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Impacts of Long Term Irrigation of Treated Paper Mill Effluent on Groundwater in Karur Block

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Abstract- **Ground water is main source of irrigation in TNPL Pugalur panchayat in Karur block. Since 1987, treated paper mill effluent is stored in underground tank then it is pumped out and delivered to agricultural field for irrigation. It seems that due to continuous irrigation, effluent may percolate through the pore spaces between the soil particles and interact with the groundwater and affects the quality of groundwater. The contaminants will be transported and contribute to the nearby well and affect the quality of water in the well too. So it is necessary to test the ground water quality and find out whether it is suitable for drinking and irrigation purpose. This study deals with impacts of long term irrigation using treated paper mill effluent on ground water resources in TNPL Pugalur panchayat. The spatially interpolated water quality map was obtained as output from ArcGIS which was helpful in understanding the variation in quality of groundwater with respect to space. Visual MODFLOW incorporated with MT3D was used to simulate the groundwater flow. The direction of groundwater flow was obtained as output from MODFLOW. The direction, concentration, magnitude of the contaminant transport was obtained as output from MT3D. In this study, TDS has been chosen as contaminant transport parameter.**

Keywords- Treated paper mill effluent, TNPL Pugalur panchayat, ArcGIS, MODFLOW, TDS contaminant.

INTRODUCTION

Paper industry is one of the high water consuming and effluent generating industries in the country. Effluent generated from pulp and paper mills are generally alkaline in nature and as a result the alkalinity of soil will be increasing. Too alkaline soil would not support fertilization owing to chemical wilting of crop. Thus this effluent has to be treated to reduce the pollutant load to stipulated limits before disposing it off into water bodies (treatment should be must if the water is used for irrigation). Alternatively it may be treated partially and used for irrigating field and plantation crops which will mitigate the water scarcity in the semi-arid and arid parts of the country to some extent and will economise the cost of effluent treatment. If the paper mill effluent is not within permissible limits the ground water quality and soil characteristics will be affected. Leachate is defined as the polluted liquid emanating from the base of the landfill. The downward transfer of leachate contaminates groundwater resources, whereas the outward flow causes leachate springs at the periphery of the landfill that may affect surface water bodies. Hence, leachate seepage is a long- term phenomenon that must be prevented in order to protect natural water resources. Long term usage of papermill effluent begins to leachate and affect the physical, chemical and biological parameters of ground water. Groundwater assessment has been based on laboratory investigation, but the advent of satellite technology and Geographical Information System (GIS) has made it very easy to integrate various databases. A three Dimensional model generated using MODFLOW software will be helpful in understanding the interaction between surface and groundwater and also in determing the flow of groundwater. The test results from laboratory (primary data) and wáter quality obtained from Tamilnadu Ground Wáter Board Taramani (secondary data) were given as inputs to the MT3D software, to obtain the contaminant transport map of that area.

NEED FOR STUDY

Groundwater is one of the most important alternative source which could be used for drinking, when there is a demand for surface water. Treated paper mill effluent can be a alternate source to irrigation water at some of villages of TNPL Pugalur panchayat in Karur Block. Though the effluent is treated and used for irrigation purpose, the soil profile, ground water source, livelihood of the people are affected. Major crops in this area cultivated in the starting period of TEWLIS (TNPL Effluent Water Lift Irrigation Scheme) are sugarcane, paddy, plantain, yuca or manioc (Maravalli kizhangu), groundnut, maize, millet and Corn. But now, 17 years of continuous usage of effluent water for irrigation purpose has led to the growth of only coconut and some of the grasses for cattle. Hence the water quality parameters of groundwater have to be tested and inferred whether it could be made use for drinking and irrigation purpose. Since the water quality parameters are spatially varied it is important to spatially interpolate it using ARCGIS software. Simulating of the contamination level, movement of groundwater and its interaction with surface water could be better understood by using MODFLOW software.

STUDY AREA

The study area is situated in between latitude 11.1087°N and 78.082°E longitude in the Karur block of Tamil Nadu. It has an average elevation of 171 meters. TNPL effluent irrigated area is situated in between latitude 11.0554°N and 78.0165°E longitude near TNPL paper mill in the Karur block. It has an average elevation of 125 meters (413 feet).The area is bounded by Cauvery river at north and Amaravathy river at south. The treated effluent water is used to irrigate about 505.87 ha (5.1km^2) of agricultural land of about 250 farmers who belong to TNPL treated Effluent Water Lift Irrigation Society. The villages Moolimangalam, Pondipalayam, Thathampalayam, Pazhamapuram and Ponniyagoundanpudur are irrigated by treated paper mill effluent.

