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Spatial Interpolation Technique For Groundwater Quality Assessment Of District Anantnag J&K

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Abstract:- Groundwater is used for a variety of purposes, including irrigation, industrial, drinking, and manufacturing. Assessment and mapping of quality of groundwater is an important because the physical and chemical characteristics of groundwater determine its suitability for agricultural, industrial and domestic usages. Geographic information system (GIS) is an efficient and effective tool in solving problems where spatial data are important. Geographical Information System (GIS) can be an effective and powerful tool for mapping, monitoring, modelling and assessing water quality, detecting environmental change, determining water availability, preventing flooding and managing water re-sources on a local or regional scale. In the present study an attempt has been made to study the Spatial variations in ground water quality in the four tehsils namely Anantnag, Bijbehara, Dooru and Kulgam of Anantnag district of South Kashmir. For achieving this spatial interpolation technique namely Inverse Distance Weighed (IDW) has been put to use to estimate the spatial distribution of the ground water quality parameters. In the present study, water samples were collected from 92 locations. The water samples were analysed for physico-chemical parameters like pH, TH, Ca, Mg, Fe, F, SO_4, NO_3, K, Cl and Na using standard techniques in the laboratory by the Department of Public Health Engineering Srinagar (PHE) and Central Groundwater Board Jammu (CGWB) and compared with the standards. The ground water quality information maps of the entire study area have been prepared using GIS spatial interpolation techniques for all the above parameters. The results obtained in the study and the spatial database established in GIS will be helpful for monitoring and managing ground water pollution in the study area. Mapping was coded for Potable with Desirable Limits, Potable with Permissible Limits and Non-potable in terms of water quality as per the BIS standards for water quality. The study holds significance keeping in view the pollution in ground water sources of the study area and will be helpful in pin-pointing the areas were this pollution has reached to the level which is not only harmful for living humans but as well as for animals.

Keywords:- IDW, Interpolation, Groundwater, GIS

I. INTRODUCTION

The continuous circulation of water between ocean, atmosphere, and land is called the hydrologic cycle. The hydrologic cycle can be viewed as a major machine on the planet, controlling distribution of water on the earth. Groundwater is one of the major links in the hydrologic cycle. Groundwater forms the invisible, subsurface part of natural hydrological cycle. Inflow to the hydrologic system arrives as precipitation, in the form of rainfall or snowmelt. Outflow takes place as stream flow or runoff and as evapo-transpiration, a combination of evaporation from bodies of water, evaporation from soil surfaces, and transpiration is delivered to streams both on the land surface, as overland flow tributary channels; and by subsurface flow routes, as inter flow and base flow following infiltration into the soil (Freeze & Cherry, 1979).

Excluding the freshwater that is locked up in the form of polar ice caps and glaciers, about 97 percent of the world's freshwater exist in aquifers. Although humans have long known that much water is contained underground, but it is only in the recent decades that scientists and engineers have learned to estimate how much groundwater is stored underground and its vast potential (U.S. Geological Survey [USGS], 1999). In India, most of the population is dependent on groundwater as the only source of drinking water supply (NIUA, 2005; Mahmood and Kundu, 2005; Phansalkar et al., 2005). Groundwater is water that is found under-ground in the cracks and spaces in soil, sand and rock. Groundwater is stored in--and moves slowly through layers of soil, sand and rocks called aquifers. Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone. These materials are permeable because they have large connected spaces that allow water to flow through. The depth of the water table below the surface varies depending on topography and climate. In humid or semiarid areas, the water table is usually anywhere from 0 to 50 feet below ground surface. In some desert environments, the water table may be hundreds of feet below the surface

The present study has been carried out in district Anantnag. Using the available physio-chemical data of 92 locations (Fig.2) of the various tehsils of district anantnag, in additions to this data ancillary data was collected from respected field departments and agencies. The ancillary data which was collected from the field agencies were assigned GPS coordinates in the excel. Further analysis of the data was done using the various spatial interpolation techniques viz: IDW interpolation in GIS environment using the Arc Map software. The results gave the detailed water quality map of the district as well as analysed the various physio-chemical properties and their influence on the ground water of the district. The study holds significance keeping in view the continuing deteriorating state of water quality in the district.

