Journal of Current Research in Engineering and Science
Bi-Annual Online Journal ( ISSN : 2581 - 611X )
Volume 6 –Issue 2,August 2023
Paper 48

# Assessment Of the Impact of Industrial Effluents on Ground Water Quality Around KMML

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***Abstract*—Quality of our life depends on the quality of the water we drink. In this era, unavailability of safe drinking water is a major problem. The Kollam coast of Kerala is a blessed coastal belt with the best mineral sand deposit of the country. The coastal sand dunes in Kollam district are rich in minerals ilmenite, rutile, zircon, monazite, leucoxene (brown ilmenite), sillimanite and garnet. The mining and processing of rare earth minerals along the coastline of Chavara, Kollam is a strategically important industry. Titanium dioxide pigment production industry operating through chloride process expels hazardous iron oxide waste byproducts rich in chloride content. The slow leaching of highly acidic and chloride rich effluents along with toxic heavy metals from iron oxide storage ponds in titanium industries pose a serious threat to the human health and environment. In the Chittoor region near Chavara, there are open ponds which have been used by companies for dumping chemical waste. It has been years since the residents of the region stopped using these drinking water sources as they claim it unfit for drinking. So the present study was done to assess the effectiveness of water quality near the industry. The GIS software was used to perform the spatial extent of pollution mapping around the KMML using the water quality parameters assessed.**

***Keywords*— Groundwater pollutants, industrial pollution, spatial variation**

## 1.INTRODUCTION

Water is essential to all life on Earth. The two main sources of water are groundwater and surface water. Groundwater pollution also called groundwater contamination occurs when pollutants are released to the ground and make their way into groundwater. This kind of water pollution can also happen naturally due to the existence of a tiny and undesired element, contaminant, or impurity in the groundwater. Human health is adversely affected by contaminated groundwater, both short term (causing poisoning, hepatitis and diarrhoea) and long term (causing cancer, skin diseases/ allergies)[1].

On the economic front, groundwater contamination renders the area incapable of supporting plant, human, and animal life and hence affects the standard of living of local population. Groundwater pollution can cause catastrophic environmental impact. The aquatic ecosystem may be altered when the pollutants combine with water bodies. Fish and other aquatic species may perish quickly as a result of too many toxins in water bodies [2].

In this study, Geographic Information System (GIS) is used to obtain spatial variations of various water quality parameters[2]. The specific objectives of the present study includes the estimation of water quality parameters for the samples collected around KMML, assessing the extent of pollution in the area around the industry and the determination of the spatial variation map of various water quality parameter s tested [3]. This is an exclusive study done with the data from the considered study area.

## 2. BACKGROUND OF THE STUDY

Kerala Minerals and Metals Ltd is a public sector enterprise that produces integrated titanium dioxide in Kolam, Kerala, India. In terms of being a strategically significant industry, the mining and processing of rare earth minerals along the coastline of Chavara, Kollam, Kerala has been a significant step towards the nation's self-reliance. However, the serious environmental effects caused by the improper management of the industrial waste from the titanium dioxide ($TiO_2$) pigment producing industry are a cause for concern. This has resulted in the deterioration of groundwater sources, as well as the geo-environmental

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degradation of the surrounding region, which is also a high background radiation location. Since 1922, enormous mineral-rich placer deposits have been mined along the Chavara - Neendakara coastline of Kollam, Kerala. The introduction of a titanium dioxide ($TiO_2$) pigment manufacturing facility in 1984 raised the industry's strategic importance. However, mining operations, as well as the processing of heavy minerals and the production of this pigment resulted in the release of a number of contaminants peculiar to the industry. These contaminants, coupled with the unintentional leakage of tickle, a raw material used for the production of $TiO_2$, from Kerala Minerals and Metals Ltd. (KMML), have resulted in the geo-environmental degradation of the industry's surrounding area within almost a 16 kilometer radius.[5]

The wastes generated by the industry are iron oxide sludge and a slurry comprising metal chlorides in liquid form and un-reacted ore and coke in solid form, which are then pumped and stored in huge settling ponds. The leakage of iron oxide sludge has been caused by a crack in this pond. Due to this as well as the unintentional release of Tickle (titanium tetra chloride, $TiCl_4$) from the storage vessels, the moderately acidic sandy soil (pH ranging from 4.5 to 6.0) that was already present was rapidly turned into extremely acidic soil. People in the region have been suffering from air, land, and water pollution for the past ten years. The signs of land contamination are evident in the total destruction of vegetation as evident in Fig. 1.

