Asian Research Consortium

Asian Journal of Research in Social Sciences and Humanities
Vol. 7, No. 3, March 2017, pp. 26-42.

ISSN 2249-7315
A Journal Indexed in Indian Citation Index

DOI NUMBER: 10.5958/2249-7315.2017.00158.7
Category:Science and Technology

Asian Journal of Research in Social Sciences and Humanities

www.aijsh.com

Suitability Analysis of Ground and Tank Water Quality for Domestic Purpose along Downstream Side of Coimbatore City

Ragunath S*; Lenin Sundar M**

*Department of Civil Engineering,
KPR Institute of Engineering and Technology,
Coimbatore, India.
sragunathragu@gmail.com
**Department of Civil Engineering,
Sri Krishna College of Technology,
Coimbatore, India.

Abstract

The tribulations of water quality have grow to be more significant than the quantity, as the environmental harms are receiving more severe in diverse parts of our planet. The supervision of the groundwater supply is a tough job globally next to the surroundings of the increasing water demand for living and non living things. This research work is linked together water qualit and quantity, which is flattering more severe owing to populace detonation, rising in farming and enhanced standard of living. This study aims to estimate the category of surface water and groundwater quality. Also to examine the interface of surface water and groundwater which is decisive in categorize to identify the special effects of best management practices on the complete scheme of water resources. For this study, four downstream tanks such as selvachindhamani, ukkadam big tank, valankulam, singanallur tankwere choicen from coimbatore city, considering these tanks were comparatively polluted due to manufacturing and municipal intervention. This study focused on ground water and surface water interactions using MODFLOWat large exclusively as a groundwater-flow simulation model.MT3D package from Visual MODFLOW was used to simulate the contaminant transport due to advection and dispersion. Semi-structured interview was prepared in the study area after acquiring the water quality test results. In view with the response given by the public, Source for drinking water, method of waste disposal and spread of disease among the people were analyzed. 50% of the people living nearby to the tanks dispose the waste into the tank, which is the most important cause for water quality deterioration.

Keywords: MODFLOW, Best Management Practices, Environmental harms, Groundwater quality, MT3D.

Introduction

Groundwater quality plays a crucial responsibility in individual existence and growth. Scarcity of water turns out to be a progressively more severe crisis in India (Dunalsk et al., 2002). Groundwater is used for commercial, municipal, irrigation purpose, etc., moreover the similar actions influence the groundwater quality (Iotrowicz et al.,2006). World's populace use groundwater as a consumption water (UNEP/RIVM,1999). Based on the recharged water, atmospheric precipitation, inland surface quality the groundwater quality fluctuates (Prasanna etal., 2011, Chidambaram et al., 2011). The groundwater quality is unswervingly or ultimately affected by the agricultural activities, industrial development and owing to over population (Jalali, 2005, Rivers et al., 1996).

Due to the random use of surface water as the majority of these are direct recipient of sewage, industrial effluent, etc. surface water become polluted water so that those water is consider as unhealthy for agriculture, fish proliferation, industrial point, frivolous actions etc. Accretion of inorganic from the high inputs of a variety of chemical industries as a result the groundwater has becoming polluted (Rachana et al., 2015). Public health gets affected due to toxicity level in the ground water, level various based on the dilution of wastewater into the waterbodies and in ground water. Predominant disease released from the sewage disposal into the environment and causes various disease to the humans. Among water pollution, surface water contamination is tedious to analyse and control. Groundwater resource is the very important source for all purposes, efforts are needed to increaseto prevent, reduce, and eliminate groundwater pollution.

Water quality has been specified auxiliary prominence in groundwater supervision (Pradhan, 2009, Ayazi et al., 2010, Manap et al., 2012, 2013). A choice of techniques has been initiated to estimate groundwater susceptibility with elevated exactness (Javadi et al., 20011a, b). In the majority cases, these measures consist of methodical tools projected to compare groundwater pollution with land activities (Tokatli et al., 2013). Presently there are three types of evaluationmethods and procedures: the process-based simulation models, the statistical processes (Harbaugh et al., 2000) and the overlay and index processes (Dixon, 2004).

Process-based simulation models commonly entails a huge quantity of main and minor data to relate the numerical models for generating the primary tool. Statistical processes utilize data on the identified areal dirtiness distribution and depict the pollution probable for a particular environmental province with accessible data in the province of attention (National Research Council, 1993) (Gong et al., 2013). Overlay and index process highlights the arrangement of dissimilar provincial maps by assigning a mathematical index. Equally, both the methods are simple to relate to geographic information system (GIS) exacting on regional level (Foster, 1987).

MODFLOW was developed by USGS which is a three-dimensional numerical model processing software.MODFLOW numerically scrutinizes the fractional differential equations for groundwater flow. The boundary of MODFLOW is alienated into three modules: the Input Module, the Run Module and the Output Module. The input Module offers the capacity to generate a graphical three-dimensional representation of the study area. The values can be directly allocated to the study area and the software generates the apposite files. The Run Module permits the user to modify the parameters and alternative that are run particularly, such as the solver package, recharge and wetting relevances and the tolerances for convergence (Patil and Chaudhari, 2014).This research work focused on to determine the physical, chemical, and biological characters of the tank water and groundwater, also to map the water quality parameter's in GIS environment. From the above results, simulating the groundwater flow using MODFLOW and contaminant transport using MT3D were performed. Finally, groundwater quality was assessed to identify the social consequences in and around the affected areas.