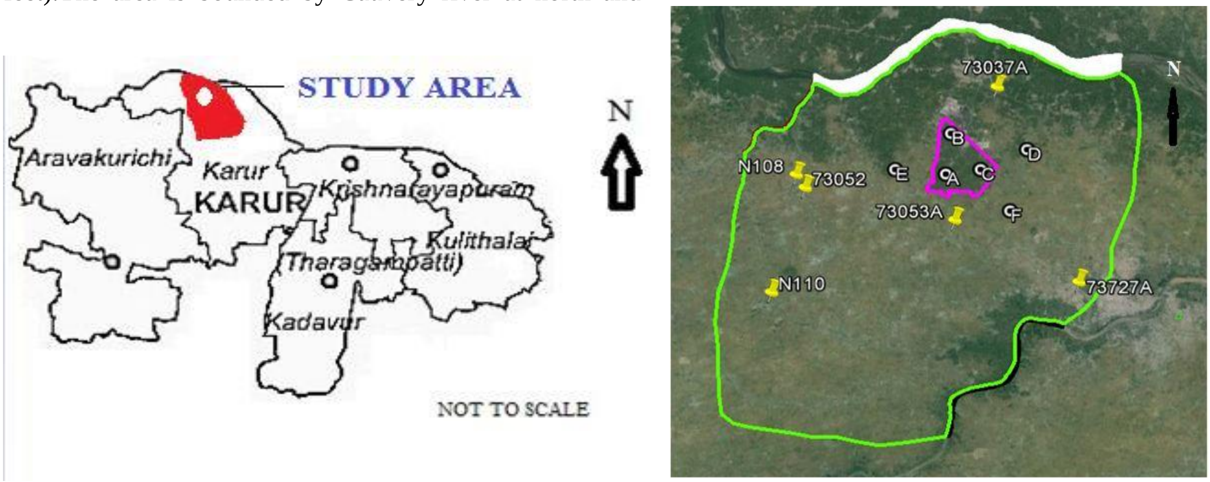


Figure 1 Study area map in Karur block

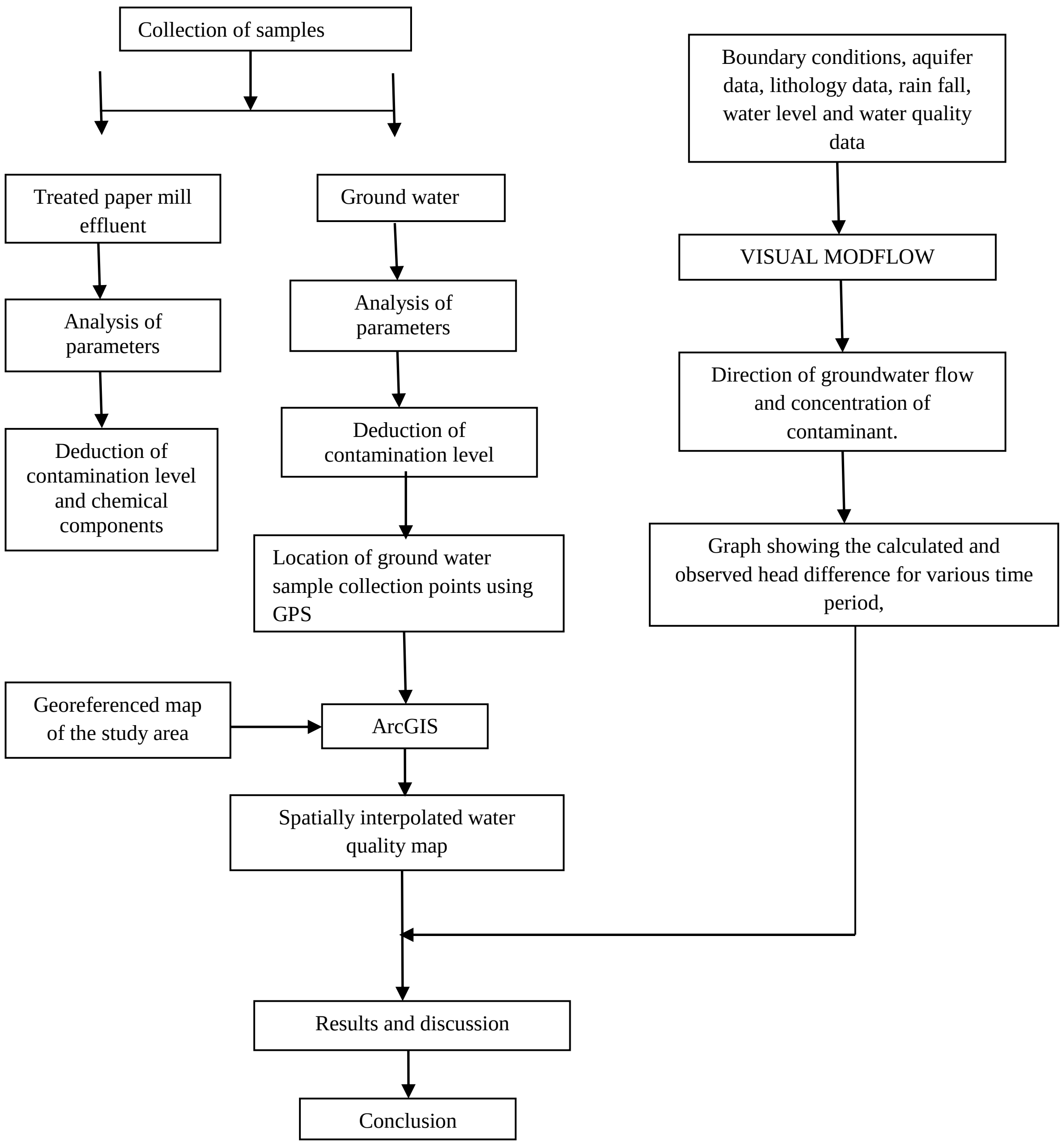
OBJECTIVE OF THE STUDY

a) To determine the physical and chemical characteristics of the paper mill effluent.
b) To study the impact on ground water quality.
c) To produce the spatially interpolated water quality map by using ArcGIS.
d) To determine the flow direction of ground water and simulate the contamination level by using MODFLOW and MT3D software.

