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ScienceDirect
Estuarine, Coastal and Shelf Science 76 (2008) 455–456
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

Editorial

Submarine groundwater discharge studies along the Ubatuba coastal area in south-eastern Brazil

Keywords: submarine groundwater discharge; radionuclides; Brazilian coast

Submarine groundwater discharge (SGD) has been receiving a significant attention in coastal science because of its importance for groundwater–seawater interactions, delivery of fresh water, nutrients and contaminants to marine estuaries, processes of importance for management of fresh water resources and protection of coastal regions. Therefore there has been great effort in past decade from estuary and marine scientists to better understand the origin of SGD, and to assess SGD fluxes in different hydrogeologic environments.

This Special Issue of Estuarine, Coastal and Shelf Science summarises the results obtained during the SGD intercomparison experiment carried out during November 2003 along the Ubatuba coastal area in south-eastern Brazil. A series of SGD investigations were carried out in the framework of the Coordinated Research Project (CRP) on ''Nuclear and Isotopic Techniques for the Characterisation of Submarine Groundwater Discharge in Coastal Zones'' organized from 2000 to 2005 by the International Atomic Energy Agency (IAEA) in cooperation with the United Nations Educational, Scientific and Cultural Organization (UNESCO). The project was coordinated by the IAEA's Isotope Hydrology Section in Vienna (P. Aggarwal and K. Kulkarni) and Marine Environment Laboratory in Monaco (P. Povinec), in cooperation with the UNESCO's Intergovernmental Oceanographic Commission (IOC) and International Hydrological Programme (IHP) in Paris. Laboratories in Brazil, India, Italy, Japan, Russia, Slovenia, Turkey and USA took part in the CRP. The objectives of the CRP included the development of radioactive as well as non-radioactive tracer techniques, automated seepage meters and electromagnetic geophysical survey techniques for quantitative estimation of various components of SGD. Establishing more refined tools for assessing SGD will help better understand the influence of SGD on coastal processes and on groundwater regimes, with implications on management of water resources in coastal areas. The joint IAEA–UNESCO SGD intercomparison exercises were carried out in Australia (2000), Sicily (2002), New York (2002), Brazil (2003) and Mauritius (2005) with the aim to test and to apply as many as possible tracer techniques for SGD investigations in different hydrogeologic environments.

Results are presented from the Brazil expedition carried out between 14 and 26 November 2003 in the Ubatuba coastal area east of São Paulo. This site was chosen for this pilot project due to its granite geological structure, previous SGD investigations carried out by the IPEN (Instituto de Pesquisas Energéticas e Nucleares in São Paulo) and the University of São Paulo, and availability of logistical support. Samples of groundwater, seawater and sediment were collected and analysed for radioactive (^{3}H, ^{222}Rn, ^{223}Ra, ^{224}Ra, ^{226}Ra, and ^{228}Ra) and stable (^{2}H and ^{18}O) isotopes, trace elements and nutrients. In addition, participants made in situ spatial mapping and time-series ^{222}Rn measurements in seawater, direct seepage measurements using manual and automated seepage meters with continuous monitoring of temperature and salinity, pore water investigations using different tracers and piezometric techniques, electromagnetic surveys and development of hydrogeologic models. All these very different techniques were applied to assess SGD at the same site and time. This represents the first time that such a complex arsenal of radioactive and non-radioactive tracer techniques have been used for simultaneous SGD investigations. The obtained results showed large fluctuations of SGD fluxes observed at sites situated only a few meters apart (from 0 cm/day to 360 cm/day; the unit represents cm^3/cm^2/day), as well as during a few hours (from 0 cm/day to over 100 cm/day), strongly depending on the tidal fluctuations. We postulate that the irregular distribution of SGD seen at Ubatuba is a characteristic of fractured rock aquifers. The electromagnetic probing and piezometric measurements helped to understand the spatial distribution of different water masses present on the coast. The isotopic composition (δ^{2}H and δ^{18}O) of submarine waters was characterised by significant variability and heavy isotope enrichment,

0272-7714/$ - see front matter
doi:10.1016/j.ecss.2007.07.022

indicating that the contribution of groundwater in submarine waters varied from a few % to 20%. However, with increasing offshore distance this contribution became negligible. Automated seepage meters and time-series measurements of ^{222}Rn activity concentration showed a negative correlation between SGD rates and tidal stage. This may be caused by sea level changes as tide effects induce variations of hydraulic gradients. The radium isotopes and nutrient data showed scattered distributions with offshore distance and salinity, which implies that a complex coast with many small bays and islands has been influenced by local currents and groundwater–seawater mixing. This has also been confirmed by a relatively short residence time of 1–2 weeks for waters within 25 km of shore, as obtained by short-lived radium isotopes.

It is satisfying that these intercomparisons produced either reasonable agreement between different techniques or displayed variations that could be explained by the geologic setting. It has been a great challenge to assess SGD along the Brazil coast using the most recently developed techniques in different hydrogeological environments. We note that SGD in the Ubatuba area is fed by coastal contaminated groundwater and re-circulated seawater with small admixtures of groundwater, which indicates potential environmental concern with implications on the management of fresh water resources in the region.

The guest editors express their sincere gratitude to the IAEA, IOC, IHP, IPEN and the University of São Paulo for their financial and logistical support that made this project possible. They also thank Dr. P. Aggarwal and Dr. K. Kulkarni of IAEA for their efforts in coordinating the CRP. All authors are acknowledged for their patience during the preparation of manuscripts, scientific reviewers for their time and expertise to improve the quality of papers, and the Chief Editor Dr. E. Wolanski for his advice during preparation of this Special Issue.

In publishing this Special Issue we would like to stimulate further work on SGD which will contribute to better understanding of groundwater–seawater interactions with implications on the protection of coastal environment and better management of fresh water resources in coastal zones.

Pavel P. Povinec*
Comenius University, Faculty of Mathematics, Physics and Informatics, Mlynska dolina F-1, SK-84248 Bratislava, Slovakia
*Corresponding author. Formerly at the International Atomic Energy Agency, Marine Environment Laboratories, Monaco.
E-mail address: povinec@fmph.uniba.sk

William C. Burnett
Florida State University, Department of Oceanography, Tallahassee, FL, USA

Joselene de Oliveira
Instituto de Pesquisas Energéticas e Nucleares, Laboratório de Radiometria Ambiental, São Paulo, SP CEP 05508-000, Brazil

20 July 2007

Available online 16 August 2007