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Heavy Metal Analysis and Modelling of Subsurface Strata in Ranipet Industrial Region Using *Modflow* Software

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ABSTRACT

Water is a major source of living organisms. The discharge of industrial wastewater into lands and lakes near the Ranipet industrial area causes contamination of groundwater and land surrounding it. Discharge of waste water from the point source and its impacts to surroundings are analyzed and modelled using visual MODFLOW software. Software requires input data such as Geological properties, Shape files, Boundary conditions, heads and other factors to generate a groundwater model. Present study deals with characteristics of subsurface stratum quality in the Ranipet region, water and soil samples were collected from different identified locations and analyzed for heavy metals present in contaminated subsurface. Tests conducted on samples conclude that arsenic, lead, cadmium concentration are above the permissible limits. MODFLOW software used for the modelling of contaminated site, movement of groundwater and for future study. Suggestions and remedial measures are given for improvement of subsurface in Ranipet region.

Keywords: *Groundwater model, subsurface Contamination, Visual Modflow, Suggestions.*

INTRODUCTION:

Ranipet is an industrial hub of southern India. There are number of large - medium scale industries which are mainly engaged in leather exports, chemical and tool manufacturing in region making lifeline for the town and villages surrounding it. Located between Vellore – Chennai highway it has 2234 km^2 in area. Ranipet is identified by The New York-based Blacksmith Institute (BI) as one of the top 10 dishevelled and polluted countries in the world in 2007 **(Kistan *et al.*, 2017)**. Due to the industrial, economic growth and the production of a variety of components and chemicals followed by increased consumption of man makes some unwanted pollutants, these pollutants cause serious problem for the environment and for man himself. Even small traces of these elements can pose serious hazards to the habitants. **(Kistan *et al.*, 2017)** The growth and industrialization of Ranipet region leading to contamination of groundwater and surface water surrounding industries causing serious pollution to the locality. More than 90% of our rural population is primarily dependent on groundwater **(Chandrasekhar *et al.*, 1999)**. Chemicals used for these processing consists of heavy metals such as Chromium, Lead, Cadmium, Arsenic etc., **and (Alebel Abebe Belay 2010)**. Monitoring heavy metal concentration is very important because of their toxicity and their bioaccumulation in living organisms **(Miller et al., 2002)** The pollution of the groundwater happens mostly due to percolation of pluvial water and the infiltration of contaminants through the soil under waste disposal site **(Jorge et al. 2004)**. Present study revolves around the Ranipet industrial region where traces of heavy metal are analysed in the study area causing contaminations to soil and water **(Vivek, S et al. 2022).** The contaminations are identified by sampling and groundwater model is created using MODFlOW software. MODFLOW is the groundwater modelling software developed by

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USGS. Visual MODFLOW is said to be the complete, and user-friendly, modelling environment for practical applications in three-dimensional groundwater flow and contaminant transport simulation **(Anjali A et al., 2015)**. In present study Visual MODFLOW flex 6.1 is used to model subsurface condition of the study area. Contaminations in groundwater should also be assessed for the groundwater flow models are used to calculate the rate and direction of movement of groundwater through aquifers **(Khadri and Chaitanya, 2016) (Namitha MR *et al*., 2019).** The relation between pollution and health problems is now well documented and reasonably well known by the general public **(Charmaine Jerome and Anitha Plus, 2011)**

MATERIALS AND METHODS:

Hydrogeological data collection involves accusation of data required to run the model. These data involves shape files, DEM, heavy metal concentration obtained from samples, ground water quality and ground water level data. These data's are necessary to run the model in Visual MODFLOW flex 6.1.

Subsurface Sample Collection done in one litre polythene water bottles as per the standard procedure of ALPHA (1998). About 10 samples were collected across the study area 6 samples are collected across tributaries from source to lake and 4 samples are collected across the lake for containment transport study. Proper safety precautions are taken while collecting samples in study area.

Heavy metal analysis and physiochemical parameters are tested on samples, Heavy metals such as Cadmium, Chromium, Lead, Iron, Zinc, Arsenic are tested for concentraions in the sample locations and pH, Electrical conductivity, Hardness, Alkalinity, Total Dissolved solids are tested in collected samples for ground water quality study purpose (**Vivek & Sashikkumar 2021)**.