DATA COLLECTION

Data collection is the important component in the model development process. Treated TNPL effluent is collected from supply tank in agricultural field and its physical and chemical parameters were analysed and compared with irrigation water standards. Six ground water samples are collected randomly inside and outside of effluent irrigated area which its physical and chemical parameters were analysed by laboratory test. The results were compared with the drinking water guidelines of Indian Standard (IS 10500:2012). Secondary data such as rainfall data, water quality data, and lithology data are collected from State Surface Water and Groundwater Board, Taramani. Area map is collected from Google earth.

Flow chart of the methodology



RESULTS AND DISCUSSION

Table 1 Test results of TNPL treated effluent

Sl no	Sample parameters of TNPL treated effluent	Range	Permissible limits (IS 2296:1982)
1	pH	7.06	6-8.5
2	TDS (ppm)	1760	1500
3	EC (micro mho/cm)	2013	2250
4	Sodium (Na) mg/l	184	-
5	Potassium (K) mg/l	32	-
6	Calcium (Ca) mg/l	94	200
7	Magnesium (Mg) mg/l	37	100
8	Chloride(mg/l)	720	600
9	F(mg/l)	0	-
10	PO_4(mg/l)	0.99	10
11	Total alkalinity	132	200
12	BOD	64	100
13	COD	162	350
14	Copper	0.0012	3
15	Zinc	3.24	5
16	SAR	4.056	1-26

From test results, TDS and Cl_2 were not within the permissible limits but other parameters like pH, Ca, Mg, BOD, COD, Na, K are within the permissible limits as per **(IS 2296:1982)** irrigation water standard.

Table 2 Test results of ground water samples

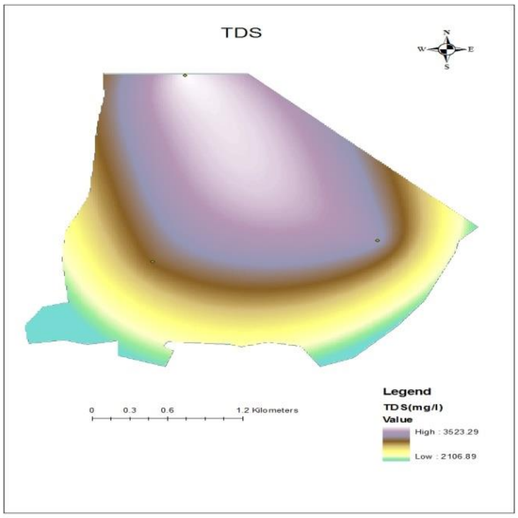
Sl no	Sample location	pH	TDS (ppm)	Mg (mg/l)	Cl_2 (mg/l)	Ca (mg/l)	Sodium (Na) (mg/l)	(K) (mg/l)	F (mg/l)	PO_4 (mg/l)
1	A	6.7	3058	151	1020	352	312	106	0.6	0.02
2	B	7.8	3524	138	1023	314	290	98	0.7	0.04
3	C	7.24	3254	129	1056	292	284	104	0.8	0.07
4	D	6.67	1024	45	976	89	271	89	0.3	0.032
5	E	6.89	1253	60	760	92	302	92	0.2	0.012
6	F	6.83	976	33	863	81	273	97	0.25	0.023
7	**BIS Acceptable limits**	**6.5-8.5**	**500**	**30**	**250**	**75**	**-**	**-**	**1.0**	**-**
8	**Permissible limits in the absence of alternative resource**	**6.5-8.5**	**2000**	**100**	**1000**	**200**	**-**	**-**	**1.5**	**-**

From the test results, open well samples are chemically not portable due to excess in TDS, TH, Ca, Mg, and Cl2 as per BIS 10500:2012. So it is unfit for drinking. SAR values of open well samples are not within the permissible limits of irrigation standard.TDS and Cl_2 are the major contaminant in that open wells but this thesis only focus about TDS concentration.

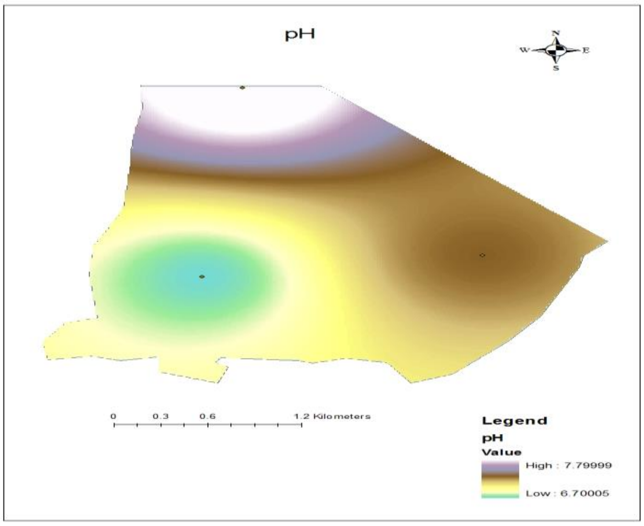
SPATIAL INTERPOLATION USING ArcGIS

GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, on a regional or large scale. Spatial interpolation technique through Kriging approach has been used in the present study for obtaining spatially interpolated water quality map for the TNPL treated effluent irrigation area. Spatially interpolated water quality map will be helpful for understanding how the quality parameter of water is varied along the study area. Figure 3 shows the spatial interpolation of effluent irrigated area for different water quality parameters like pH, TDS, chloride, calcium, magnesium