Fig 1. Vegetation and soil destruction due to acidic discharge

The wells in the region are also no longer useful for any purposes. Fig. 2 shows a well that has been kept unused as the water has turned unfit for any domestic purposes as well as for watering plants. In addition to land and water pollution, there are frequent gas leaks, which cause residents to be hospitalised. The region has one of India's highest rates of cancer occurrences, and those who live nearby the industrial area frequently experience bronchitis, asthma, cancer, and skin diseases. The air and water quality assessments in this region indicated the pollution [5].

This necessitated the need for analysing the water quality around the KMML area and also to prepare a spatial variation map of water quality in the region.

## 3. METHODOLOGY

### 3. 1 STUDY AREA

The study is carried out in the surrounding areas of Kerala Minerals and Metals Ltd. (KMML) industry in Chavara, Kollam District, Kerala which is located near the National Highway 47 at 8°59' 54.2" N latitude and 76°32' 07.5" E longitude. The KMML industry spans over an area of 210 acres. The western side of KMML is bordered by the Arabian Sea, and the other sides are residential areas with vegetation. The study area is shown in Fig 3. In India, KMML is one of the top producers of titanium dioxide. The rutile grade Titanium dioxide pigment is made by KMML using the chloride method[5].


Fig 2. Study Area

### 3. 2 DATA COLLECTION

After conducting an extensive review of previous research work done in the area, three wards (Mekkadu, Ponmana, and Chittoor) in the Panmana Panchayath were selected for collecting the water samples for testing. It was understood that these wards were the maximum affected by the pollution from KMML. These wards are located in the coastal region of KMML. We collected four samples from Chittoor, three samples each from Mekkadu and Ponmana, and one sample of treated water provided by KMML for the people living around the industrial area.

In the month of February, we collected groundwater samples from 10 wells. We used sterile water bottles to collect 2 litres of water from each sampling station, and we transported the samples to the laboratory on the same day for further analysis

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Fig 3. Unused well due to pollution

| ID | WARD | Lat/ Long | Usage Condition | istance from KMML (km) |
|---|---|---|---|---|
| P1 | PONMANA | 9.008030 / 76.522521 | USING FOR EVERYTHING, NO FILTRATION DONE | 1.287 |
| P2 | PONMANA | 9.0076440 / 76.525888 | NOT USABLE | 0.966 |
| P3 | PONMANA | 9.00852778 / 76.5274722 | NOT USABLE | 1.08KM |
| S1 | TREATED WATER FROM KMML | - | USED FOR DIFFERENT PURPOSES-DRINKIG, BATHING etc. | - |
| C1 | CHITTOOR | 9.0017540/ 76.525166 | HIGHLY CONTAMINATED ACID WATER NOT USED EVEN FOR WETTING PLANTS, CATTLE BATHING etc. | 0.966KM |
| C2 | CHITTOOR | 9.0041480/ 76.52512 | AREA SURROUNDED BY YELLOW ACID.HEALTH PROBLEMS INCLUDING CANCER, SKIN DISEASES,RESPIRATORY DISEASES. | 0.96 KM |
| C3 | CHITTOOR | 9.00552/ 76.523741 | SKIN ALLERGIES,NOT USING WELL WATER FOR ABOUT 12 YEARS | 1.1263 KM |
| C4 | CHITTOOR | 9.0007570/ | WATER USED FOR WASHING PURPOSE | 0.643KM |
| | | 76.529246 | NOT USABLE FOR DRINKING PURPOSE | |
| M1 | MEKKADU | 8.998685/ 76.529246 | FOR GARDENING, WASHING PURPOSE | 0.643 KM |
| M2 | MEKKADU | 8.997437/ | FOR GARDENING ,WASHING PURPOSE | 0.8045KM |