Study Area

Coimbatore is located as the western division of Tamilnadu, its latitudes are between between10°13' N and 11° 23' N and 76 °39'E and 77°30'E longitudes. It wraps with a total geographical area of 7,649 km^2.Coimbatore city has entirely 8 surface water tanks beside the noyal river stretch. Around 21 Anaikuts and 31 Tanks in the noyal river system were located, among them 8 tanks weresituated in Coimbatore namely, Narasampathi, Krisnampathi, Selvampathi, Kumarasamy tank, Selvasindhamani, Ukkadam periyakulam, Valankulam, Singanallur tank, that supplywater to Coimbatore district and were positioned in north of Noyal River. The study area of this research work is 4 downstream tanks,seeing as the downstream tanks wererelatively more contaminated due to industries and public interference. Coimbatore has a pleasing, hygienic climate due to its propinquity to densely forested mountain ranges and the cool gust blowing through the Palghat gap which makes the constant hot temperatures pleasant. The average annual rainfall is around 700 mm (27.6 in) to the North East and the South West monsoons causative to 47% and 28% correspondingly of the total rainfall.

Geomorpology

Coimbatore city is an Upland plateau region with hill ranges, hillocks and undulating plain. The major drainages of the city are Bhavani, Noyil, Amaravthi and Ponnani rivers.

Groundwater Status

Groundwater level in the district has gone down drastically in a few places. Recent reports with the Tamil Nadu Water Supply and Drainage board (TWAD) docummented the drop level in water for about five metres in coimbatore district. Twice a year TWAD verify the water level and its supply using 38 surveillance wells which covers 12 panchayat unions. The worst affected areas in the district are the northern and eastern pockets.

Methodology

Description of the Methodology

The quality of groundwater is directly have impact on surface water quality based on lithological charateristics. Hence both water monitoring is important to maintain the quality, using some laboratory experiments such as physico-chemical tests. In order to study about the impact of these wáter on human health and other social consequences. MODFLOW software for model generation is usefull in understanding the interaction between surface and groundwater and also in determing the flow of groundwater. After obtaining the test results a integrated water quality map of study area will be prepared considering the ground water quality parameters obtained from the laboratory test results using GIS software (ARCGIS). The detailed description of the study area is explained below. Flow chart of the methodology is shown in Figure1.

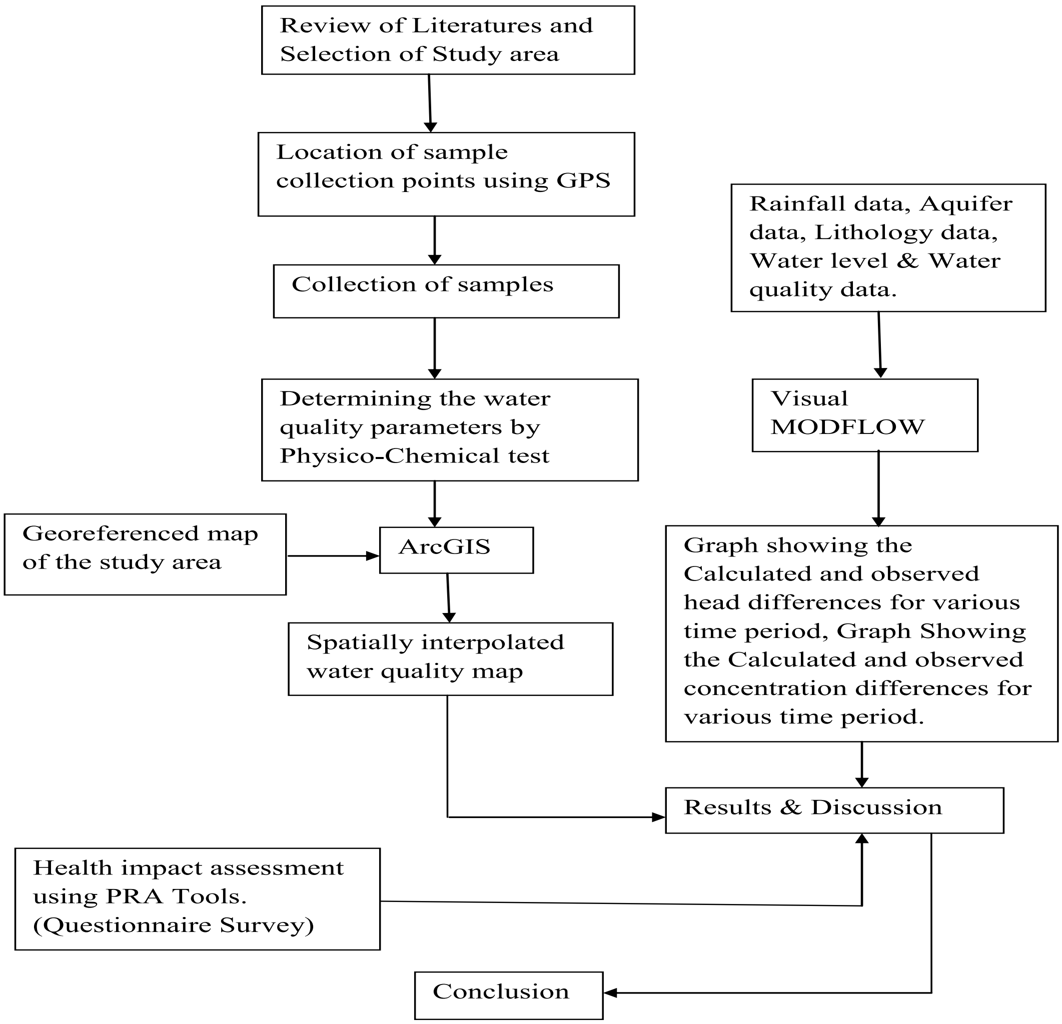

Figure1 Flow Chart of the Methodology

Data Collection

Primary data comprise of assortment of water samples beside the extend of four tanks, namely, selvachindhamani, ukkadam big tank, valankulam, singanallur tank. Secondary data, such as rainfall data, water quality data, groundwater level data, lithology data and aquifer parameter data for the year of 1980-2010 are collected from State surface Water and Groundwater Board, Taramani.