STUDY AREA:

The Ranipet Town is located at 12°93'20" to 12°55'55" Northern latitude and 79°33'66" to 79°20'47" eastern longitude and is 93 KM west of Chennai, it is geographically 25 Km away in the North East of Vellore, the District Headquarters of Vellore District and has an area about 2234.32 Sq. Kms. The Ranipet district is a plain region with small hillocks, it is enriched with good thickness of alluvial soil. The major source of fresh water is groundwater and Palar River. Palar River is sloping towards east, it is not a perennial river and occurrence of flood is only on heavy rainfalls during Monsoon seasons. The Geology of the study area has 90% of hard rock and rest 10% is of sedimentary, the geological formation of hard rocks available are Charnockite, Granite, Gneiss, Pegmatite, Quartzite and sandy formations are of sedimentary respectively. About 10 samples were collected around the study region, in that 6 were near tributaries which connect from source to lake and rest 4 are around the lake. During monsoon seasons these lakes reaches its full capacity and all the runoff water moves toward the Palar River. The contaminated water further gets contaminated with domestic, agricultural wastes then reaches the Palar River causing future contamination.

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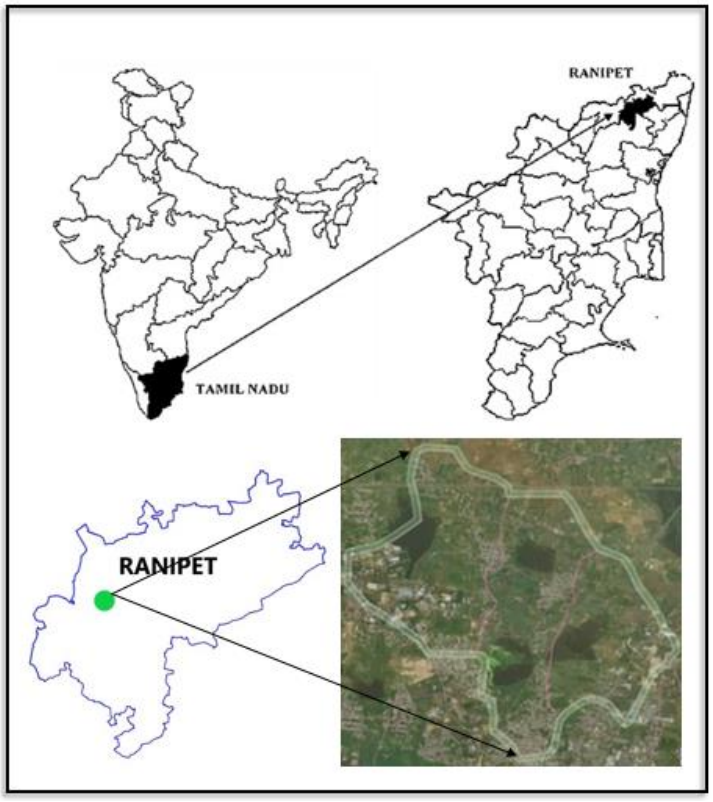

Fig. 1 Study Area

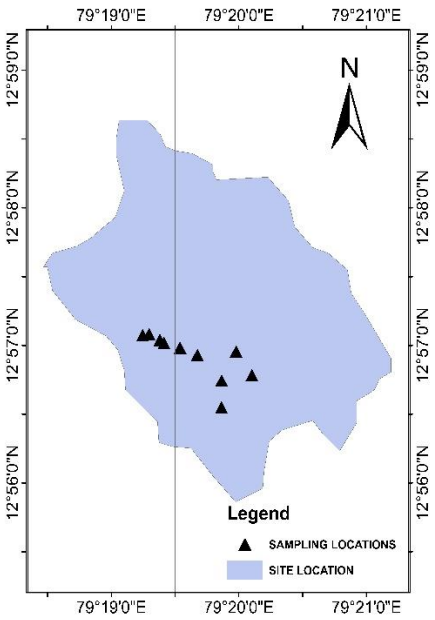

Fig. 2 Sampling Locations.