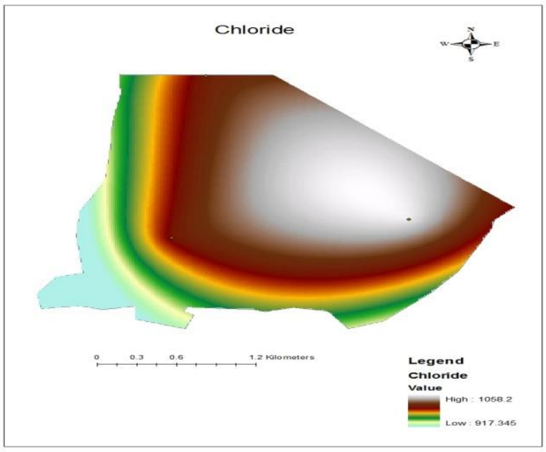
Figure 3 Spatially interpolated water quality map for TNPL effluent irrigated area



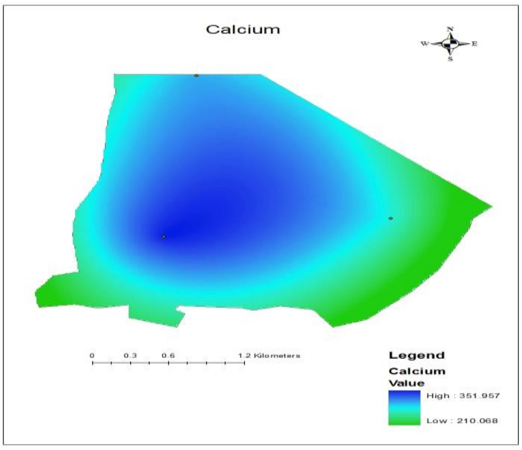
Spatially interpolated water quality map for TDS



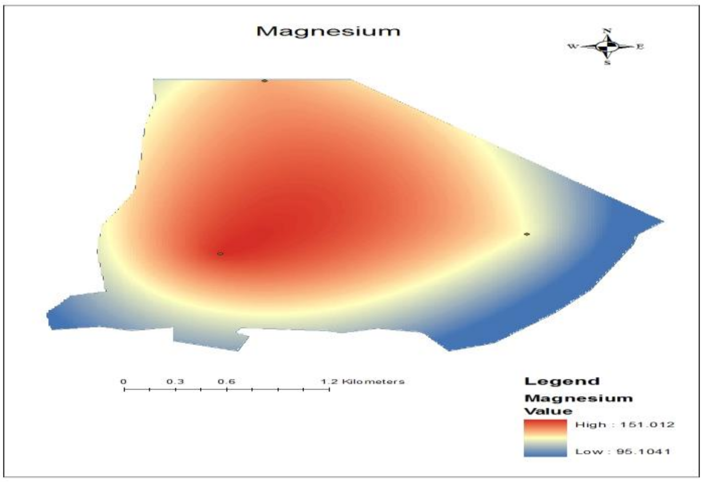
Spatially interpolated water quality map for pH



Spatially interpolated water quality map for chloride



Spatially interpolated water quality map for calcium



Spatially interpolated water quality map for Magnesium

GROUNDWATER MODELLING USING VISUAL MODFLOW

A groundwater model is a mathematical tool designed to represent a simplified version of the physical, chemical and biological processes taking place in a real field site. In this study, groundwater water has been simulated for ten years, from 2006 to 2014. The model has been calibrated for five years, validated for next four years. The groundwater flow has been predicted for the next three years (2014 to 2017) with the increased pumping rate. Since the concentration of TDS was above the permissible limits for all well, contaminant transport for the study area has been done for TDS as the water quality parameter using MT3D package.

a) Importing Base Map to in Visual Mod flow

The base map created from Google Earth (LANSAT image) was digitized using ArcGIS and imported to the Visual MODFLOW. .The digitized map of the study area with the well locations is presented.

b) Creation of Grid

The model area was divided into cells containing 50 columns and 50 rows. The inactive cells of the model domain were defined.

c) Range of Elevations of Different Layers

Table 3 Range of Elevations of Different Layers

Layers	Maximum elevation (with respect to MSL)	Minimum elevation(with respect to MSL)
Ground surface	+179.02	+124
Bottom of layer 1	+164.25	+117.6
Bottom of layer 2	+160.42	+110.7

d) Importing pumping wells and observation wells

Pumping wells for the command area is assumed based on the water level from the year 2006 -2014 (09 years).Water level based on monthly variations is given as an input to respective well locations in the model domain. The monthly pumping quantity of these representative six wells was given as the input. Pumping rate is assumed depending on the per-capita demand and its range was given to input as 350 - 2300 m^3/day. The observation well water level are collected from State surface Water and Groundwater Board, Taramani . All the observation wells are monitored by the various Government agencies (PWD, CWGB).

e) Importing conductivity and storage data

The conductivity values are assumed and assigned for each layer separately depending upon the type of soil and the permeability of the soil in. The conductivity values are assigned equal for entire area of layer1. Storage is assumed depending on the aquifer properties and the value is assigned for the entire study area. Other details such as initial concentration and dispersion coefficient are also assigned in order to run the transport model.