II. STUDY AREA

Anantnag district is southernmost district of Kashmir valley separated from the Jammu Province by the mighty Pir- Panjal Range & connects both the regions by the famous Jawahar Tunnel. The district with its headquarters at Anantnag forms the southern part of Kashmir valley and is located between 33°17'20" and 34°15'30" North latitude and between 74°30'15" and 74°35'00" East longitude.

The district is also famous for Holy Amarnath Cave situated in Pahalgam tehsil where Lacs of pilgrims visit every year from all over the country. A Kashmiri Muslim family discovered the cave.

The district has a total geographical area of 3,984 sq km, comprising of 605 villages (605 inhabited). Administratively, the district is divided into 05 tehsils (Anantnag, Kulgam, Bijbehra, Pahalgam & Dooru) and 12 blocks (Achabal, Breng, Dachnipora, D. H. Pora, Kulgam, Khovripora, Qazigund, Qaimoh, Shahabad, Shangus, Devsar & Pahloo).

As per 2001 census, the district has a population of 11,70,013 persons with density of population 294 persons per sq. km. The male and female population in the district is 6,08,640 and 5,61,373 respectively with a male/female sex ratio of 922.

The main source of irrigation is canals and an area of 73,582 hectares is brought under irrigation by various sources like canals, tanks, wells and other sources. A sizeable part of the cultivated area of the district is not having the assured irrigation facilities and the agriculturists have to depend on the vagaries of weather.
Central Ground Water Board has carried out extensive hydro geological studies both by conventional and non-conventional methods in the district. Under Ground Water Exploration, 15 exploratory wells have been drilled ranging in depth from 19.50 m to 300.29 m. CGWB monitored 10 NHS, which were regularly monitored up to the year 1989 where ground water levels, fluctuations and quality were monitored.

The climate of the district is Temperate cum Mediterranean type. In the higher reaches the temperature remains cold throughout the year. Average minimum and maximum temperature varies from –11°C to 33°C. The district forms part of the Jhelum sub basin of Indus basin. River Jhelum is the major river, originating at the place Verinag, with its tributaries viz., Lidder, Vishav, and Sandarn Rivers drains the area. Soil is poor in hilly areas and fertile in plain areas. Productivity in higher ranges is poor while in central regions is fertile. The rock formations underlying the district range in age from Cambrian to Quaternary

Hydro-geologically, the district is divided into two distinct and well-defined aquifer systems, viz., hard rock or fissured aquifer constituted mainly by semi-consolidated to consolidated rock units and soft sedimentary or porous aquifer constituted mainly by unconsolidated sediments. The fissured formation includes the semi-consolidated to consolidated rock formations exposed in the district are igneous, metamorphic and sedimentary origin. These forms low and high hill ranges throughout the district. Fractured and jointed igneous, metamorphic rocks and the scree/talus deposits in the foothills form low to moderate potential aquifers with poor to moderate yields. Occurrence and movement of the ground water is mainly controlled by secondary porosity originated due to fracturing and faulting and related tectonic disturbances and weathering. Ground water oozes in the form of springs, seepages in the hilly areas and is utilizing for domestic purposes. There are numerous springs in the district generally concentrated along the contact zones and also in the hilly area. At some places shallow hand pumps and tube wells are constructed for ground water development. The yield of the shallow tube wells and hand pumps constructed along these secondary porous zones varies from 0.5 to 3.0 lps. The study area is shown in Fig.1.

