Hydrogeological and Hydrogeochemical Investigation of a Coastal Aquifer in Dar-es-Salaam, Tanzania

Ibrahimu Chikira Mjemah
Promotor: Kristine Walraevens

Department of Geology and soil science, Ghent University

Public defence: 14 September 2007

Water, the lifeblood of Mother Earth has always been important for the existence of human life from time immemorial. The shortage of good quality water from surface sources has made groundwater to be an important source in many urban areas, including Dar-es-Salaam. The Dar-es-Salaam City is the largest urban centre in Tanzania, with a population of about 3 million. Due to population growth in the area, to get a safe and reliable water source to meet the demand has been a problem since many years. The primary objective of this study was to investigate groundwater quantity and quality by focusing on the hydrogeological characteristics of the unconsolidated sediments of quaternary age, which form the major aquifer in the coastal area of Dar-es-Salaam region.

The study was based on data acquired from previous studies and fieldwork campaigns conducted between 2004 and 2006. The study area comprises three major parts, distinguished by the geological formations outcropping: the central coastal plain with Quaternary fluviatile-deltaic sediments, the deltaic Mio-Pliocene clay-bound sands and gravels in the northwest and southeast and the Lower Miocene fluviatile sandstones of Pugu Hills in the west of the study area.

The groundwater reservoir in Dar-es-Salaam area, in the coastal plain, mainly consists of two aquifers: the unconfined and the semi-confined aquifer. These aquifers are mainly consisting of sands and are separated by a clay aquitard. The groundwater recharge is considered to be both of regional and local type, and is contributed by the faults present in the study area as well as by the nature of the sandy soil type within the coastal plain. The major source of renewable groundwater in the aquifer is rainfall. Hence, long term average recharge to the aquifer was estimated using the balance method of Thornthwaite and Mather (1957) and is quantified at 122 mm a year. The results of the water level measurements from 84 boreholes show that the groundwater flow generally is from Kisarawe and Pugu Hills areas toward the Indian Ocean. The general direction of the groundwater flow is west to east. This was also confirmed in the developed groundwater model of the area. The depths to water level in the study area range from less than 10 m in the centre of the coastal plain to about 50 m in the southeast and northwest of the basin.

The Dar-es-Salaam area has four main rivers namely Mzinga, Kizinga, Msimbazi and Mbezi and several seasonal streams. During the fieldwork campaign, the river discharge measurements were taken in the same period in June 2004 and July 2006, after the end of the long rainy season which usually occurs between March and May, in the three perennial rivers Mzinga, Kizinga and Msimbazi. Mbezi River north of the Morogoro Road is usually dry except for flash floods during the rainy periods. The results show that the aquifer contributes to the flow of the main rivers (Mzinga, Kizinga and Msimbazi), keeping them flowing during the dry period. The lithology of the drainage basin proved to play a major role in river flow: Mbezi River is located within the clay-bound sandsarea, favouring runoff and reducing groundwater recharge; Kizinga River (as well as Msimbazi River) is located within the coastal plain, where the sandy sediments favour infiltration, such that groundwater can continue to discharge to the river, sustaining river flow during the dry season; Mzinga River, on the border of the coastal plain and the clay-bound sands area, undergoes both influences.

The pumping tests conducted in the area for 39 boreholes included single-well tests as well as tests with measurements on the pumping well and at least one observation well. The tests were conducted for 6 hours and 30 minutes. 6 hours for pumping and the remaining 30 minutes were used for recovery measurements. The methods used to analyze the pumping test data included: specific well capacity (which was calculated for both aquifers), Neuman type curve fitting (for the unconfined aquifer) and Walton type curve fitting (for the semi-confined aquifer) under constant discharge. Transmissivity was additionally, estimated based on specific well capacity and by Thiem's method for steady state. The results from the curve fitting methods show the following parameters: an average transmissivity and hydraulic conductivity of 34 m^2/d and 1.58 m/d respectively for the unconfined aquifer; the semi-confined aquifer has an average value of 63 m^2/d and 2.14 m/d for transmissivity and hydraulic conductivity respectively. For the storativity, the unconfined aquifer has an average early-time elastic storativity of 0.01 while the lower aquifer has 0.002. Transmissivities estimated from specific well capacity and Thiem's method were similar to values obtained by Walton's method for the semi-confined aquifer, but were 2 to 3 times higher than values deduced by Neuman's method for unconfined aquifer.

Analysis of groundwater samples from the study area indicated signs of deterioration contributed mainly from point sources of pollution. The high NO_3^- and $SO4^{2-}$ concentrations (up to 421 mg/L and 475 mg/L respectively) could be due to contamination from point sources: mainly wastewater (grey-water, septic tanks, pit latrines etc) from the inhabitants and to some extent from urban agriculture such as manure and fertilizers. The dominant watertype is NaCl for both aquifers, except for the unpolluted shallow wells, where $CaHCO_3$ prevails. The origin of non-anthropogenic salinity might be influenced largely by water flowing from faults in the Pugu Hills and clay-bound sands in the northwest. This water probably ascends from deep marine Miocene Spatangid Shales. Moreover, the deltaic clay-bound sands will contribute salinity by themselves. Other sources include saltwater incursion on the border of the Indian Ocean and some salinity within the Quaternary aquifer, especially in intercalated clays in the fluviatile deposits, showing some marine influences.