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Effects of seasonal change and seawater intrusion on water quality for drinking and irrigation purposes, in coastal aquifers of Dar es Salaam, Tanzania

Giuseppe Sappa [a,*], Sibel Ergul [a], Flavia Ferranti [a], Lukuba Ngalya Sweya [b], Giulia Luciani [a]

[a] Department of Civil, Building and Environmental Engineering DICEA, Sapienza – Università di Roma, Via Eudossiana, 18, 00186 Rome, Italy
[b] Department of Environmental Science and Management, Ardhi University, P.O. Box 35176, Dar es Salaam, Tanzania

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ABSTRACT

Groundwater is the major source to meet domestic, industrial and agricultural needs in the city of Dar es Salaam, Tanzania. However, population growth, increasing urbanization, industrialization and tourism, and climatic changes have caused an intensive exploitation of groundwater resources leading the aquifers become more vulnerable to seawater intrusion. The aim of this study is to examine the variations of groundwater chemistry (as resulting from natural and anthropogenic inputs) depending on seasonal changes, in order to evaluate water quality for drinking and irrigation purposes. Physical and chemical data come from the analysis of groundwater samples, collected from 72 wells, used for the evaluation of water quality parameters, during a year of monitoring. Pattern diagrams, geochemical modeling techniques and Principal Component Analysis (PCA) have been used to identify the main factors influencing groundwater composition. Based on the hydrochemistry, the groundwater was classified into three types: (a) Na–Cl, (b) Ca–Cl, (c) mixed Ca–Na–HCO_3–Cl (d) mixed Ca–Mg–Cl–SO_4. The geochemical modeling results show that groundwater chemistry is mainly influenced by evaporation process, as it is suggested by the increase of Na and Cl ions concentrations. According to irrigation water quality assessment diagrams of USDA, most water samples from dry and rainy seasons, distributed in category C2–S1, C3–S1, C3–S2, C4–S2 highlighting medium to very high salinity hazard and low to medium sodium content class. PCA evidenced the role of seawater intrusion, evaporation process and anthropogenic pollution (i.e. high NO_3 levels due to agricultural activities), as the major factors that influenced the water chemistry, and hence the water quality. Based on Pearson correlation matrix, the presence of high correlations (>0.8) among Na, Cl, Mg and SO_4, in association with EC, were interpreted as the seawater intrusion effects. In this area groundwater quality is generally low, and often exceeds permissible limits of standard guideline values of WHO and FAO, referred to EC and chloride values. The high salinity and the groundwater level depletion create serious problems for current use of water supplies as well as future exploitation.

1. Introduction

Water pollution is not only an ecological problem but also a health problem. Worsening of water quality has become a global issue of concern as populations grow, industrial and agricultural activities expand, and climate change alters groundwater recharge causing significant alterations to the hydrological cycle (IPCC, 2001). Generally, groundwater is less susceptible to pollution than surface water and is considered the best supply for drinking water, in some cases however, groundwater can become contaminated from natural (i.e. seawater intrusion, water–rock interaction, geothermal effects, mineralogy of bedrock) and anthropogenic factors such as municipal and industrial disposal, agricultural pollutants and mining activities (Sappa et al., 2012 and Singh et al., 2008; Vengosh et al., 2005). Coastal aquifers are very important source of freshwater and are largely exploited to respond to human needs. However, their vulnerability to seawater intrusion is due to groundwater over-exploitation, matching intensive water demand associated with population growth in coastal zones. The seawater intrusion threatens coastal freshwater resources globally, rendering groundwater non-drinkable (Re and Zuppi, 2011; Sarath Prasanth et al., 2012; Richter and Kreitler, 1993). Many coastal

* Corresponding author at: Dipartimento di Ingegneria Civile, Edile ed Ambientale, Sapienza – Università di Roma, Via Eudossiana, 18, 00186 Rome, Italy. Tel.: +39 0644585010; fax: +39 0644585016.
E-mail address: giuseppe.sappa@uniroma1.it (G. Sappa).
URL: http://w3.uniroma1.it/giuseppe.sappa/index.htm

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aquifers in the world are subject to seawater intrusion caused by both natural and anthropogenic processes (agricultural practices, domestic wastewater/industrial influent). Alteration of saltwater/freshwater equilibrium is related to variations in aquifer recharge, sea level fluctuations (tidal effect), sea level rise, over abstraction of groundwater (Cartwright et al., 2004; Lambrakis and Kallergis, 2001; Melesse and Shih, 2002; Petalas and Diamantis, 1999; Vengosh, 2003). Land use increasing, including groundwater exploitation and climate change, involving, mainly, groundwater recharge reduction, are the most important factors, which can change water quality, especially accelerating salinization in coastal aquifers (Mahesha and Nagaraja, 1996; Taylor et al., 2013). Chemical composition of groundwater is affected by a combination of these factors. Thus, the management of groundwater resources has become an important issue, which deals with planning, developing, distributing and managing the optimum use of water resources, mainly in coastal areas.

Water quality is the most important factor that influence human health and quantity and quality of agricultural production. The assessment of seasonal changes in groundwater composition is important to evaluate temporal variations in water quality and evaluation of water pollution (Mimikou et al., 2000; Eckhardta and Ulbrichb, 2003; Kumar and Jain, 2010). Understanding the factors and how and why water quality is changing over time in the source area is essentially required to develop appropriate management strategies for the protection of the groundwater resources and to ensure the safety and health of the drinking water (Mondal et al., 2009).