Selvachindamani Tank | Ukkadam Tank

Valankulam Tank | Singanallur Tank

Sample Collection Points Located in Google Earth

Groundwater Modelling

Groundwater models illustrate the groundwater flow, fate and transport procedures using mathematical equations that are based on assured shorten assumptions. The equations that express the groundwater flow, fate and transport methods can be resolved using dissimilar forms of models (Shanmugam Jayalakshmi et al., 2015).

The process of aquifer modeling, in general consists of the following activities.

1. Identification of parameters characterizing the physical framework of the aquifer and stress acting on it.
2. Field estimation of the relevant hydrogeological parameters at as many control points as possible, particularly those at boundaries.
3. Interpolation/extrapolation of these parameters to characterize the entire area understudy.
4. Integration of the entire hydrological data to conceptualize and resurrect the full scale natural system.
5. Appropriate mathematical equations describing the groundwater regime in terms of observable such as groundwater levels or concentrations of pollution etc.
6. Calibration of the model for steady and transient condition.
7. A sensitivity analysis of the model to identify those parameters, which need to be estimated more accurately and also to decipher the error bounds.
8. To evolve efficient management options to protect the groundwater.

General Mass Balance Equation

The equation intervening the movement of dissolved components in groundwater owing to advection and dispersion, conservation of mass approach and utilizing Fick's law of dispersion the mass balance of contaminant transport can be avowed as,

$$\mathrm{I} + \mathrm{P} - \mathrm{O} - \mathrm{L} = \mathrm{A} \qquad \text{(eq 1)}$$

Where I, input; P, production; O, output; L, loss; A, accumulation.

Modflow

MODFLOW is considered as an international standard for suggesting and envisaging groundwater surroundings and groundwater/surface-water interactions. MODFLOW modular configuration has offered a robust framework for amalgamation of additional simulation competence that arise on and develop its innovative span. Grounwater, surface water, transport of solute, density flow, aquifer system compaction and other parameter estimation can be analysed in MODFLOW. This software is essential for this study to appreciate about the interface among groundwater and surface water, to calculate the flow of groundwater and the flow of contaminants etc.

Flow Model

The subsurface surroundings comprise anintricate, three dimensional diversifies hydrogeologic setting. The elementary volume of the porous medium, a common equation for conservation of mass for the volume is articulated as

Rate of inflow – Rate of outflow = Rate of change

Mathematical equation $Q = kiA$
(eq 2)

Where, Q, discharge (m^3/s); K, hydraulic conductivity (m/s); I, hydraulic gradient and A, area of flow (m^2)

A wide-ranging groundwater flow equation in Cartesian form as,

$$\partial x \quad \partial y \quad \partial y \quad \partial z \quad \partial z \quad \partial t$$

(eq 3)

W - volumetric flux / unit volume and K - hydraulic conductivity. Kx, Ky, Kz, hydraulic conductivity along the x, y, z axis were assumed, (m/day); h, piezometric head, m; Q, volumetric flux per unit volume (m^3); S_S,specific storage coefficient; t, Time in seconds.

Solute Model

The equation signifies the movement of flux of solute mass throughout a control volume.

$$\frac{\partial C}{\partial t}=\left[\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial z}\left(D_z\frac{\partial C}{\partial z}\right)\right]-\left[\frac{\partial}{\partial x}(V_xC)+\frac{\partial}{\partial y}(V_yC)+\frac{\partial}{\partial z}(V_zC)\right]$$

(eq 4)

Where, $D_{x,}$ $D_{y,}$ D_z, Dispersion coefficient along the x, y, z axis which are assumed, (m/day); C, Constant concentration. Model calibration involves the field circumstances at a location be appropriately particular. This study standardized the model from 2003 to 2010.

ArcGIS

ArcGIS is a geographic information system for functioning with maps and geographic information. This software is essential for the research to fabricate a spatially interpolated water quality map. The data, establish with questionnaire survey and results from MODFLOW will be practical to identify the collision of water quality on human and further social consequences might be estimated using PRA tools. Participatory Rural Appraisal (PRA) is the suitable tool for Sociological study and this research work consequently espouse this tool, once acquired the contamination extent of the groundwater model.

Results and Discussion

The representation of sample collection points positioned in google earth was shown in fig 1. The ground water and surface water collected commencing a variety of sampling locations were examined for dissimilar water quality parameters like pH, Electrical conductivity, Total Dissolved Solids (TDS), Total Hardness, Alkalinity, Chloride and Fluoride in the KPR chemicals Pvt.Ltd. The results were compared with the drinking water Standard (IS 10500:2012).The test result shows that Chloride, TDS, Hardness and Alkalinity values are exceeding the permissible limits.