Table 4 Aquifer Properties for Model Input in Each Layer

Layers	Hydraulic Conductivity Range (kx = ky) m/day	Porosity Range in %	Specific yield Range in %
1	3.2	0.32	0.28
2	1.18	0.26	0.21

f) Boundary conditions

Boundary conditions such as river and recharge are assigned for the study area based on the available input parameters.

g) Recharge boundary condition

The maximum recharge value was obtained for in the study area is 239.25 mm/year. 15 -20% annual average rainfall is taken as a recharge of that area.

h) Flow boundaries condition

In the study area, Cauvery river, Noyyal river, and Amaravathy river are located. Thus three boundary conditions were assigned for the study area. Top portion of study area is covered by Cauvery River. Bottom right part of the study area is covered by Amaravathy river.

SIMULATION OF GROUNDWATER FLOW

Direction of flow in the study area has been obtained as output from the model, after providing some input parameters constant concentration, recharge concentration, evapotranspiration concentration and all the necessary boundary condition details, the model is made to run to simulate the flow of groundwater.

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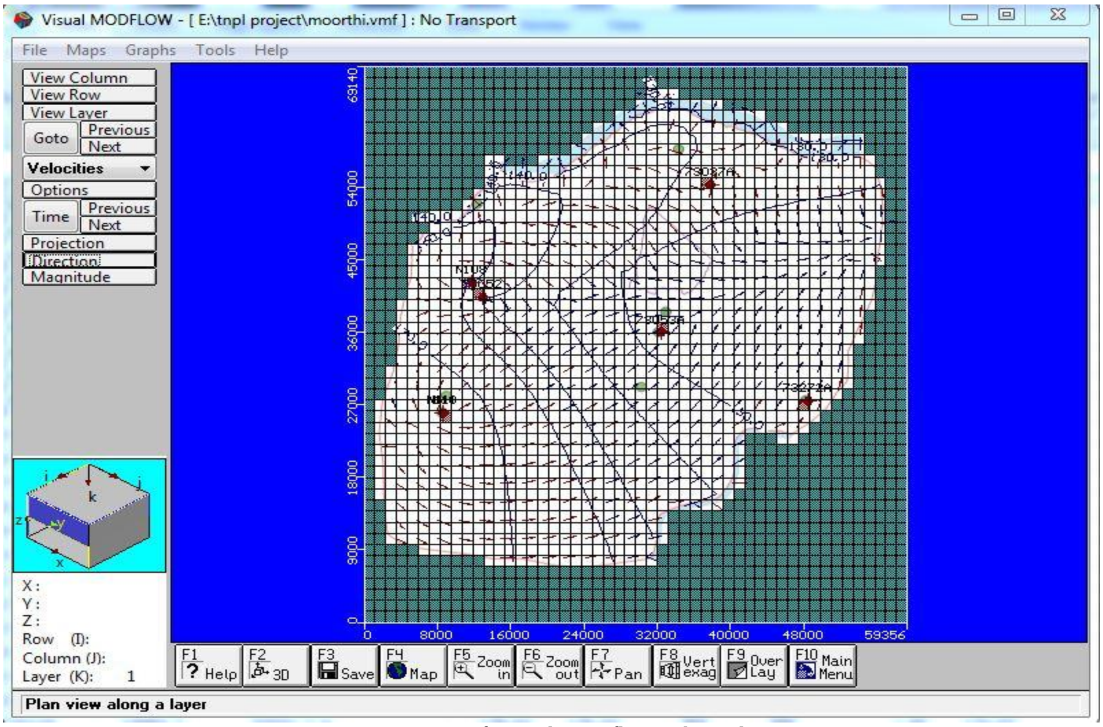


Figure 4 Direction of ground water flow in the study area

Figure 4 shows the direction of flow of water in the study area. From this figure, we could infer that the flow of water is mostly towards the river and very rarely away from the river.

Model calibration and validation

After providing all the required input, groundwater has been simulated for ten years, from 2006 to 2014. The model has been calibrated for five years, validated for next four years. The groundwater flow has been predicted for the next three years (2015 to 2017) with the increased pumping rate. Output graph of calculated vs. observed head for the time period of 1800 days (calibration period) is shown in Figure 5.