Visual MODFLOW Flex 6.1:

Visual Modflow flex is a powerful software package that provides the tool for building three-dimensional groundwater conceptual and numerical model using raw GIS data objects. Building Conceptual model involves following components such as geologic formation structures, hydrologic propreties, boundary conditions and grid mesh model. These components allows the processing of model converting Conceptual model to numerical model, from working with grid-independent data it allows to incorprate physical geology and geographic conditions into model with minimal data in pre-processing. Concepual models are high level representation of ground water models with defined hydrologic properties, these models can be converted into different types of numerical models with inputs such as surface, polyline, polygons and points. The changes conceptual model input values or datas are simultaneously shown in 2D and 3D views.

Numerical models provides tools for defining, viewing and editing the properties, boundaries assigned to grid cells. The work flow in numerical modelling involvels defining objectives, editing grid / mesh, defining properties, defining boundary conditions, defining zone budgets, define particles and selectons of desired engine to run the model. After selection of an engine translation of visual modfloe flex file formats to data files required to run the numeric engine. After successful complition of run the results are available in the form of charts and maps, in charts visulation involves calculates heads vs observed head, time series, mass balance and Zone Budget. In Maps visulation can be in many output models such as concentrations, pathlines, residuals, heads, drawdown, budget, velocity of watertable, flood cells and these outputs can be exported in variety of formats such as *.CSV, *.xlsx,*.SHP and *.GRD files.

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Data Collection:

Coordinates of sample locations in the study are noted manually using GPS, these locations are important for mapping in study area as well as modelling the flow of contaminants at a particular region.

- Shape files are downloaded from DIVA-GIS diva-gis.org/gdata and required shapefile is exported using Arc GIS 10.5 software.
- Ground Water data are obtained from India-WRIS indiawris.gov.in, (2010-2021) range of data collected are used for the modelling of subsurface
- Potential Evapotranspiration and Porosity, climate data are collected form High-resolution gridded datasets Climate Reserch Unit (University of East Anglia) and NCAS crudata.uea.ac, (2010-2021) range of data obtained are used to run model.
- Groundwater level and quality data obtained from Public Works Department (PWD) GW wing, Tharamani, and Central Ground Water Board (CGWB), located at Chennai for 11 years (2010-2021) these data used to define the soil layer properties of model.
- Digital Elevation Model (DEM) for the study area is downloded from USGS Earth explorer digital elevation, SRTM – SRTM1 Arc-secon Global and required details are extracted using Arc GIS 10.5.

These are some basic datas required to be procerssed for running an Visual MODFlow program.

CONCEPTUAL MODELLING:

Conceptual modelling in visual modflow involves creating a project and importing raw data as polygon, polyline, points, surface and maps, these imported data are assigned to a new conceptual model there by defining the structure with surface characteristics of layers as horizons. **Property zones** are defined by structural zones they involve parameters such as Conductivity, Storage and Initial heads, the property assigned to this model are listed below along with units. These parameter values are obtained form research journals of the study area. **Boundary Conditions** is set by Arc GIS 10.5 a major tool used for extraction and trimming of data in datasets obtained from major sources, BC are set according to heads of polygon in left Boundary of the model, the simulation domain lies on top of the model in constant heads and attributes are of model are defined in this stage. **Grids** or mesh which are arranged to the study area of the polygon are sixed as 50x50 and thickness of these cells are 65, Xmax and Xmin, Ymax and Ymin, Zmax and Zmin are grid extents which are set by polygon coordinates in Finite Difference Grids. **Translate** allows the input files such as polyline, surface and parameters to applicable modelling Engines, Initial head, solvent, output control can be adjusted in the translation stage of Conceptual modelling and new numerical model tab will be created.

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Sl.No	Layer No	Soil Type	Hydraulic Conductivity m/sec	Property Zones	
1	Top	Alluvial Soil	K_x	4E-05	6E-05
2	Middle	Weathered Rock	K_y	4E-05	6E-05
3	Bottom	Hard Rock	K_z	4E-06	6E-06
4	Initial heads		210m		

Table.1 Hydraulic Properties of Study Area

NUMERICAL MODELLING:

Numerical model is followed by conceptual model in visual modflow where finite difference grid is created or edited by importing old conceptual model datas and defineing modelling objective with assigning parameters such as heads, hydraulic conductivity to selected polygon and grid of model by cell to cell. Setting **Boundary Conditions** to assigned numerical model by polygon or by using data object and by cells (individual cell selection), some values can be edited using edit option in numerical model. USGS MODFLOW 2005 from WH and transport engine MT3DMS are used to run model in numerical model. Translation of numerical model is done for the calibration and minimizing errors while running model, after successuful complition of model run results are shown in maps and charts.