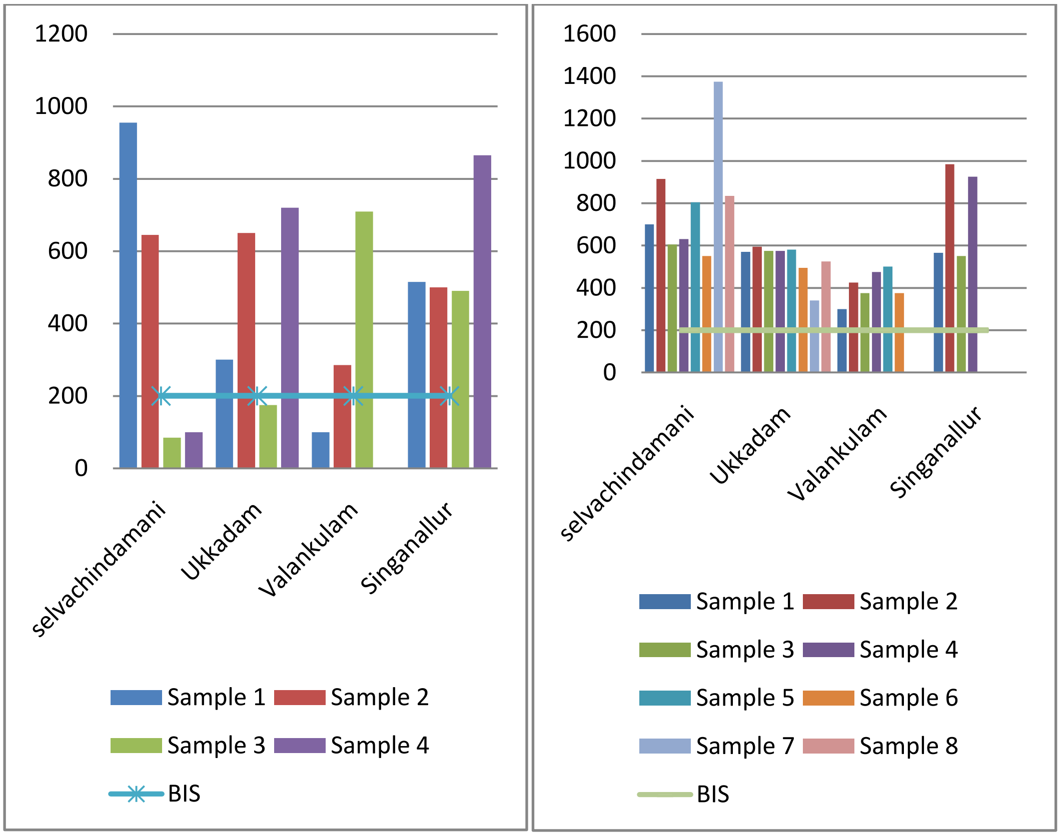

Figure 2 Comparison of Alkalinity Values for Surface Water and Groundwater Samples

It is inferred from Figure 2 that the alkalinity values of surface water samples collected from location 1&2 of selvachindamani tank, location 1,2 & 4 of ukkadam tank, location 2 & 3 of the valankulam tank and all the location of singanallur tanks are exceeding the permissible limits. The Alkalinity values of all the groundwater samples from all the tanks are exceeding the permissible limits. The presence of more alkalinity is because of the presence of carbonates and bicarbonates in that locality.

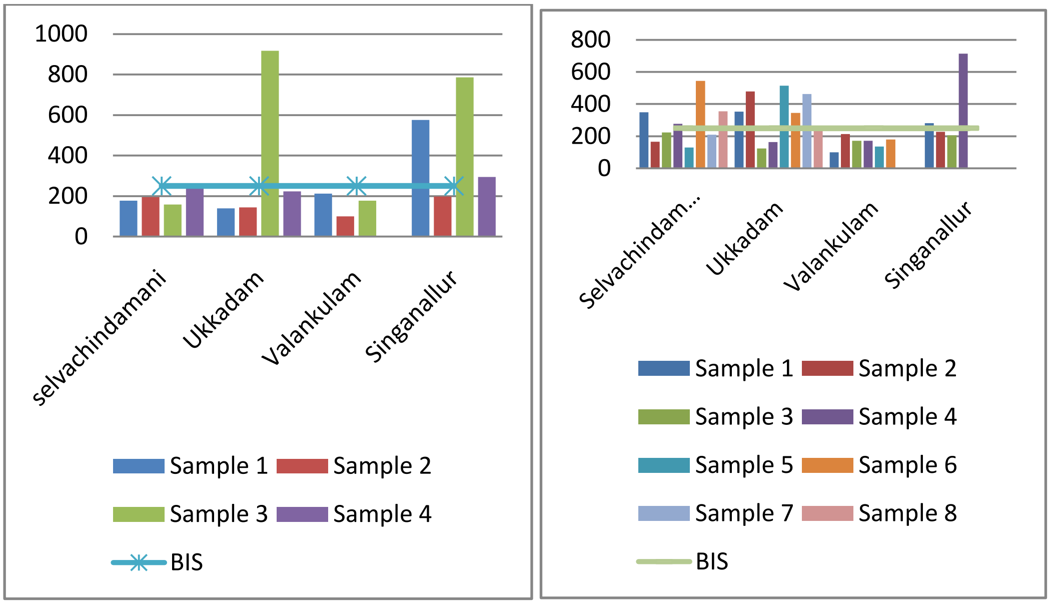

Figure 3 Comparison of Chloride Value of Surfacewater and Ground Water Samples

From Figure 3 it is evident that the chloride concentration of surface water samples at location 3 to valankulam tank and location 1 & 3 of singanallur tank is exceeding the permissible limits. Surface water of selvachindamani and valankulam are free from chloride concentration. The chloride concentration of groundwater samples at location 1, 2, 3, 4, 6 & 8 of selvachindamani tank, location 1, 2, 5, 6 & 7 of ukkadam tank, location 1 & 4 of singanallur tank is exceeding the limit.