Table 1. Sample collection details

## 3.3LABORATORY TEST OF COLLECTED SAMPLES

To determine the quality of groundwater the following tests were conducted.[4]

1.pH

pH indicates the hydrogen ion concentration in water. It is the negative logarithm of hydrogen ion concentration in water. pH determines how much the liquid solution is acidic or basic. It ranges from 0 to 14.

2.Turbidity

It is the measure with which water losses its transparency due to the presence of total suspended particles. It is measured using turbidimeter. Turbidimeter is used to measure the obstructions due to chemical substances present in water. It is measured in NTU.

3.Acidity

Acidity of water is the quantitative capacity to neutralize a strong waste to designated pH. Strong minerals acids, weak acids such as carbonic and acetic and hydrolysing salts such as ferric and aluminium sulphates may contribute to the measured acidity. According to the method of determination, acidity is important because acid contributes to corrosiveness and influences certain chemical and biological processes. It is the measure of the amount of base required to neutralize a given sample to the specific pH.

4.Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. It is primarily due to salts of weak acids, although weak or strong bases may also contribute. Alkalinity is usually imparted by bicarbonate, carbonate and hydroxide.

5.Chlorides

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If water containing chlorides is titrated with silver nitrate solution, chlorides are precipitated as white silver chloride. Potassium chromate is used as indicator, which supplies chromate ions. As the concentration of chloride ions approaches extinction, silver ion concentration increases to a level at which reddish brown precipitate of silver chromate is formed indicating the end point.

6.Sulphates

The Turbidimetric method of measuring sulphates is based upon the fact that Barium sulphate tend to precipitate in a colloidal form and that this tendency is enhanced in the presence of NaCl-HCl solution containing glycerol and other organic compounds. The absorbance of Barium sulphate solution is measured by a Nephelometer or turbidimeter and the sulphate ion concentration determined by comparison of the reading with a standard curve.

7.Hardness

| Sl no. | Parameters | Acceptable limit | Permissible limit |
|---|---|---|---|
| 1 | pH | 6.5-8.5 | No relaxation |
| 2 | Alkalinity(mg/l) | 200 | 600 |
| 3 | Chloride(mg/l) | 250 | 1000 |
| 4 | Turbidity(NTU) | 1 | 5 |
| 5 | Hardness(mg/l) | 200 | 600 |
| 6 | TDS(mg/l) | 500 | 2000 |
| 7 | Sulphate(mg/l) | 200 | 2000 |
| 8 | Iron(mg/l) | 0.3 | No relaxation |
| 9 | Fluoride(mg/l) | 1 | 1.5 |

Hardness is the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing cations are calcium, magnesium, strontium, iron and manganous ions associated with bicarbonates, carbonates, chlorides and sulphates. The determination of hardness of water is important in assessing its suitability for domestic and industrial use.

8.Total Dissolved Solids (TDS)

It is the weight of residue obtained after a water sample is evaporated to dry state. It includes calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride and sulphate. As per BIS TDS for potable water should be <500 mg/l.

9.Fluoride

Groundwater contains fluoride released from various fluoride bearing minerals mainly as a result of groundwater-host rock interaction. Fluoride greater than 1.5 mg/l in drinking water cause decolouration of teeth.

10. Iron

The most common sources of iron in groundwater are weathering of iron-bearing minerals and rocks. The iron occurs naturally in the reduced $Fe^{2+}$ state in the aquifer, but its dissolution increases its concentration in groundwater.

