ABSTRACT

The demand for water has increased over the years and this has led to water scarcity in many parts of the world. India is heading towards a freshwater crisis mainly due to the improper management of water resources and environmental degradation. The solid and liquid wastes that are generated everywhere, if not treated properly, can cause pollution of the environment and in turn the groundwater environment. Saltwater intrusion is identified as one of the major sources of pollution along the coastal regions of the world. Through an exhaustive literature review the gap areas are identified. The objectives of the present study are formulated to bridge these gap areas.

The study area used is a selected stretch of coastal tract in Thiruvananthapuram district. All the ongoing and planned developmental activities in Thiruvananthapuram city, Kerala, can tamper the delicate groundwater system of the district and it would be more pronounced along the coastal tracts. Therefore, understanding of the groundwater system along the coastal tracts of Thiruvananthapuram district is inevitable.

In the present study, a stretch from Menamkulam to Pozhiyur towards south of coastal tracts is selected and modelled under varying anthropogenic and natural stresses. This was done through multivariate statistical analysis such as factor analysis on groundwater quality data. Geographical Information System (GIS) was also used wherever necessary for the analysis. The vulnerability to saltwater intrusion for the selected stretch was assessed through GALDIT model (An empirical model for estimating impact of existing status of saltwater intrusion). The saltwater - freshwater interface was determined using geophysical method. Appropriate software tools like Modflow and SEAWAT (softwares for simulating groundwater flow and seawater intrusion) are used for modelling groundwater flow and transport of contaminants. Hydrogeological data, elevation with respect to mean sea level, water level data, pumping rate etc. were used as input for model. Values of hydraulic conductivity, effective porosity and total porosity of the formations are obtained through calibration of the model. The calibrated model has been used for simulation and prediction of groundwater head for future years. Groundwater flow modelling is a pre-requisite for contaminant transport modelling. Solute concentrations of water in the pumping wells and observation wells, boundary conditions of river and the sea

were given as input in the contaminant transport model. After the calibration of this model, the parameters such as dispersion (longitudinal and transverse), coefficient of dispersion etc. were estimated. The calibrated model was then used for simulation and prediction of future concentration of solute in the study area. The groundwater heads and the lateral and vertical extent of saltwater intrusion under various scenarios like increased pumping, decreased recharge, average sea level rise and their combinations were estimated for future period.

The temporal analysis of land use change in the study area revealed that the area has undergone dramatic changes in terms of land use during the last 30 years. The behaviour of water table indicated that the water table is below the level of mean sea level at many places in the study area. The hydro-geochemical data indicated the salinity hazard and zones of saltwater intrusion along the coastal stretches. The analysis of hydrochemical facies revealed the enrichment of sodium and Chloride in the groundwater system indicating the intrusion of saltwater into the coastal aquifers. The R-mode factor and cluster analyses indicated that the saltwater intrusion is the key factor, which determine the chemistry of the groundwater system. Q-mode multivariate analysis was useful in delineating zones of saltwater intrusion. GALDIT model of the coastal stretch was capable of identifying the highly vulnerable to less vulnerable stretches to saltwater intrusion during the pre monsoon as well as post monsoon seasons. Various indicators as well as indices of saltwater intrusion were used to zone the study area with respect to the intensity of the saltwater intrusion. These indices also indicated the role of anthropogenic activities in infuriating the problem. The lateral extent of saltwater intrusion was also worked out based on the above mentioned indicators and this analysis gave a range of 0.75 to 2.5 km extent during pre-monsoon and 0.4 to 2 km during post monsoon. The iso-resistivity contours drawn for different depths using the apparent resistivity values indicated the spatial behaviour of the saltwater-freshwater interface at different depths. It also gave an idea about the limiting depth for open wells and also horizontal extent from the seacoast for the safe location of these wells.

The groundwater heads were simulated by modelling the existing groundwater system. This was attempted by using the software MODFLOW (software for modelling of groundwater flow). After simulation it is seen that the observed and simulated groundwater heads at all observation wells follow the same trend and closely match each other. The

contaminant transport modelling was also attempted by using the software SEAWAT (software for modelling seawater intrusion). The match between the observed and calculated concentrations was reasonably good. This was used to find out the extent of saltwater intrusion at various locations during the normal pumping rate. The groundwater heads and the extent of saltwater intrusion were modelled for various stretches of the study area with respect to many scenarios such as, increase in pumping rate for every year by 1%, decrease in recharge at the rate of 5 % for every year (in par with the ongoing land use change) and average sea level rise. Also for various combinations of the above said scenarios the lateral and vertical extent of salt water intrusion were estimated.

To address important groundwater quality management problems, it is necessary to couple groundwater flow and solute transport models by optimization techniques like simulation optimisation(S/O) approach. Optimisation model using Genetic Algorithm is developed using a Modular Groundwater Optimizer (MGO) incorporating Modflow/ MT3DMS(Three dimensional transport modelling software). MGO is a general-purpose simulation-optimization code developed for field scale applications. An optimum pumping rate has been developed for each pumping well in the study area. . The existing pumping rate is found to be similar with the derived optimum pumping rate at a few locations ((Adimalathura and Karichal). The derived optimum pumping rate is found to be lower than the normal pumping rate at a few other locations (Karikkakom, Pulinkudi and Valavunada), implying the threats of aggravated saltwater intrusion. Since the developmental activities are taking place along the coastal area, it is necessary to keep the normal rate of pumping for meeting the water requirements. Hence, an injection well with an injection rate of $150m^3$/day is provided near the Valavunada pumping well location to meet the current water requirement. Thus the study brings out important suggestions and conclusions, so that existing groundwater pumping system is rejuvenated for meeting the future needs.