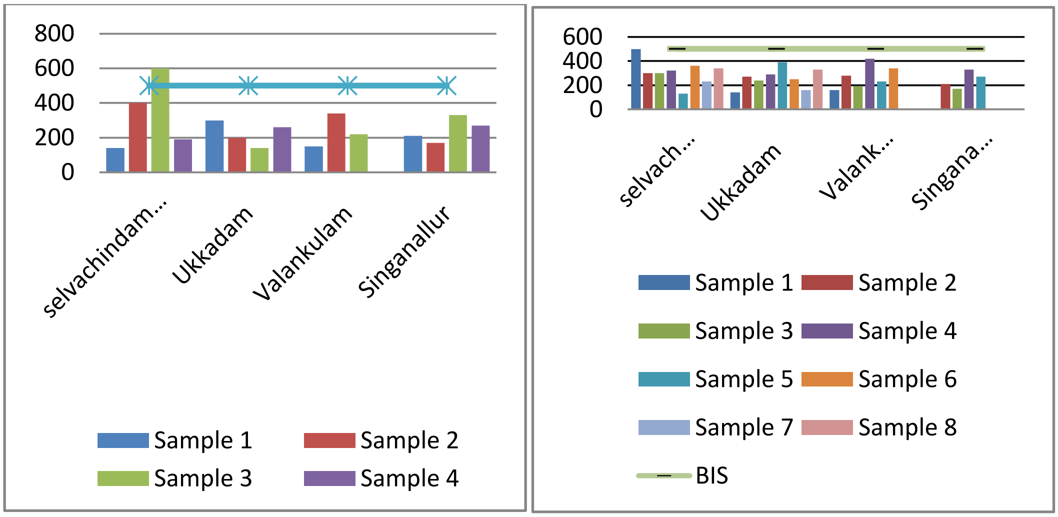

Figure 4 Comparison of TDS Values of Surface Water and Ground Water Samples

From Figure 4 it is evident that the TDS value of the sample water collected at location 3 of selvachindamani tank is the only sample exceeding the permissible limits. All the other samples are well within the permissible limits. The TDS values of all the groundwater samples are well within the permissible limits.

Davis and De Wiest, (1996) documented that the salinity sorting during premonsoon 2008 illustrate that 52.38% of samples categorized under fresh water, 47.725 of samples arevaguelysaline and 2.35% of samples arefairly saline. During postmonsoon period, 70% of the samples comes under fresh water, 25% of samples arefaintly saline and 2.5% of samples in fairly saline. Water with a hardness < 50 ppm is reflect as soft water. The hardness less than 500 ppm is suggested for drinking purpose (Rao, 1975).

Spatial Interpolation using ARCGIS

Spatial interpolation technique through Natural neighbor approach has been used in the present study for obtaining spatially interpolated water quality map for the four tanks. For Selvachindamani tank (SC) the Spatial variation of pH value of the surface and groundwater values is shown in the Figure 5. Likewise for all other tanks the various parameters value for surface and groundwater has been independently interpolated.

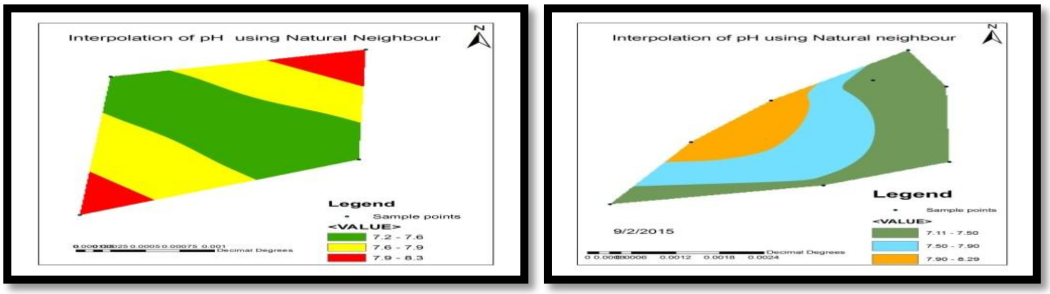

Figure 5 Spatially Interpolated Water Quality Map for pH

Importing Water Level Data

There are 5 observation wells within my study area for groundwater model development. All the 5 observation wells are assigned into the model and the monthly water level data obtained from State surface and groundwater data collection center is given as input to the respective wells. About 50 pumping wells are assumed and assigned in the study area. Pumping rate is assumed depending on the per-capita demand and the other water requirements.

Importing Base Map to Visual MODFLOW

Providing the initial values, the base map of the study area which is developed with google earth is imported into the model with 30 rows and 80 columns. The region other than the study area is completely inactive.

Boundary Conditions

In this study, Noyalriver has been allocated as boundary for one side and the other sides are marked as no flow boundaries. Details of water sources such as river, lake, tanks etc.., available in the study area are allocated. The recharge is assigned as 10% to 15% percent of rainfall based on the assumption. Figure 6 shows the direction of groundwater flow in the study area.

Figure 6 Direction of Flow in the Study Area

Once providing all the required input, groundwater has been simulated for ten years, from 2003 to 2013. The model has been calibrated for eight years, validated for next two years. The groundwater flow has been predicted for the next three years (2014 to 2016) with the increased pumping rate. Output graph of calculated vs. observed head for the time period of 240 days (calibration period) is shown in Figure 7.

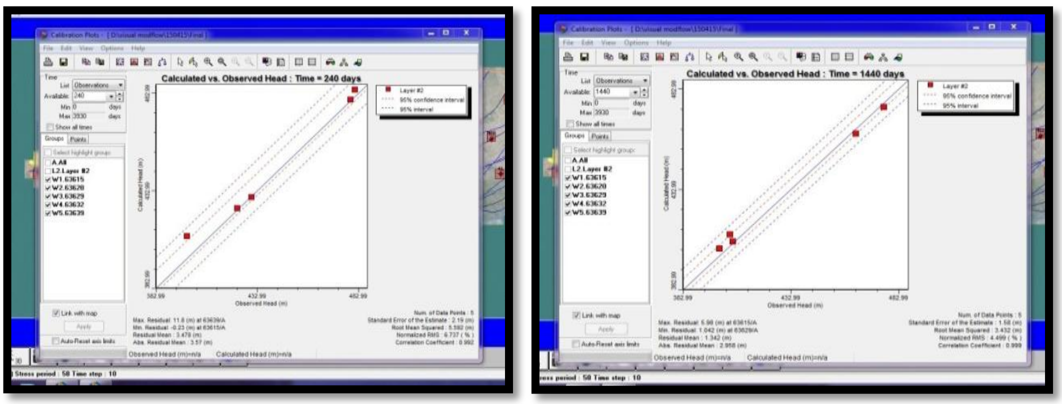

Figure 7Calculated vs. Observed Head (Calibration and Validation)

Contaminant Transport using MT3D

Contaminant transport for the study area has been done with chloride as the water quality parameter using MT3D package. Figure 8 shows the contaminant transport map of the study area.

