ABSTRACT

Massive tsunami occurred on December 26, 2004, triggered by a 9.0 magnitude earthquake off the west coast of Sumatra, killed more than 2,50,000 people and displaced thousands in countries around the Indian Ocean. Tsunami waves entered in land up to 0.2-1 km, which caused extensive damage to life and property to all coastal districts along the east coast of Tamil Nadu, India. Although, there are major impacts of the tsunami on infrastructure and human life, it also resulted in deterioration of groundwater quality of the coastal region. Study of processes of salinisation of groundwater by tsunami and the time that it will take for the natural recharge processes to flush this salinity is of great importance. There are no systematic studies carried out so far to understand the processes of groundwater salinisation due to tsunami. The present research was carried out in the Kalpakkam region, Southern India to determine the impact of tsunami on major and minor ions, trace elements, nutrients and isotopic concentrations in the coastal aquifer, and to understand the processes of improvement in the quality of tsunami-affected groundwater by solute transport modeling.

The study area includes a portion of Kalpakkam region situated in the Kancheepuram District of Tamil Nadu state in southern India. The study area is located 75 km south of the Chennai city (formerly Madras) and covers an area of 2 km² extending about 2 km along the north-south direction and about 1 km along the east-west directions. A set of 20 wells was established in this
area for regular monitoring. These wells are spread throughout the study area and were monitored monthly for a period of 26 months from January 2005 to February 2007. Out of twenty well, six wells were from tsunami inundated zone and rest of them are from uninundated zone. The hydrogeochemical characteristics of water were obtained from physiochemical analyses of water samples. Major ions such as Ca, Mg, Na, K, HCO$_3$, CO$_3$, SO$_4$, Cl and minor ions like Br, Li, F, NH$_4$, NO$_3$ and PO$_4$ were analysed in the laboratory. Trace elements like Zn, Fe, Mn, Cu, Pb and O18, D2 isotopes were analysed. Groundwater flow and solute transport modeling was carried out using a finite element model FEFLOW 5.2.

Mean annual precipitation at Kalpakkam exceeds 1,300 mm, most of which falls during the northeast monsoon (October to December). Geologically, this study area has two distinct formations: crystalline Chamockite rocks of Archean age and Quaternary/recent sediments. Crystalline chamockite are overlain by Quaternary recent sediments. The Quaternary/recent sediments, weathered and fractured crystalline chamockite function as an unconfined aquifer system. The geophysical study reveals that the study area has a single layer aquifer system with unconsolidated formation comprised of mostly of sand, silt and sandy clay. The groundwater head follows the topography, that is, it flows towards the east and west from the central part of the area.

Observation of seasonal variation in concentration of major ions, indicate that there is a gradual decrease in the EC of groundwater in all the inundated wells after the tsunami until the month of July 2005. However, after
the rains during the months of August and September 2005, EC and major ions of groundwater increased in the wells located in the inundated zone. The recharge of fresh water through the unsaturated zone resulted in washing of the salts deposited in the unsaturated zone due to the evaporation of seawater that entered during the tsunami. The recharging water may also flush the salts in sediments brought by the tsunami. After the subsequent rainfall the quality of groundwater has comes to normal other than the southeastern region. Seasonal variation in Chloride and bicarbonate ratio of groundwater from the inundated zone wells also support the inference made earlier. The results of minor ions like Br, Li, F also confirms that the seawater has entered the Kalpakkam coastal aquifer zone during the tsunami. Oxygen-18–Deuterium diagram supports the evaporation process has taken place after the tsunami in the coastal aquifer.

A groundwater model was developed to simulate the groundwater flow and solute concentration in the study area. Constant head boundary was considered in east, west and south of the model area. The northern side was considered as variable head boundary. The model was calibrated in steady and transient state conditions. The model simulated groundwater flow and solute for 2 years from January 2005 to January 2007. The model was used to forecast groundwater flow and solute concentration by varying the hydraulic conductivity. The model forecast indicates that tsunami-induced salinity in this aquifer system would be flushed out with normal annual rainfall by February 2008. Thus, solute transport modeling carried out using this finite element model helped to understand the process of salinisation, and
remediation of the aquifer by natural recharge. This study demonstrated the application of hydrochemical studies and groundwater modeling to understand the process of salinisation of groundwater resources by tsunami. It has also helped to determine the time that it would take for remediation of the aquifer system by rainfall recharge. Such a study can be also carried out in other areas to identify the effect of artificial recharge methods in regions that got seriously affected by the tsunami in order to achieve rapid remediation.