11. Electrical Conductivity

Electrical conductivity is a measure of ions present in water. The conductivity of a solution increases with the increase in amount of ions. Electrical Conductivity in water is mainly due to the presence of ions like sodium, chloride, calcium, magnesium etc. It is determined by using electrical conductivity metre.. In the agricultural field electrical conductivity plays an important role, because of salinity aspect.

12. Biological Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters and wastewater under controlled conditions of temperature and incubation period. The methodology of BOD test is to compute a difference between initial and final dissolved oxygen of the samples incubation.

## 3.4COMPARISON WITH WATER QUALITY STANDARDS

According to the Indian Standards and Specifications for drinking water (IS 10500:2012), the acceptable and permissible limit of different water quality parameters are listed in the Table 2

Table 2. Acceptable and Permissible limit of different water quality parameters

## 3.5 PREPARATION OF SPATIAL VARIATION MAP

The spatial variation map of different groundwater quality parameters obtained from various sampling stations nearby KMML Chavara was prepared using QGIS. The map shows the intensity of groundwater pollution that is it gives a broad idea about good, moderate and poor groundwater quality zones in the study area. This map offers a more accurate representation of the available groundwater quality in the study area and may be utilised for any groundwater development programme [6].

## 4.Water quality assessment using water quality index

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Water quality index (WQI) is a very useful and efficient method for assessing the quality of water .WQI is also a very useful tool for communicating the information on overall quality of water. WQI is a single unitless number of 100-point scale that provides a pointer to the quality of water source. According to this water quality index, the maximum permissible value is 100. Values greater than 100 indicate pollution and are unfit for human consumption.[5]

Weightage can be determined based on literature review or expert opinion or different mathematical formula.[6] Here weightage is determined based on mathematical formula. Standard value of different water quality parameters are obtained as per IS 10500:2012.[7]

$$WQI = \sum_{i=1}^{n}\sum_{i=1}^{n} W_i Q_i \quad ....(1)$$

Where $W_i$ is the weighting factor for the selected parameter i and given by the equation,

$$W_i = K/S_n \quad ...(2)$$

Where K is the constant of proportionality given by the equation,

$$K = 1/\sum_{1}^{n}\sum_{1}^{n}(\frac{1}{S_n})\frac{1}{S_n}) \quad ...(3)$$

And $S_n$ is the value of water quality standards obtained from IS 10500:2012, $Q_i$ is the quality rating given by equation,

$$Q_nQ_n = 100 \times \frac{(V_{actual}-V_{ideal})\ (V_{actual}-V_{ideal})}{(V_{standard}-V_{ideal})(V_{standard}-V_{ideal})} \quad ...(4)$$

Where $V_{actual}V_{actual}$ = Value of water quality parameter obtained from laboratory analysis

$V_{standard}V_{standard}$ = Value of water quality standards obtained from the standard tables

$V_{ideal}V_{ideal}$ = 0 for all parameters except for pH

$V_{ideal}V_{ideal}$ = 7 for pH

Table 3.Categorisation of water quality for drinking water quality suitability

| Water Quality Index | Water Quality Status |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very Poor |
| >100 | Unfit for consumption |

## 5.RESULTS AND DISCUSSIONS

The various physico-chemical characteristics of water such as pH, turbidity, total alkalinity, total dissolved solids, total hardness, chloride, conductivity, acidity, sulphate, fluoride ,iron etc. were found out. The results obtained were given in table 4.

Table 4. Physico-Chemical characterization of well water

| Sample ID | Turbidity (NTU) | pH | Total Alkalinity (ppm) | TDS (ppm) |
|---|---|---|---|---|
| M1 | 0.38 | 7.918 | 138.79 | 191.6 |
| M2 | 78.4 | 6.839 | 75.52 | 159.8 |
| M3 | 0.3 | 7.849 | 126.54 | 241.2 |
| P1 | 1.81 | 7.477 | 179.61 | 1446 |
| P2 | 29.3 | 6.983 | 46.94 | 123.8 |
| P3 | 17.11 | 7.297 | 114.3 | 235.1 |