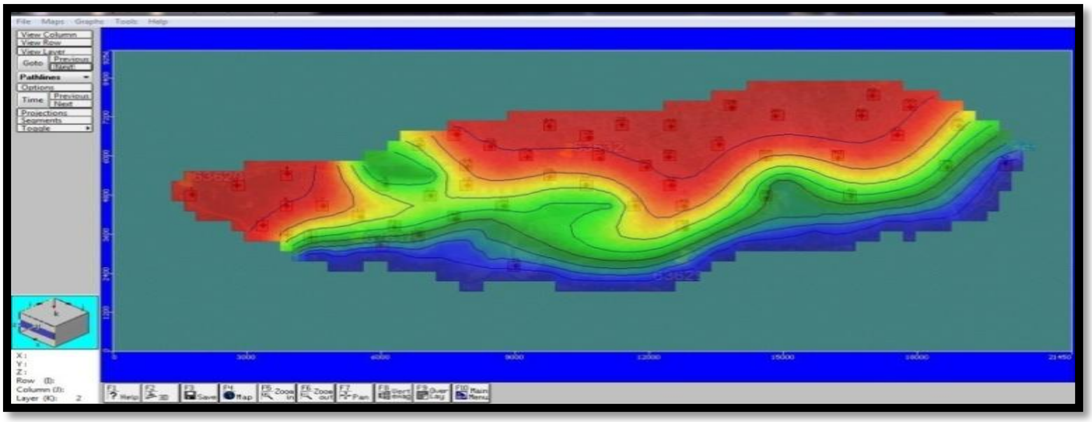

Figure 8 Contaminant Transport Map

In this research work, Semi-structured interview was chosen as a PRA tool. PRA Tools is used to determine the anthropogenic activities that take place in and around the tanks. There are many PRA tools like mapping tools, ranking tools, focused group discussion etc.., are available. In this study, Semi-structured interview was chosen as a PRA tool. A semi-structured interview has been conducted in all the households where the groundwater samples were collected. Based on the response given by the people, some analysis have been made and plotted in the form of graphs and charts.A semi-structured interview has been conducted in all the households where the groundwater samples were collected. Based on the response given by the people, some analysis have been made and plotted in the form of graphs and charts. The percentage of people using Corporation water, Bore water and Tank water in all the four tanks separately is shown in Figure 9.

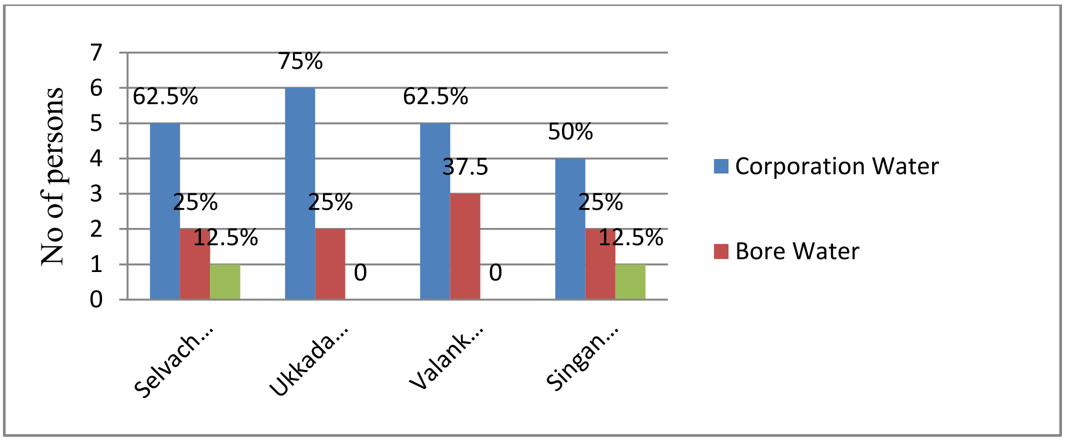

Figure 9 Source for Drinking Water

Method of Waste Disposal

The method of waste disposal of people residing around each tank is shown in figure 5.56. From this figure 10 we could clearly infer that regarding selvachindamani tank, 12.5% people use dustbin for disposing their waste, 62.5% of people dispose their waste into the tank and 25% of people dispose their waste in the street corner. In ukkadam tank, 25% people use dustbin for disposing their waste, 50% of people dispose their waste into the tank and 25% of people dispose their waste in the street corner. In valankulam tank, 12.5% people use dustbin for disposing their waste, 75% of people dispose their waste into the tank and 12.5% of people dispose their waste in the street corner. In singanallur tank, 12.5% people use dustbin for disposing their waste, 62.5% of people dispose their waste into the tank and 25% of people dispose their waste in the street corner. From this graph, it is clear that majority of people around all the four tanks dispose theirwaste into the tank. This is the main reason for deterioration of water quality.