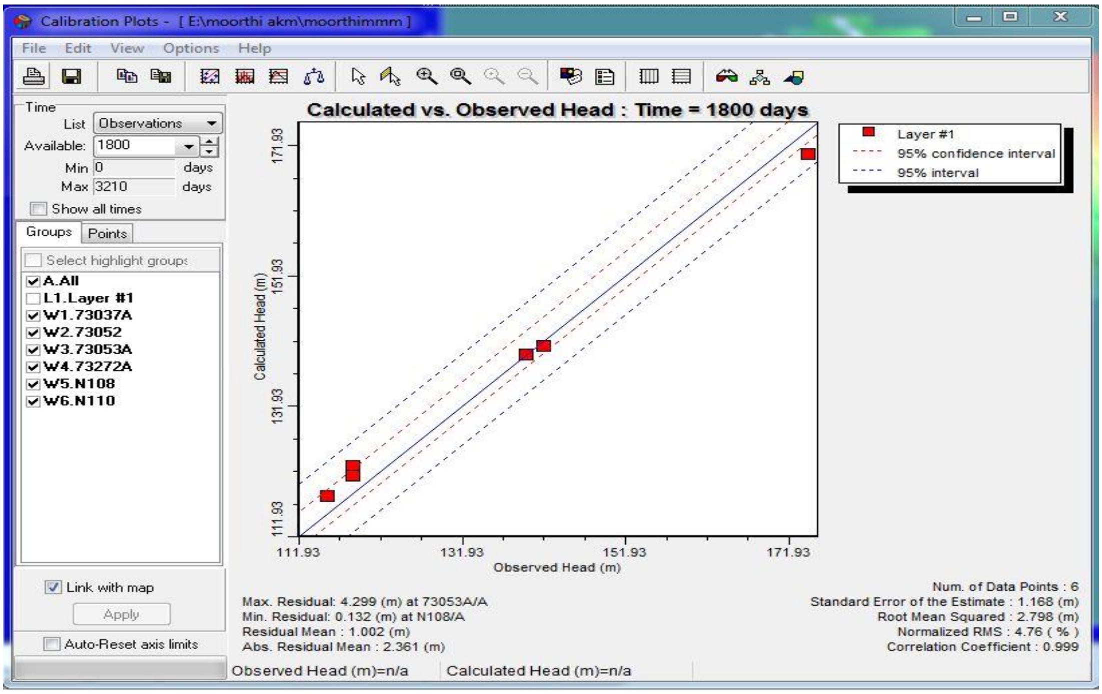


Figure 5 Calculated vs. observed head (calibration)

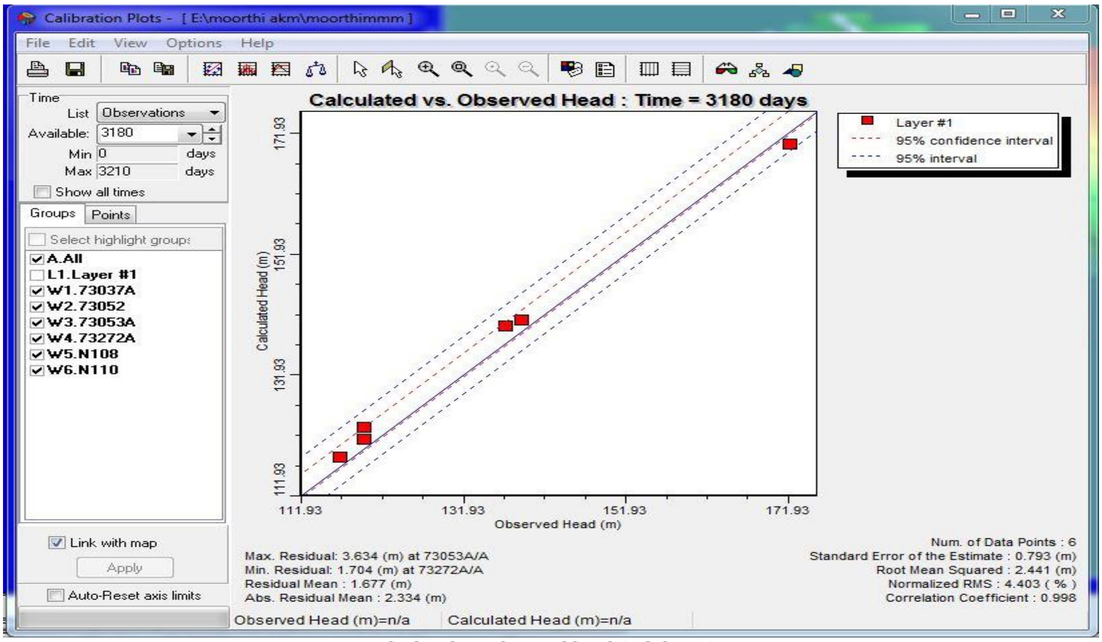


Figure 6 Calculated vs. observed head (validation)

From figures 5 and 6, we could infer that the difference between the calculated and observed head for all the wells of calibration and validation are within the 95% confidence interval. The correlation coefficient of the wells are (0.999 and 0.995) nearly to 1 and therefore the model has been calibrated and validated successfully.