| | | | | |
|---|---|---|---|---|
| C1 | 24.3 | 7.89 | 93.89 | 283.1 |
| C2 | 0.74 | 7.915 | 187.77 | 355.3 |
| C3 | 4.48 | 7.882 | 465.35 | 790.5 |
| C4 | 0.52 | 7.837 | 48.98 | 85.78 |

| Sample ID | Total Hardness (ppm) | Chloride (ppm) | Conductivity (µS/cm) | Acidity (ppm) |
|---|---|---|---|---|
| M1 | 140 | 9.71 | 336.2 | <5 |
| M2 | 80 | 21.35 | 280.5 | 25.01 |
| M3 | 150 | 27.17 | 423.3 | <5 |
| P1 | 400 | 873.45 | 2537 | 7.7 |
| P2 | 54 | 21.35 | 217.2 | 18.28 |
| P3 | 100 | 33 | 412.5 | 7.7 |
| C1 | 156 | 62.11 | 496.8 | <5 |
| C2 | 202 | 64.05 | 623.5 | < 5 |
| C3 | 276 | 124.22 | 1387 | <5 |
| C4 | 46 | 15.53 | 150.5 | <5 |

| Sample. No. | Sulphate (ppm) | Fluoride (ppm) | Iron (ppm) |
|---|---|---|---|
| M1 | 4.67 | 0.07 | 0.06 |
| M2 | 23.88 | <0.01 | 3.57 |
| M3 | 14.86 | 0.36 | 0.06 |
| P1 | 56.15 | 0.39 | 0.28 |
| P2 | 17.72 | <0.01 | 2.73 |
| P3 | 34.42 | 0.07 | 2.48 |
| C1 | 7.08 | 0.01 | 2.58 |
| C2 | 19.57 | 0.25 | 0.08 |
| C3 | 46.52 | 0.34 | 0.55 |
| C4 | 1.47 | 0.08 | 0.03 |

Based on the laboratory results the quality of water was analysed using the water quality index method. The status of excellent was obtained for M1 and S1, where S1 is treated water provided by the KMML to the people residing around the industry. M2, M3, C4 is of good quality but C1, C2, C3, P1, P2, P3 were unfit for consumption.

Table 5. Analysis based on water quality index

| Sample station | WQI | Water quality status |
|---|---|---|
| M1 | 18.89 | Excellent |
| M2 | 35.96 | Good |
| M3 | 26.47 | Good |

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| | | |
|---|---|---|
| S1 | 20.30 | Excellent |
| C1 | 969.65 | Unfit for consumption |
| C2 | 2158.16 | Unfit for consumption |
| C3 | 174.38 | Unfit for consumption |
| C4 | 28.34 | Good |
| P1 | 100.11 | Unfit for consumption |
| P2 | 1090.04 | Unfit for consumption |
| P3 | 817.71 | Unfit for consumption |

## 6. Spatial Variation Map

Spatial analysis allows to solve complex location-oriented problems and better understand where and what is occurring in your world. It goes beyond mere mapping to let you study the characteristics of places and the relationships between them.

The result analysis is shown below for each parameters:

### a)Acidity

The acidity value ranges from 25.01 mg/L to less than 5 mg/L.

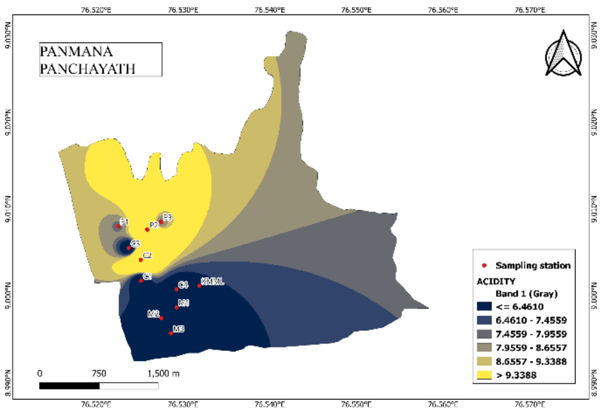


Fig. 4. Spatial variation map of acidity

### b)Chloride

The chloride value of the samples ranges from 9.71mg/L to 873.45 mg/L. The maximum acceptable limit is 250 mg/L as per IS 10500-2012. The chloride value is higher in sample well P1.

