THE SALTWATER CONTAMINATION IN THE VENICE WATERSHED BETWEEN THE SOUTHERN EDGE OF THE VENICE LAGOON AND THE ADIGE RIVER, ITALY

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Abstract

The salt water contamination process in the Venice watershed between the southern edge of the lagoon of Venice and the Adige River extends up to 20 km inland from the coast. The depth of the fresh/salt-water interface varied from 2 to 30 m below the ground level and exhibits a significant, mainly seasonal, time variation and its dynamics is especially sensitive to the riverbed seepage of sea water, encroaching from river mouths.

Keywords: *Saltwater intrusion, hydrogeology, Venice Lagoon catchment.*

INTRODUCTION

The coastland surrounding the southern Venice Lagoon, Italy, is a precarious environment subject to both natural changes and anthropogenic pressure. A number of critical problems affect this lowlying area, i.e. relative land subsidence (Tosi et al., 2000; Gambolati et al., 2005; Teatini et al., 2005, 2007), periodic flooding during severe winter storms, and saltwater intrusion (Carbognin et al., 2005, 2006; Pousa et al., 2006). The investigated area is the catchment located south of the Venice Lagoon, where multidisciplinary studies (ISES, BRENTA and Co.Ri.La. 3.10 Projects) provided evidence of a phreatic aquifer contamination due to saltwater intrusion from the sea and the lagoon.

SALTWATER CONTAMINATION

A network (ISES Network).was established to monitor the water contamination and hundreds of analyses and geophysical investigation have been carried out showing that the saline water may extend inshore up to 20 km far from the Adriatic Sea coastline. The saltwater plume is observed from the near ground surface down to 100 m depth (Carbognin and Tosi, 2003; Rizzetto et al., 2003; Carbognin et al., 2005).

Geological studies pointed out that geomorphologic features and stratigraphic setting can favour or mitigate this process. In particular, well developed paleo-river systems and permeable sediments represent preferential environments of communication between waters characterized by different salinity, whereas thick silt-clayey layers can preclude the salty pollution from the lagoon and the sea.

Changes in river discharge, regulation of phreatic water levels by means of pumping stations, climatic conditions, fresh-water input for irrigation purpose, and riverbed seepage are important factors that cause saltwater contamination. The latter, influenced by tides and river discharges, takes place when sea and lagoon waters flow up rivers and channels (Fig. 1). For example, in summer 2003, when a severe drought happened, salt water flowed up the Brenta and Bacchiglione rivers for more than 15 km (Fig. 2) (Carbognin *et al.*, 2005), inducing high soil salinization and consequently serious problems to agriculture.

The ground elevation of the territory, generally below the mean sea level up to -4 m, enhances the process especially in those sectors where land subsidence, mainly due to peat soil oxidation in close connection with the agricultural practices, is responsible for a subsidence rate varying between 1.5 and 2 cm/yr (Tosi *et al.*, 2000; Gambolati *et al.*, 2005; Teatini *et al.*, 2005, 2007).

The interpretation of the results obtained from the investigations allowed producing maps of the top and bottom of the saltwater intrusion (Fig. 3) (Carbognin & Tosi, 2003). The former indicates the depth of the fresh/salt water boundary and shows the thickness of the surface fresh water aquifer. Six classes were distinguished: the first one is related to a very critical situation because it

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represents areas where saltwater contamination can be superficial and so responsible for damages to agriculture.

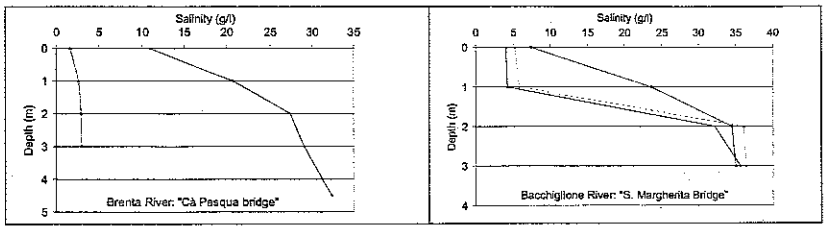

Figure 1 - Example of salt water encroachment variation along the Brenta (left) and Bacchiglione (right) rivers due to the combination of tide level and river discharge changes.