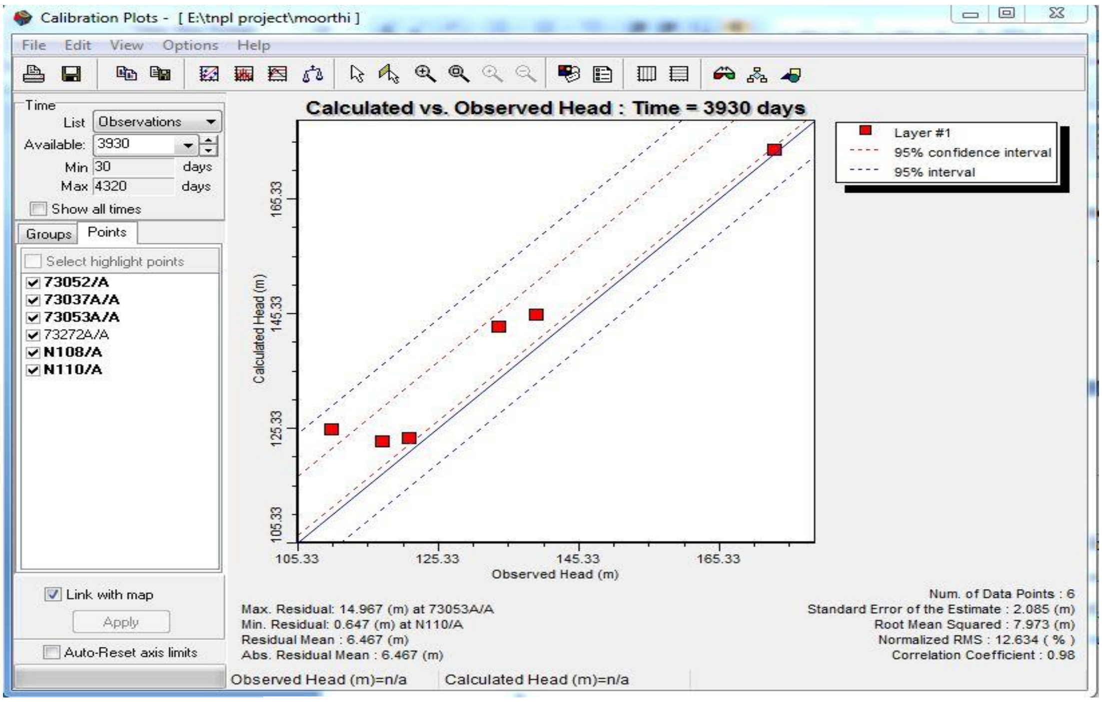


Figure 7 Calculated vs. observed head (prediction)

Figure 7 shows the prediction scenario of the model. After calibrating and validating the model, future flow has been predicted with the assumption of increased pumping rate. Because of increase in pumping rate the water level will be reduced, which has been indicated by reduced calculated head in the model

Contaminant transport using MT3D

Contaminant transport has been done by choosing TDS as water quality parameter. Figure 8 shows the contaminant transport map of the study area. Contaminant transport map is obtained as the output from the transport model after giving some parameters like concentration observation wells, initial concentration, constant concentration, recharge concentration and evapotranspiration concentration.

