sources maintain these environments in nitrate and manganese reducing conditions. Here extreme reducing condition are never found (see P3 and P8 along the transect). The piezometer P8 shows both the above discussed environments along its profile. The upper part corresponds to the ancient sandy delta lobes and the lower part to the prodelta sediments. Another complicating factor is that the aquifer is stressed by a complex drainage system with many canals and ditches forming the land reclamation network. This stress creates steep vertical head gradient causing a mix of groundwater from different depositional environments. Despite of this, the horizontal fine layers greatly diminish the vertical permeability and act as a barrier to the complete mixing.

CONCLUSIONS

The study correlates the hydrochemical facies and depositional environments in the salinized coastal aquifer of Ferrara (IT). Given the structural features of this aquifer and the paleogeography of the region, saline and hyperhaline water are associated with fine sediment of back barrier, salt-marsh and lagoonal environments, relic of Holocene transgression; while brackish and fresh waters are associated with relict dune-beach systems. Organic rich fine sediment and peat layers, which are characteristic of palaeo-marsh depositional environment, contribute to sulphate reduction.

Salt accumulated in the sediment can be leached by dissolution processes and transported from the bottom to the top of the aquifer by a steep vertical head gradient that has been measured in these sediments and causes a mix of groundwater from different depositional environments.

Recognizing all these factors enhances the understanding of the salinization dynamics within shallow coastal aquifers.

REFERENCES

Amorosi A., Colalongo M.L., Pasini G., Preti D. (1999) – Sedimentary response to late Quaternary sea-level changes in the Romagna Coastal Plain (Northern Italy). Sedimentology 46: 99-121.

Antonellini M., Mollema P., Giambastiani B.M.S., Bishop K., Caruso L., Minchio A., Pellegrini L., Sabia M., Ulazzi E., Gabbianelli G. (2008) – Salt water intrusion in the coastal aquifer of the southern Po Plain, Italy. Hydrogeol. J., 16(8): 1541-1556.

Bondesan M., Favero V., Viñals M.J. (1995) – New evidence on the evolution of the Po delta coastal plain during the Holocene. Quatern. Int. 29/30: 105-110.

Bonzi L., Calabrese L., Severi P., Vincenzi V. (2010) – L'acquifero freatico costiero della regione Emilia-Romagna: modello geologico e stato di salinizzazione. Il Geologo dell' Emilia-Romagna – Bollettino Ufficiale d'Informazione dell'Ordine dei Geologi Regione Emilia-Romagna, anno 10/2010 n. 39.

Custodio E. (2010) - Coastal aquifers in Europe: an overview. Hydrogeol. J. 18: 269–280.

Gaofeng Z., Yonghong S., Chunlin H., Qi F., Zhiguang L. (2010) - Hydrogeochemical processes in the groundwater environment of Heihe River Basin, northwest China. Environ. Earth Sci. 60: 139–153.

Gattacceca J.C., Vallet-Coulomb C., Mayer A., Claude C., Radakovitch O., Conchetto E., Hamelin B. (2009) - Isotopic and geochemical characterization of salinization in the shallow aquifers of a reclaimed subsiding zone: The southern Venice Lagoon coastland. J. Hydrol. 378: 46-61.

Lambrakis N., Kallergis G. (2001) - Reaction of subsurface coastal aquifers to climate and land use changes in Greece: modelling of groundwater refreshening patterns under natural recharge conditions. J. Hydrol. 245(1-4): 19-31.

Post V., Abarca E. (2009) - Preface: saltwater and freshwater interactions in coastal aquifers. Hydrogeol. J. 18(1): 1-4.