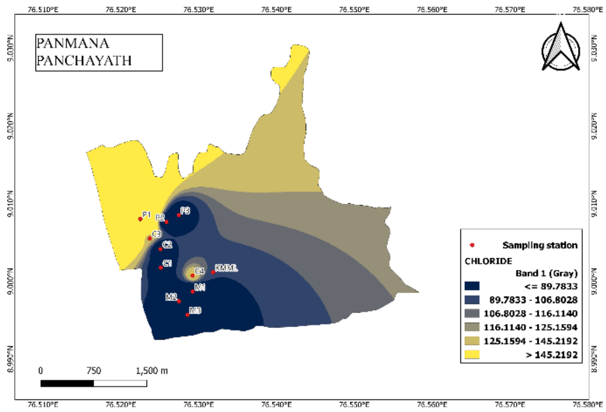


Fig. 5. Spatial variation map of chloride

### c)Electrical Conductivity

The conductivity value of the samples ranges from 150.5 to 1387 .

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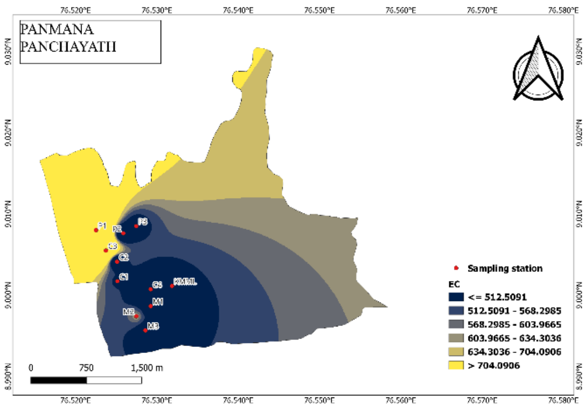


Fig.6. Spatial variation map of Electrical conductivity

d)Fluoride

The fluoride concentration of the samples ranges from 0.39 to less than 0.01. The maximum acceptable limit of fluoride is 1 mg/L as per IS 10500-2012. Hence the fluoride concentration is within the limit for all the water samples.

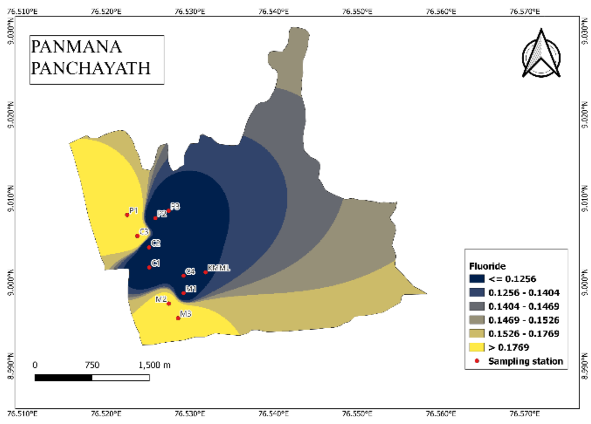


Fig. 7. Spatial variation map of Fluoride

e)Iron

The iron concentration of the samples varies from 0.03 mg/L to 3.57 mg/L. The maximum acceptable limit of iron in drinking water is 0.3 mg/L as per IS 10500-2012. Hence the iron concentration is higher in sample wells M2, P2, P3, C1, C3.