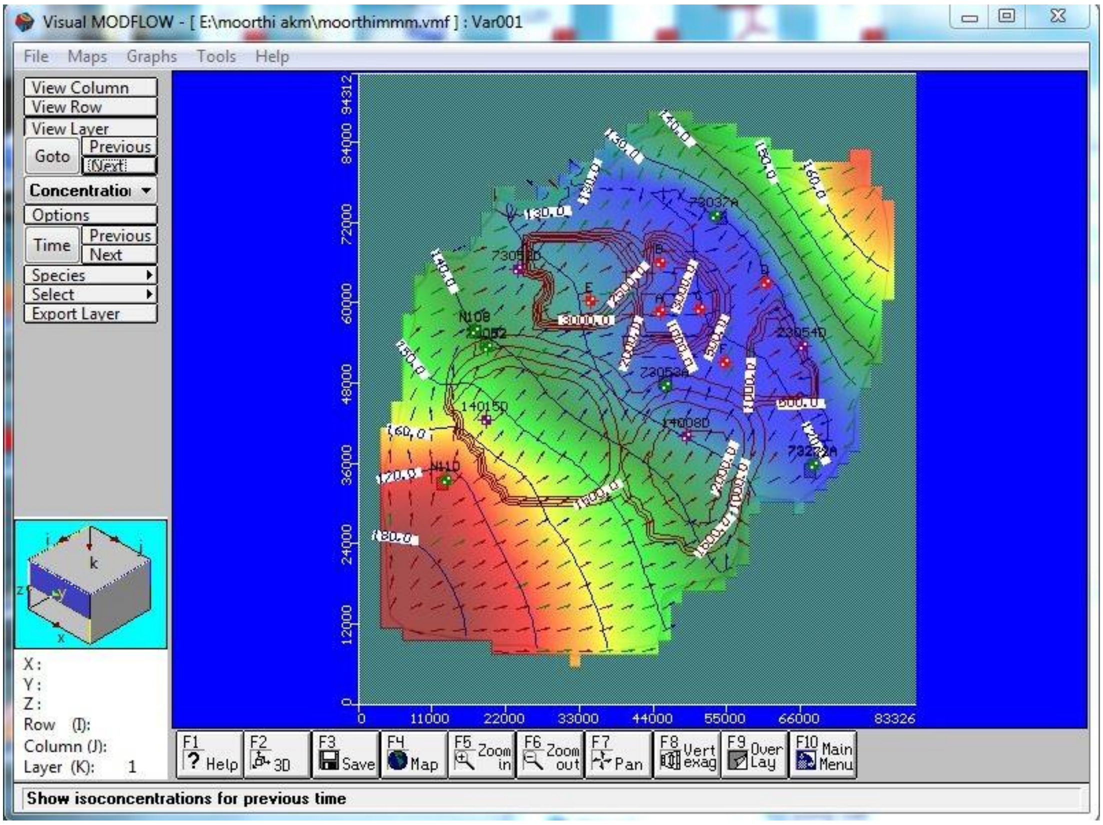
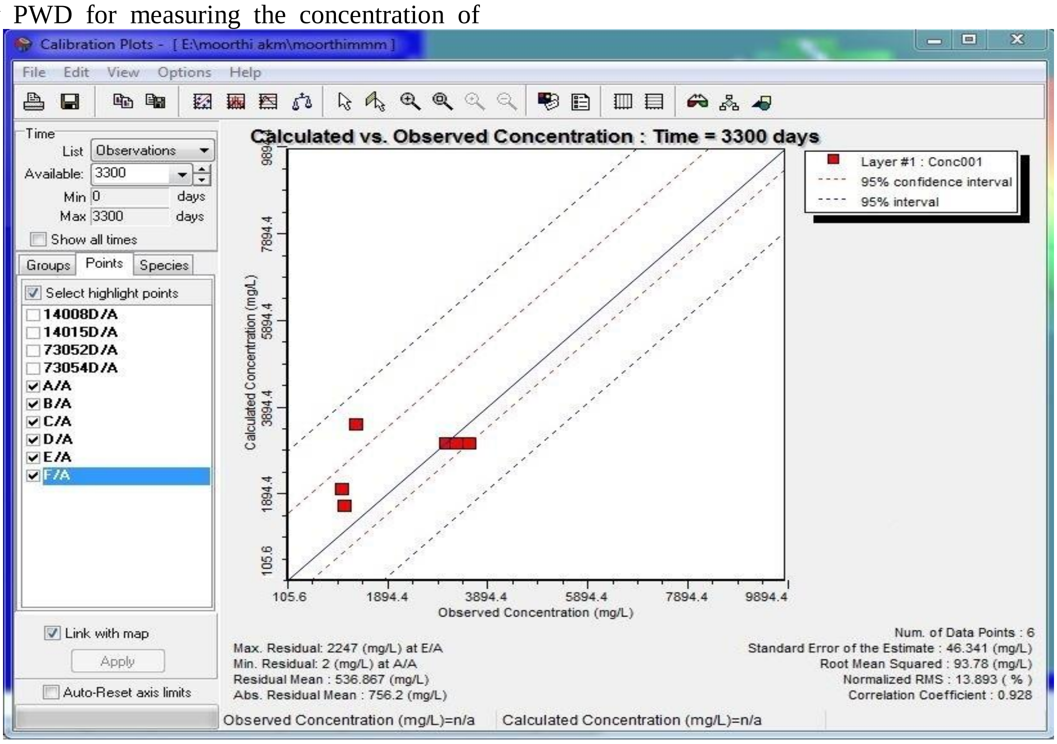


Figure 8 Contaminant transport contour map

Figure 8 shows the output in the form of graph for calculated vs. observed concentration for the secondary wells. Secondary wells are those wells which are maintained by PWD for measuring the concentration of contaminants. Correlation coefficient for the secondary wells is 0.928, therefore the output is acceptable.



Calculated vs. observed head (Primary wells)

Primary wells are those wells where the water samples have been collected and tested in the laboratory. Figure 5.17 shows the output graph of calculated vs. observed concentration for the primary wells. The correlation coefficient for the primary wells is 0.965 and, therefore the output is acceptable.

CONCLUSION

The TNPL treated effluent and ground water quality parameter determined by conducting physico-chemical test in the laboratory clearly shows that TDS and chloride values are not within the permissible limits for effluent. For ground water samples chloride, TDS, magnesium, calcium values have exceeded the permissible limits.

Spatially interpolated water quality map was obtained using ArcGIS which would be helpful in viewing the spatial variation along the study area of TNPL effluent irrigated area.

The direction of groundwater flow for study area has been simulated using groundwater flow model and the output indicates that the direction of groundwater flow is away from the effluent irrigated area to downstream side.

Calculated vs. observed head difference is obtained in the form of graph from MODFLOW.The correlation coefficient value is around 0.9, standard error of the estimate value is within 2m and the Root mean squared value is within 8m and therefore we could conclude that the field condition has been matched well with the model and the model has been trained well.

Model was validated from 2011 to 2014, Finally the groundwater flow was predicted for 2015 to 2017.

The actual values of the flow and dispersion parameters such as dispersion, hydraulic conductivity and porosity would help better for prediction of solution movement.

The contaminant (TDS) flow direction was simulated using MT3D package. The contaminant concentration contour map, output from the MT3D is helpful in understanding the movement of contaminant. It indicates that the direction of contaminant movement is towards the eastern side of the study area. Noyyal River has polluted due to textile industry and those contaminant also moved towards the study area and affected the ground water partly.

From the contaminant contour map, we can conclude that the area between Noyyal river basin and effluent irrigated area has more TDS concentration. The results of semi-structured interview was helpful to understand that the source of drinking water for the people is Cauvery river and for agriculture they depended only on ground water source. From the analysis of this study, we can suggest that salt tolerant crops are suitable for this study area.

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