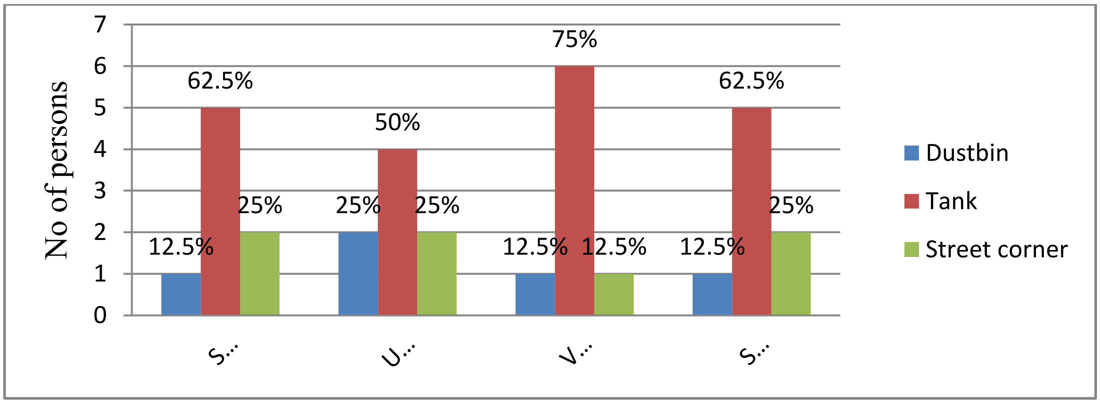

Figure 10 Method of Waste Disposal

Spread of Diseases

Spread of water borne diseases among the people residing around allthefour tanks is shown in Figure 11.Out of eight persons interviewed in ukkadam tank, in the recent six months, one person is affected by malaria, one person is affected by dengue, Two person are affected by cholera, Two person are affected by typhoid, one person is affected by chikungunya and one person is affected by Diarrhoea. Out of eight person interviewed in Selvachindamani tank, in the recent six months, Two person are affected by malaria, one person is affected by dengue, One person is affected by cholera, One person is affected by typhoid, Two person are affected by chikungunya and one person is affected by Diarrhoea. Out of eight person interviewed in Valankulam tank, in the recent six months, One person is affected by malaria, Two person are affected by dengue, One person is affected by cholera, One person is affected by typhoid, Two person are affected by chikungunya and one person is affected by Diarrhoea.Out of eight persons interviewed in Singanallur tank, in the recent six months, one person is affected by malaria, one person is affected by dengue, One person is affected by cholera, Two person are affected by typhoid, one person is affected by chikungunya and Two person are affected by Diarrhoea.This analysis was done based on the Semi-structured interview that was carried out in the study area after obtaining the test result.

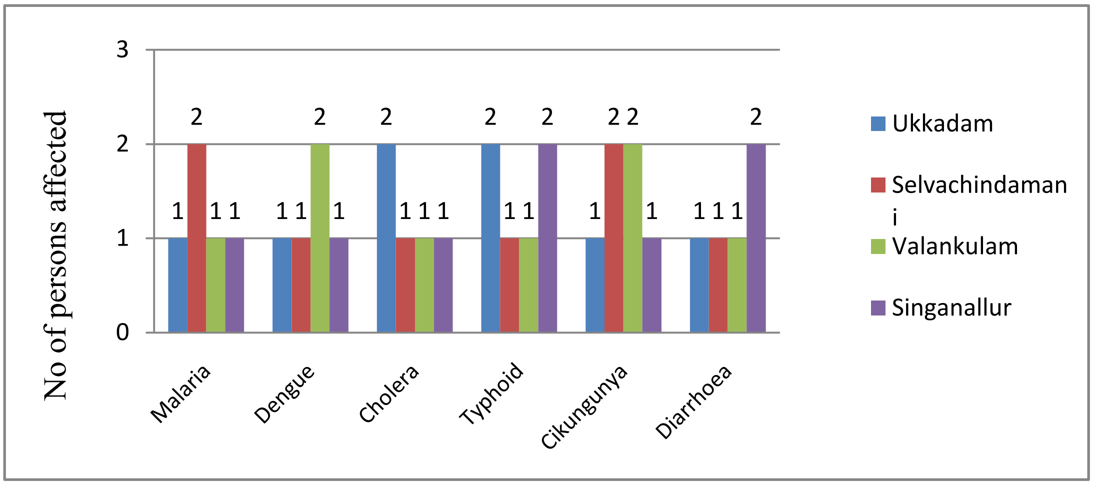

Figure 11 Spread of Diseases

Summary

Groundwater is widely distributed under the ground and is replenish able resource. It plays a vital role in daily demand of a society. Natural and manmade activities result in subsurface contamination and affects aquifers or part of aquifers. By the time the pollution is identified, it is very difficult to apply remedial measures.

The quality of groundwater is dependent on the quality of surface water up to some extent. Therefore it is important to assess both the quality of surface and ground water to study about the impact of affected water quality on human and other living organisms. In the present study water samples from the four tanks namely, Selvachindamani, ukkadam, valankulam and singanallur were collected and ground water samples were collected all around the circumference of all the above mentioned tanks separately. The collected samples were tested in the laboratory for various water quality parameters. The obtained water quality results show that the chloride, TDS, and hardness of most of the sample are exceeding the permissible limits.

Georeferenced map of the study area is opened in ArcGIS. The sample collection points are located in the map by providing the latitude and longitude noted down in GPS during sample collection. After locating the sample collection points, Primary water quality parameters were given as input to obtain the spatially interpolated water quality map. Spatially interpolated water quality map will be helpful in showing the spatial variations in the water quality along the study area.

Visual MODFLOW was used to simulate the groundwater flow taking into consideration some of the external stresses like discharge from the wells, Groundwater recharge , Conductivity of the soil and other losses. Groundwater flow was assumed to be under transient state. The water table data from January 2003 values were used for initialisation. The simulation obtained was calibrated using the observed data for 2003. The accuracy of the computed head was judged by considering the correlation coefficient, Normalised RMS value and Standard root mean error. The output from this simulation is the head contours, Groundwater flow direction of the study area and the cell by cell flow vectors.

MT3D package from Visual MODFLOW was used to simulate the contaminant transport due to advection, dispersion and source/sink mixing and to determine the present concentration with respect to space. MODFLOW simulation serves as the basis for MT3D simulation. The chloride concentration data for January 2003 values were used for initialisation. The simulation was calibrated using the observed data for 2003. The accuracy of the computed concentration was judged by considering the correlation coefficient, Normalised RMS value and Standard root mean error. The output from this simulation is the contaminant concentration contours.

Semi-structured interview was done in the study area after obtaining the water quality test results from the laboratory. Based on the response given by the people, Source for drinking water, method of waste disposal and spread of disease among the people were analysed.