RESULTS AND DISCUSSION:

Results shows the basic water quality parameters of tested waste water sample and graph of heavy metal concentration. The graph is plotted against concentration vs sample location, this shows the contamination growth in moving water sample. Output results of charts are shown below, drawdown, heads, watertable and velocity of the study area is obtained in Visual MODFLOW.

Sl.no	pH	Electrical conductivity	Hardness	Alkalinity	TDS
Unit		µS/cm	mg/L	Ppm	Ppm or mg/l
1	6.54	184.0	70	400	362
2	7.21	179.4	100	600	767
3	7.32	143.4	50	1000	612
4	7.25	115.1	40	600	515
5	7.54	81	50	500	568
6	7.5	92.9	30	400	536
7	7.2	87.2	50	600	651
8	6.2	106.3	40	400	561
9	6.5	178.8	80	800	783
10	6.3	108.8	70	300	593

Table.2 Water Quality Parameters

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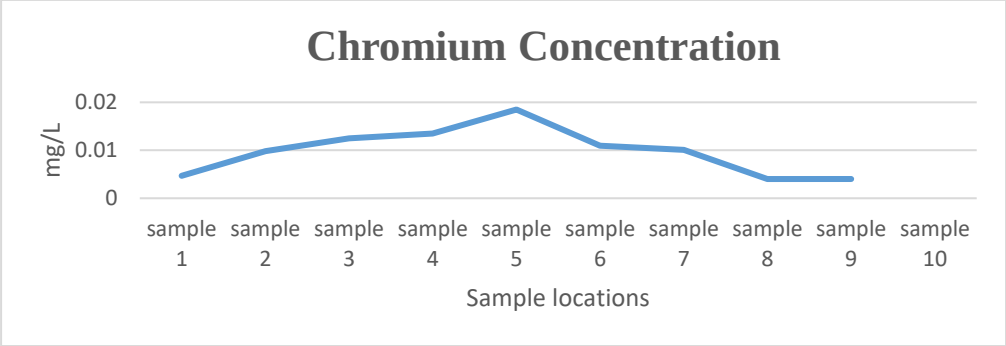
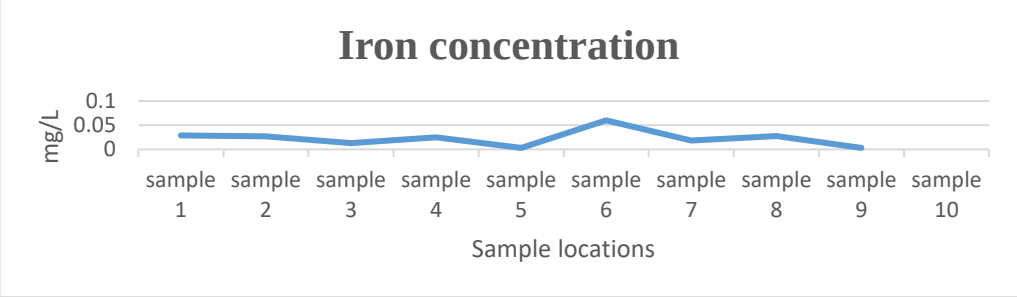
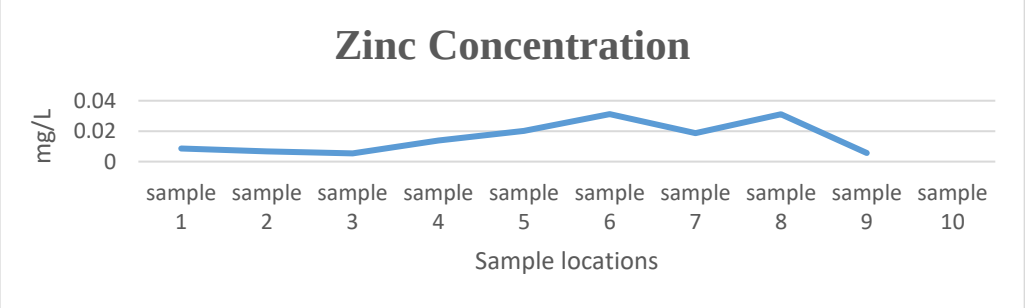