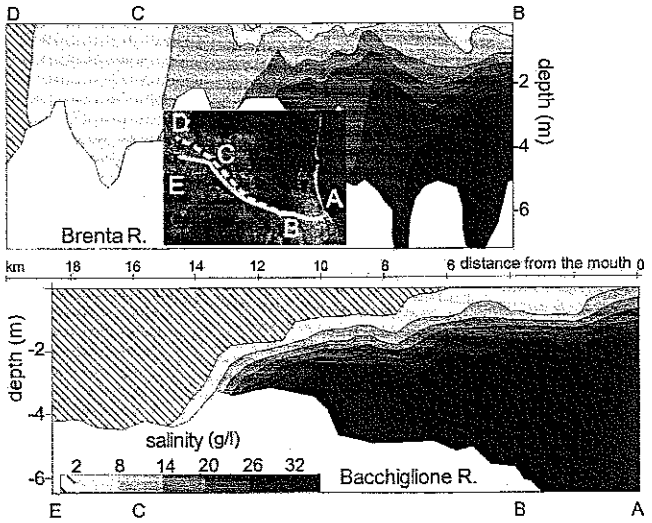

Figure 2 - Salt water encroachment along the Brenta and Bacchiglione rivers in the summer 2003 (after Carbognin *et al.*, 2005).

The second class includes the zones where soil salinization depends on seasons and climate variability.

The map of the bottom of saltwater contamination indicates the depth of the aquitard, which represents a natural obstacle to saltwater intrusion in the deeper deposits. It depends on the presence and characteristics of clayey layers

(permeability, thickness, extent) and deepens southward, ranging from 15-30 m to 60-75 m depths.

The maps of saltwater contamination show that on the southern Venetian littoral a system of sand dune ridges contains a reservoir of freshwater up to 15 m thick (Rizzetto *et al.*, 2003). In the mainland the thickness of the surface aquifer is frequently reduced up to 1 m because of the critical ground elevation of the area, the pumping to maintain drainage, and particular local sedimentological and geomorphologic features, that enhance the saltwater intrusion landward.

Patterns of saltwater contamination (Fig. 3) show that only the area between the Brenta and Bacchiglione rivers, where Piove di Sacco and Codevigo towns are located, is not affected by soil salinization process.

CONCLUSIVE REMARKS

The farmland bounding the southern Venice Lagoon suffers from the saltwater contamination process which involves soils devoted to agricultural and horticultural activities that are the main economic resources. The salt water contamination process in the Venice watershed between the southern edge of the lagoon of Venice and the Adige River was investigated through hydrogeological and geophysical surveys and a new monitoring network of surface water and shallow groundwater (ISES Network).

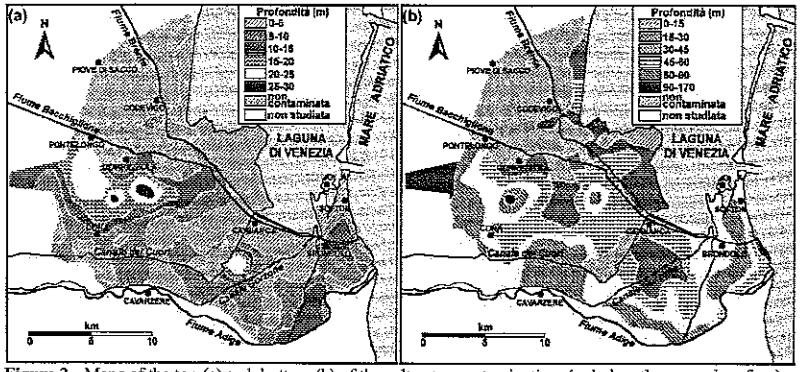

Figure 3 - Maps of the top (a) and bottom (b) of the saltwater contamination (m below the ground surface).

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The contamination process in this part of the Venice coastland is due to complex inter-relationships between ground-, surface-, and lagoon-water levels superposed to a very heterogeneous subsoil. The results show that: the presence of saline water extends up to 20 km inland from the coast; the depth of the fresh/salt-water interface varied from 2 to 30 m below the ground level and exhibits a significant, mainly seasonal, time variation; the bottom of the contaminant plume penetrates from 10 even to 100 m depth in the subsoil. Further investigations, still in progress, are showing that the dynamics of the soil salinization process is especially sensitive to the changes in the river (Brenta, Bacchiglione, Adige, Gorzone) discharge, water levels in a complex drainage network regulated by a number of pumping stations, and climatic conditions.

Other important factors are fresh-water releases for irrigation purpose and riverbed seepage. The latter is influenced by the tide dynamics which, together with river discharge, control the sea water encroachment along the river mouths. In summer 2003, for example, characterized by a severe drought, salt water flowed up the Brenta and Bacchiglione rivers for about 20 km. The saltwater intrusion has been enhanced by the ground elevation generally below the mean sea level, especially in southern sector where land subsidence, mainly due to peat soil oxidation, has induced an elevation loss greater than 1 m over the last few decades (Tosi et al., 2000; Teatini et al., 2005, 2007). The combined effect of sea level rise, land subsidence and saltwater contamination has enhanced the risk of soil desertification with serious environmental and socio-economic impacts.

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