Conclusion

The output from the MODFLOW, direction of groundwater flow in study area could be determined. The correlation coefficient value is around 0.9, Standard error of the estimate value is within 2 m and the Root mean squared value is within 8 m and therefore the field condition has been matched well with the model and the model has been competent sound. Model was validated from 2011 to 2013 and the Groundwater flow was envisaged for 2013 2014 to 2016. From the contaminant concentration map, the ukkadam and singanallur has more chloride concentration. From the analysis of the semi-structured interview, it is clear that more than 50% of the people residing around the tanks dispose the waste from their households into the tank, which is the major reason for water quality deterioration. Since the quality of water is being depreciate because of anthropogenic activities, the contaminant gets transported and affects the groundwater quality.

Refrences

APHA Standard methods for examination of water and waste water, 19th Edition. Washington, DC: American Public Health Association, 1995.

Ayazi MH, Pirasteh S, Arvin AKP, Pradhan B, Nikouravan B, Mansor S. Disasters and risk reduction in groundwater: Zagros Mountain Southwest Iran using geoinformatics techniques. Disaster Adv 3(1):51–57, 2010.

Chidambaram S, Karmegam U, Prasanna MV, Sasidhar M, Vasanthavigar M. A study on hydrochemical elucidation of coastal groundwater in and around Kalpakkam region, Southern India. Environ Earth Sci 64 (5): 1419–1431, 2011.

Davis, S.N., and De Wiest. “Hydrogeology”, John Wiley & Sons, New York, P. 463, 1996.

Dixon B. Prediction of groundwater vulnerability using an integrated GIS-based neuro-fuzzy techniques. J Hydrol 4(309):17–38, 2004.

Foster SS. Fundamental concepts in aquifer vulnerability, pollution risk and protection strategy. In: Duijvenbooden W van, Waegeningh HG van (eds) TNO Committee on Hydrological Research, The Hague Vulnerability of soil and groundwater to pollutants. Proceedings and Information, vol 38, pp 69–86, 1987.

Harbaugh AW, Banta ER, Hill MC, Mcdonald MG. MODFLOW-2000, The US Geological Survey Modular Ground-water Model- Users guide to modularization concepts and the ground-water flow process. US Geological Survey Open-File Report 00-92, 121, 2000.

Indian Standard specification for drinking water: IS: 10500-1992.

Jalali M. Nitrates leaching from agricultural land in Hamadan, western Iran. Agric Ecosyst Environ 110:210–218, 2005.

Javadi S, Kavehkar N, Mohammadi K, Khodadi A, Kahawita K. Calibration DRASTIC using field measurements, sensitivity analysis and statistical method to assess groundwater vulnerability. Water Int 36(6):719–732, 2011b.

Javadi S, Kavehkar N, Mousavizadeh MH, Mohammadi K. Modification of DRASTIC model to map groundwater vulnerability to pollution using nitrate measurements in agricultural areas. J Agr Sci Tech 13(2):239–249, 2011a.

Manap MA, Nampak H, Pradhan B, Lee S, Sulaiman WNA, Ramli MF. Application of probabilistic-based frequency ratio model in groundwater potential mapping using remote sensing data and GIS. Arab J Geosci, 2012.

Manap MA, Sulaiman WNA, Ramli MF, Pradhan B, Surip N. A knowledge-driven GIS modelling technique for groundwater potential mapping at the Upper Langat Basin, Malaysia. Arab J Geosci 6(5):1621–1637, 2013.

National Research Council. Groundwater vulnerability assessment: predicting relative contamination potential under conditions of uncertainty. Committee for assessing ground water vulnerability. National Academy Press, Washington, DC, 1993.

Pallavi A. Patil, Chaudhari.S.Pravin. Simulation of Contamination of Groundwater Using Environmental Quality Model, International Journal of Innovative Research in Advanced Engineering, vol.1, pp.188-192.pp.4953, 2014.

Pradhan B. Ground water potential zonation for basaltic watersheds using satellite remote sensing data and GIS techniques. Cent Eur J Geosci 1(1):120–129, 2009.

Prasanna MV, Chidambaram S, Shahul Hameed A, Srinivasamoorthy K. Hydrogeochemical analysis and evaluation of groundwater quality in the Gadilam river basin, Tamil Nadu, India. J Earth Sci 120 (1): 85–98, 2011.

Rao, K.L. Assessment of Flow and Quality of Water Health – Its Assessment Uses and Projection", Suji Mukherjee Orient Longman Ltd, New Delhi,1975.

Rivers CN, Hiscock KM, Feast NA, Barrett MH, Dennis PF. Use of nitrogen isotopes to identify nitrogen contamination of the Sherwood sandstone aquifer beneath the city of Nottingham, UK. Hydrol J 4 (1): 90–102, 1996.

IOTROWICZ R., KRASKA M., KLIMASZYK P., SZYPER H., JONIAK T. Vegetation Richness and Nutrient Loads in 16 Lakes of Drawieński National Park (Northern Poland). Pol. J. Environ. Stud., 15, (3), 467, 2006.

DUNALSKA J. Influence of Limited Water Flow in a Pipeline on the Nutrients Budget in a Lake Restored by Hypolimnetic Withdrawal Method. Pol. J. Environ. Stud. 11,(6), 631, 2002.

GONG D., GAO X., NTAKIRUTIMANA T., GUO J., LI K. Water quality status along the Liangtan River and control planning alternatives for pollution reduction. Pol. J. Environ.Stud., 22, (4), 1061, 2013.

Shanmugam Jayalakshmi, Esakimuthu VelappanAssessment of Water Quality Index in the St. Thomas Mount Block Using GIS and Remote Sensing. Pol. J. Environ.Stud., 24, (4), 1611-1619, 2015.

TOKATLI C., ÇIÇEK A., KÖSE E. Groundwater Quality of Türkmen Mountain (Turkey). Pol. J. Environ. Stud., 22, (4),1197, 2013.

Rachana, P., Dhanesh, S., Saroj, K., & Sujata, K. Analysis of ground water of Raigarh coal mining area. IJCS, 3(1), 38-40, 2015.