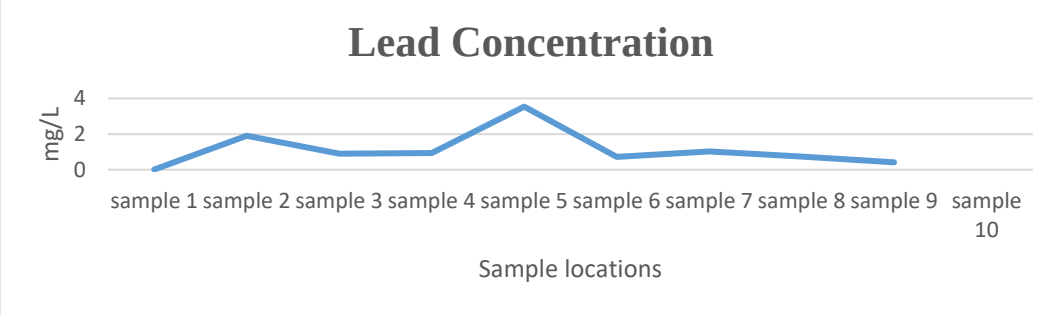
Graph.1 Chromium



Graph.2 Iron



Graph.3 Zinc



Graph.4 Lead

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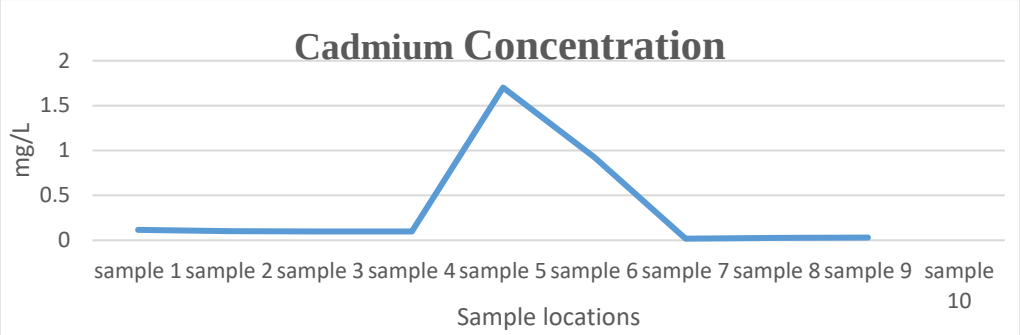
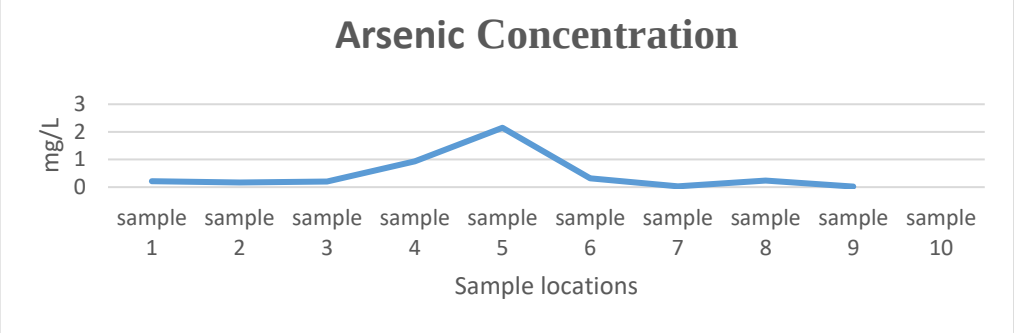