In Dar es Salaam, Tanzania, groundwater is the major source of drinking water and is a vital source for industrial and agricultural uses. However, water availability has decreased, due to rising population pressure, climate change and declining groundwater levels. Previous works have shown that continuous decrease of infiltration and the consequent depletion of groundwater recharge over the last ten years might be attributed to both land use changes and decrease in precipitation. The decreasing trend of groundwater availability, due to unplanned and uncontrolled groundwater exploitation, because of population growing up, influenced the aquifer water balance, triggering seawater intrusion (Sappa et al., 2013; Van Camp et al., 2014; Mjemah et al., 2009). The excessive concentrations of major ions in groundwater may be a health threat for consumers and eventually render freshwater resources unusable. Thus, preserving and conserving water have become an increasingly important issue in the area. Present research focuses on the identification of main processes controlling the groundwater composition in the coastal aquifers of Dar es Salaam city, and on assessment of seasonal changes of groundwater quality for drinking and irrigation purposes, by comparing the identified parameters with guideline values. Accordingly, a detailed investigation was carried out on 72 public supply wells based on physico-chemical parameters (pH, temperature, electrical conductivity, etc.) and major ion chemistry during a year of monitoring. Then, conventional graphical plots, principal component analysis and geochemical modeling techniques were applied for the evaluation of the factors mentioned above.

2. Geology and hydrogeology

The study area is located in the East African coast in Dar es Salaam City (Tanzania) bordering the Indian Ocean to the east. It extends from Mbezi River and Msasani Bay in the north to the area between Kizinga and Mzinga River system in the south (Fig. 1). Dar es Salaam city, located in the eastern part of the Tanzanian mainland, between latitudes 6°36′ and 7°0′ South and longitudes 39°0

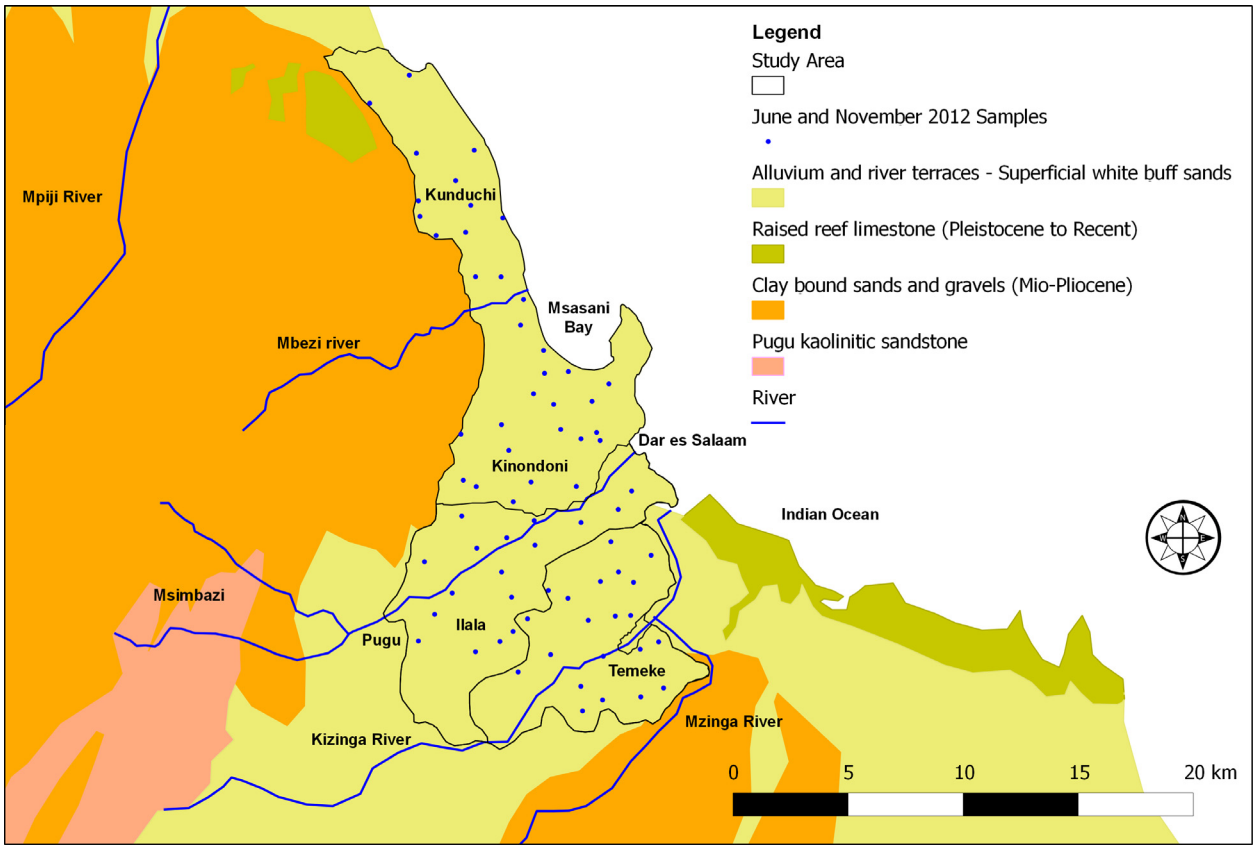

Fig. 1. Simplified hydro-geological map of the study area.