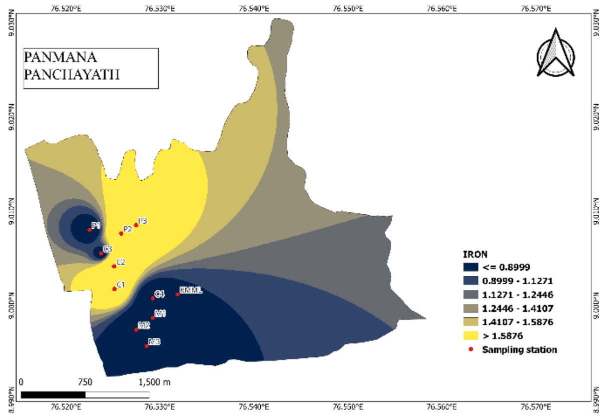


Fig. 8. Spatial variation map of Iron

f)Sulphate

The sulphate value of the samples ranges from 1.47 mg/L to 56.15 mg/L. The maximum acceptable limit of sulphate is 200 mg/Las per IS 10500-2012. Hence the sulphate concentration is within limit for all the samples.

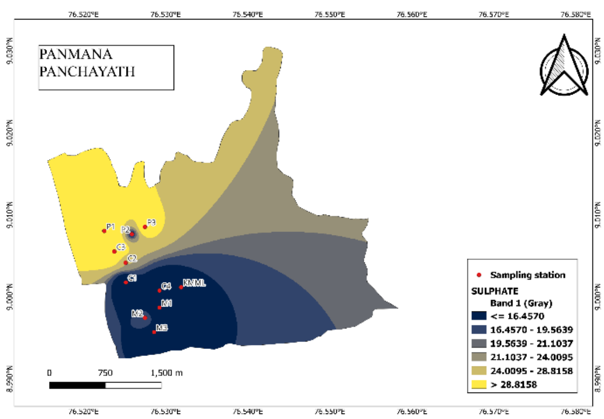


Fig. 9. Spatial variation map of Sulphate

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## g)Total Dissolved Solids

The total dissolved solids value ranges from 85.78 mg/l to 1446 mg/l. The maximum acceptable limit is 500 mg/l as per IS 10500-2012. Its value is higher in sample wells P1 and C3.

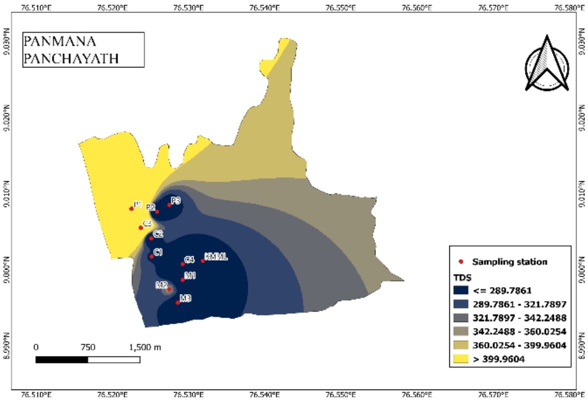


Fig. 10. Spatial variation map of TDS

## h)Total Alkalinity

The total alkalinity ranges from 46.94 ppm to 465.35 ppm. The maximum acceptable limit is 200 mg/L as per IS 10500-2012. Total alkalinity is high in sample well C3.

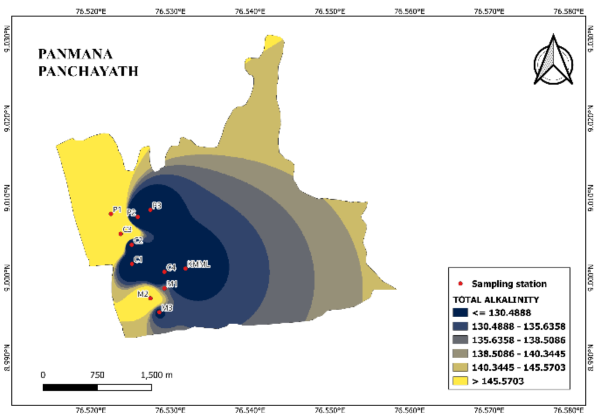


Fig. 11. Spatial variation map of Total alkalinity.