Graph.5 Cadmium



Graph.6 Arsenic

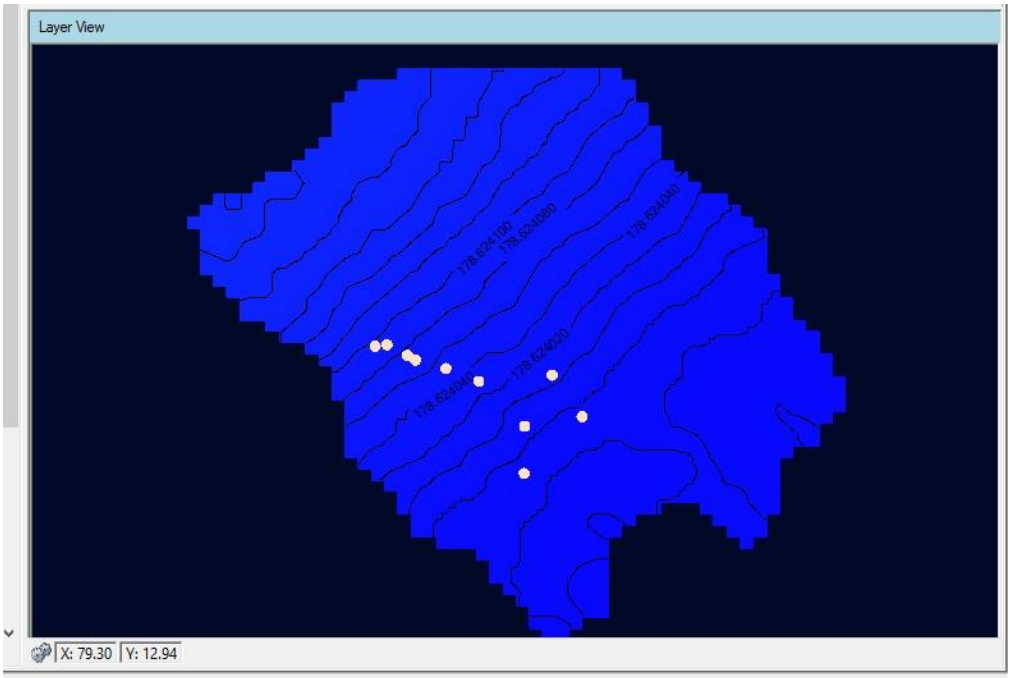


Fig.1 Heads of Horizon 1

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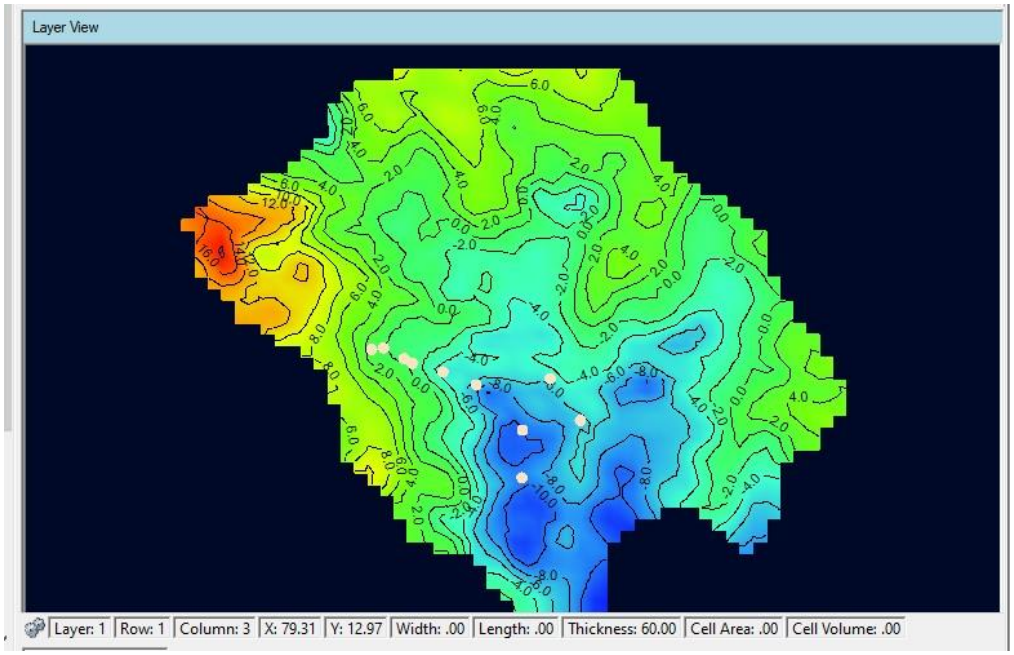

