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Boron contamination of Mediterranean groundwater resources: Extent, sources and pathways elucidated by environmental isotopes

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0.1 Background

Recently, the element boron has been classified as a pollutant of drinking water in national and international drinking water legislation (WHO Guidelines: 0.5 mg/l, EU Directive 98/83/EC: 1 mg/l). Moreover, boron becomes toxic for sensitive crops (e.g., mango, avocado, citrus fruits) at concentration levels even below 1 mg/l in irrigation water. Entire regions in many countries that border the Mediterranean suffer from boron contamination of their scarce groundwater and surface water resources, rendering them unusable for human consumption or even for irrigation purposes.

Furthermore, boron is contained in high concentrations in domestic waste water and seawater. Neither standard waste water treatment nor desalinisation of seawater by reverse osmosis is able to eliminate boron from the raw water so that residual boron contamination is a serious drawback for the use of unconventional water resources.

The EU FP5 project BOREMED aimed to find answers to a series of simple but fundamental questions concerning the specific water quality problem raised by boron contamination of Mediterranean groundwater resources. Main goals were to: (1) Asses the magnitude of the "boron problem" with respect to agriculture and EU drinking-water standards (2) Develop a methodology for identifying the sources and pathways of boron and salinity (3) Evaluate the health impact of boron in drinking water (4) De-

velop, test and apply new technologies for boron removal from contaminated groundwater, waste-water as well as from desalinated brackish and sea water (5) Develop water management policy that integrates the technical solutions with the political and legal institutional setting.

Degree of boron contamination of Mediterranean groundwaters

The overall extent of boron contamination of groundwater bodies around the Mediterranean can be deduced from a first survey of Mediterranean groundwater resources in EU countries (France, Italy, Greece) New Member States (Cyprus) and non EU states (Israel/Gaza). The BOREMED water quality base includes now the available data on boron contents of the groundwater resources at 6400 groundwater points, with 17400 individual boron analyses, and a total of 204000 chemical and isotopic analyses. Some preliminary conclusions can be drawn on the extent of boron contamination with 30% of the B-values are above 0.3 mg/l, 23% above 0.5 mg/l which are the former and present limits recommended by the WHO (1994, 1998) and 14% above the limit fixed by the EU Drinking Water Directive (1 mg/l). The highest values are found in Italy, in particular in areas with geothermal activity, in Northern Greece and the Attic region, in the central part of Cyprus and east of the Gaza strip. Most regional anomalies can be linked to specific geological settings and to the lithology of aquifer rocks. Public access to the data base is facilitated by a user friendly online GIS.

Sources and pathways of boron contamination

The identification of anthropogenic as well as natural sources of boron is a fundamental necessity for the assessment, investigation and remediation of the boron problem by water managers confronted with contaminated groundwater bodies.

A methodology for the identification of sources of boron contamination based on isotopic fingerprinting (B, Sr, O, H isotopes) and geochemical tracers was applied on four Mediterranean study sites: Italy (Cornia aquifer), Israel/Palestinian Authority (NE Gaza strip, Mediterranean coastal aquifer), Cyprus (3 small areas representative of the geological settings of the island) and Greece (Katsika-Petralona karst system on the Chalkidiki peninsula).

Specific studies were conducted on the boron in geothermal fluids of Larderello (Cornia study site), of boron in aquifer sediments (Cornia), on the isotopic fingerprinting of desalinised seawater (Israel, Cyprus) and on boron leaching from loess sediments (Israel). Major conclusion is the that in all studied settings, natural "geogenic" background pollution was predominant. Water-rock interaction seems a major source of regional B anomalies, seawater intrusion and geothermal fluids are secondary or indirect sources.

In **Italy (Corina)**, boron is derived from complex interaction with the clay fraction of the aquifer material, that acquired its boron in the past from the contact with boron rich geothermal fluids. In **Israel/Gaza**, saline, boron rich groundwaters flow from the east into the coastal aquifer, boron comes from leaching of the overlying loess and is modified by adsorption-desorption processes. In **Greece (Chalkidiki)** , thermal waters mix with fresh karst groundwaters and seawater and give rise to high boron contents in drinking and irrigation waters. In **Cyprus**, several types of high boron groundwaters were evidenced, main processes are leaching of both sedimentary and igneous rocks, mixing with sedimentary brines, gypsum dissolution and, to some extent, seawater intrusion.

Anthropogenic B from waste water, agriculture or industry is negligible for the investigated cases and probably for most regional boron anomalies. This has important consequences on the management of the contaminated resources: Source control is impossible in a context where the source lies in the aquifer material itself or in adjacent groundwater bodies.

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