## i)Total Hardness

The total hardness ranges from 46 mg/L to 400 mg/L . The maximum acceptable limit is 200 mg/L as per IS 10500-2012. . Its value is higher in sample wells P1, C2 and C3.

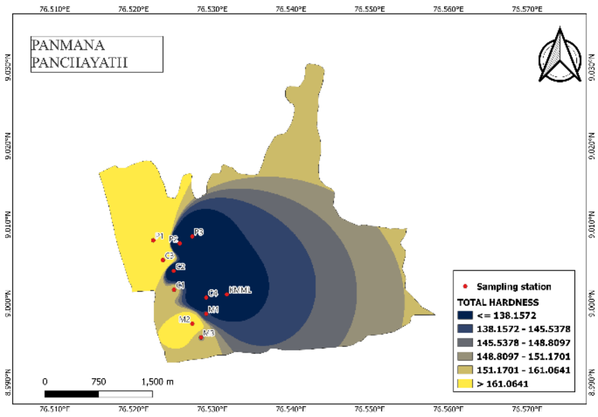


Fig. 12. Spatial variation map of Total Hardness

## j) Turbidity

The turbidity value ranges from 0.3 NTU to 78.4 NTU. The maximum acceptable limit is 1NTU as per IS 10500-2012. Turbidity is high in sample wells M2, P1, P2, P3, C1, C3

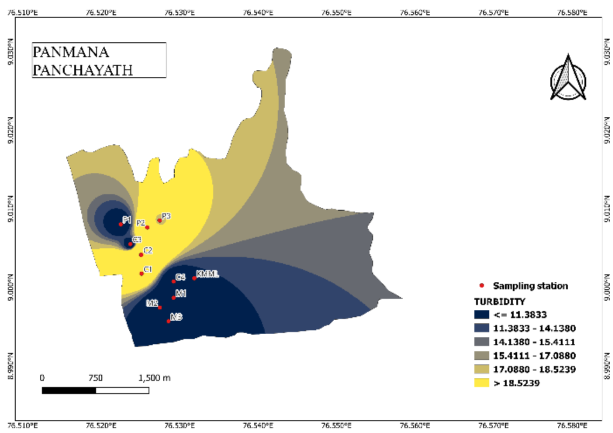

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Fig. 13. Spatial variation map of Turbidity

## k) pH

The pH variation is shown in above table 3.It ranges from 7.918 to 6.839. The sample wells M2 and P2 shows slightly acidic nature and all other samples shows alkaline nature.

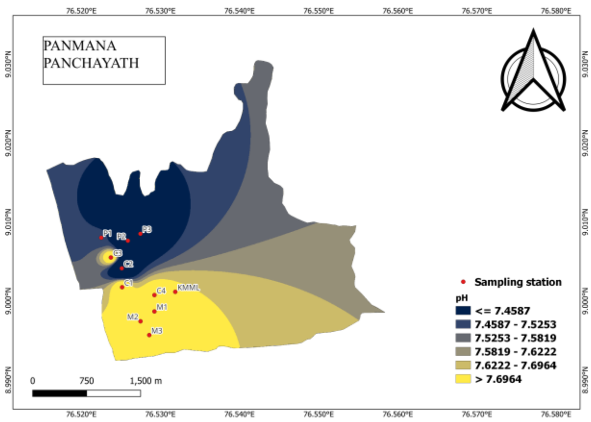


Fig 14. Spatial variation map of pH

## 7.CONCLUSION

The study was conducted to assess the ground water quality around KMML, Chavara, Kollam by testing various water quality parameters such as pH, chloride, iron, hardness, fluoride , sulphate etc. On analysing the results using water quality index it is found that majority of the groundwater samples were unfit for consumption. The result analysis using spatial variation map reveals that the samples were unfit for consumption except the samples from M1, M3,C4 as the water quality parameters are within the acceptable limit for these stations.

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