Fig.2 Drawdown of Horizon 1

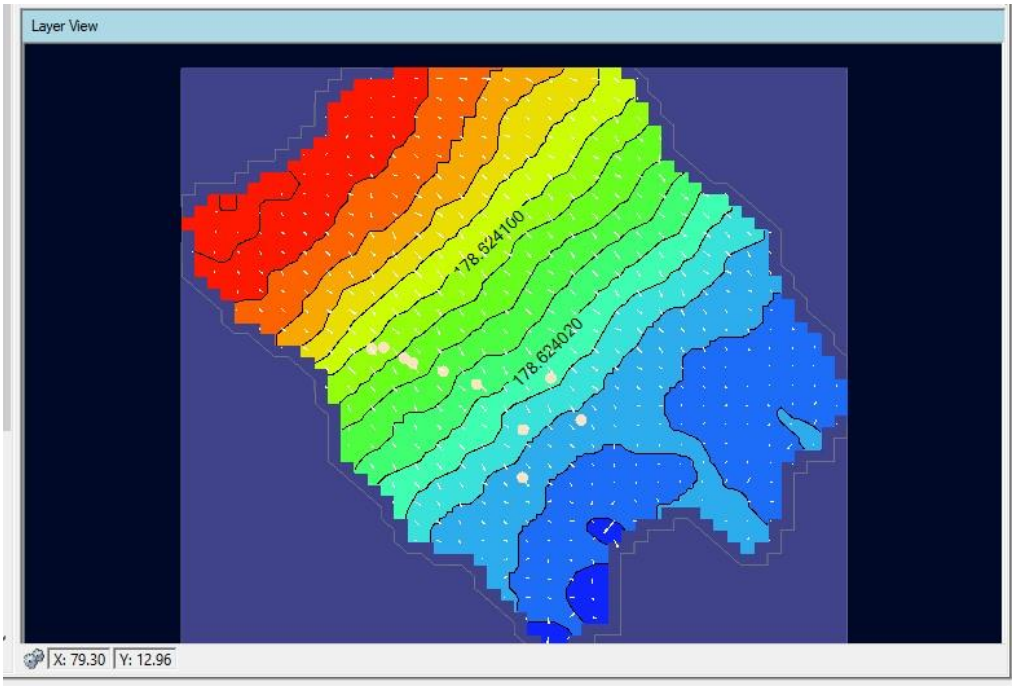

Fig.3 Water Table of Horizon 1

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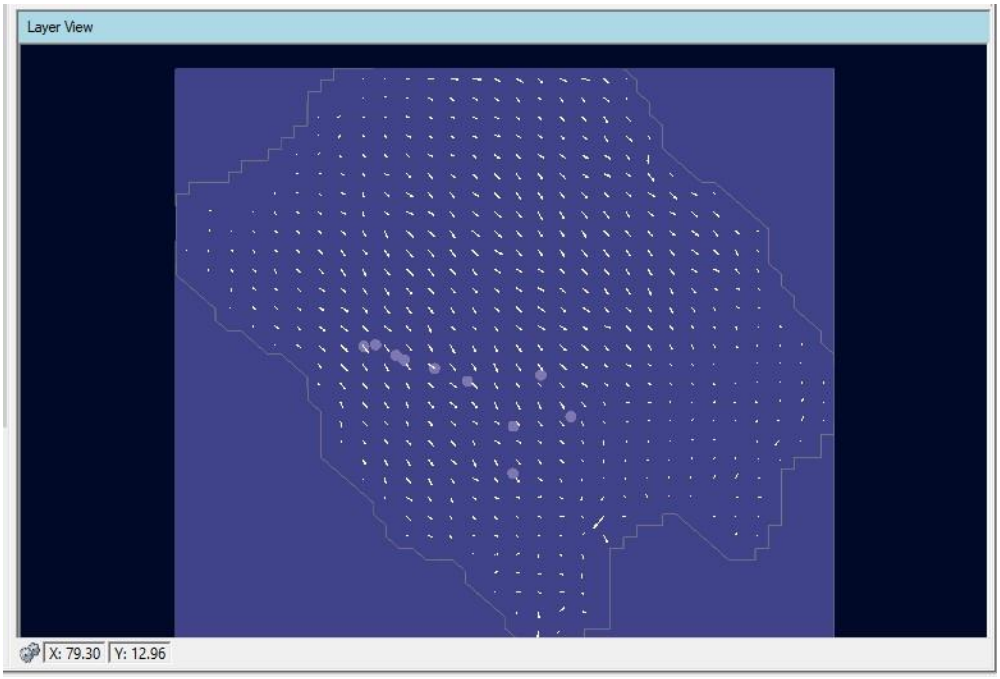

Fig.4 Velocity of Horizon

CONCLUSION:

Samples were collected in Ranipet region across the study area; basic water quality parameters were tested and are tabulated. Impacts of heavy metals are also identified from these samples and graph is plotted for concentration and sample locations. A result shows that the water and soil are contaminated; heavy metals are present in these samples and are above permissible limits.

The results shows that high amount of lead, arsenic and cadmium are present in these samples compared to chromium and other heavy metals on the region, Visual MODFLOW Flex is effectively used to model and predict the future subsurface condition of the area by using Output flow models generated such as Head, Drawdown, Velocity and Water table. Using these results and model outputs we recommend that

- Discharge of effluents into lakes and open sources must be regulated tightly to avoid contaminant transport. Discharge parameters must be within stipulated values by CPCB and TNPCB.
- Output maps of model conclude that velocity flow of G.W is towards Palar River, so care must be taken to avoid contaminant transport in subsurface.
- Use of ZLD and Advanced Treatment systems must be implemented by industries to reduce the wastewater discharge in lakes. Residential sewer lines must be directed to STP's of Ranipet to avoid surface and subsurface contamination.
- Treatment methods such as phytoremediation, bioventing, bio-augmentation and biosparging must be adopted for the entire Ranipet region to reduce concentration and improve G.W quality.
- Dumping of solid waste near Lakes of Ranipet region is quiet high, steps must be taken no manage solid wastes near lakes and regulate it to landfill sites.
- Government must take initiatives to restore the lake to its original capacity near Ranipet and all over Tamilnadu to improve G.W quality and improve ecosystem surrounding lakes and water bodies.

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REFERENCE:

1. K. Arumugam, T. Karthika, K. Elangovan, R.K. Sangeetha and S. Vikashini (2020) Groundwater Modelling Using Visual MODFLOW in Tirupur Region, Tamilnadu, India Nature Environment and Pollution Technology An International Quarterly Scientific Journal Original Research Paper e-ISSN: 2395-3454.
2. R.Rajamanickam and S.Nagan Groundwater Quality Modeling of Amaravathi River Basin of Karur District, Tamil Nadu, Using Visual Modflow International Journal of Environment Sciences Vol. 4 No. 2 (July-December, 2018).
3. Namitha MR, Devi Krishna JS, Sreelekshmi H and Muhammed Ashik P Ground water flow modelling using Visual MODFLOW Journal of Pharmacognosy and Phytochemistry 2019; 8(1): 2710-2714.
4. Khadri SFR, Chaitanya Pande. Ground water flow modeling for calibrating steady state using MODFLOW software: a case study of Mahesh River basin, India. Model. Earth Syst. Environ. 2016; 2:39.
5. N.C. Mondal, (2018)' Groundwater Modelling using Visual MODFLOW in the Last Two Decades in India: A Review' International Journal of Science and Research (IJSR) ISSN: 2319-7064.
6. Sushant Kumar, M. K. Choudhary, T. R. Nayak Groundwater Modelling in Bina River Basin, India using Visual Modflow IJSRD - International Journal for Scientific Research & Development| Vol. 5, Issue 05, 2017 | ISSN (online): 2321-0613.
7. Subbarayan Saravanan, S Pitchaikani and G Venkatesan Assessment And Evaluation Of Groundwater Vulnerability Index Maps Of Upper Palar River Basin, Tamilnadu, India J. Earth Syst. Sci. (2020) 129:162.
8. Rebecca C. Doble, Craig T., Simmons and Glen R.Walter (2009) 'Using MODFLOW 2000 to Model ET and Recharge for shallow groundwater problems' Ground Water Vol. 47 No. 1 pp. 129135.
9. Vivek, S., & Sashikkumar, M.C. (2021). Hydro-Geochemical and Quality Assessment of Groundwater for Irrigation Purpose in Tirupur Taluk, Tamil Nadu, India. *Journal of Environmental Protection and Ecology*, *22(*5), 1836–1850.
10. Vivek, S., Sashik kumar, M.C., Logesh, N., Priyadarsi, C Roy, D., Lakshumanan, C. (2022). Vulnerability Assessment of Groundwater in Industrialized Tiruppur Area of South India using GIS-based DRASTIC model. *Journal of Geological Society of India, 98,* 696-702.

 https://doi.org/10.37896/pd91.5/91537