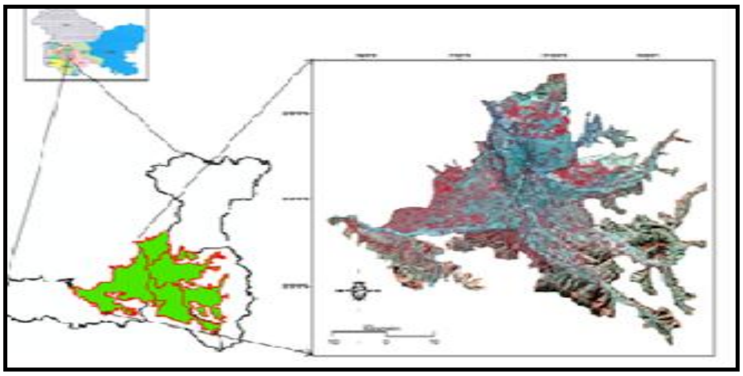

Fig. 1: Location of the study area

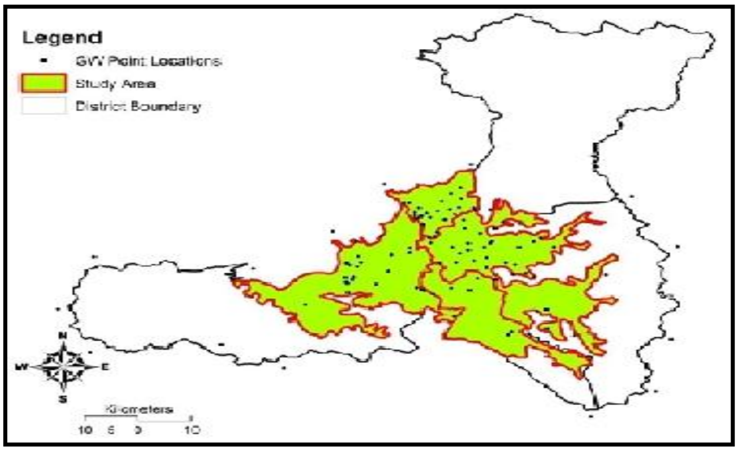

Fig.2: Distribution of Ground water points

III. METHODOLOGY ADOPTED

In order to carry out the research the groundwater ancillary data containing various water quality parameters such as pH, and other physio-chemical parameters like concentration of Na, Fe, SO_4, NO_3 etc were collected from the department of the Public Health Engineering Srinagar and central groundwater board Jammu. Later field work to various locations was organised to collect the co-ordinates (lat/long) of the locations of the ancillary data, with the help of Global Positioning System (GPS) pertaining to the water quality parameters collected from the two respective departments.

The further step was to digitized groundwater ancillary data using the MS Excel and assigning of GPS locations to each points which was otherwise without locations for the creation of the database Then the groundwater ancillary data and the spatial data (co-ordinates) which were collected with the help of GPS were joined in the ArcGIS 9.2 software After linking the spatial and non-spatial data the groundwater quality point layer was generated for further analysis. Later on the other analysis was carried out using the IDW (Inverse Distance Weighted) Interpolation in Geographic information system environment using the Arc Map soft-ware. Interpolation creates a continuous (or prediction) surface from sampled point values. The continuous surface representation of a raster dataset represents height, concentration, or magnitude—for example, elevation, pollution, or noise. Interpolation makes predictions from sample measurements for all locations in a raster dataset whether or not a measurement has been taken at the location. In the present data analysis we used IDW (Inverse distance weighted) interpolation technique. Inverse Distance Weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight; it has in the averaging process, the overall methodology adopted is shown in Fig.3 below.

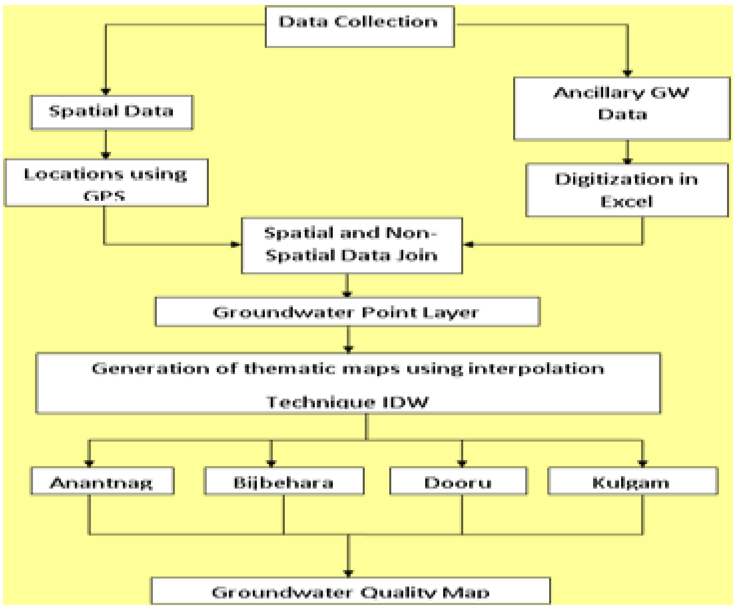

Fig.3: Methodology

IV. RESULTS AND DISCUSSIONS

The interpolation technique viz; IDW, was chosen for studying the influence of each and every physio-chemical property of the ground water in the district Anantnag and accordingly the maps generated shows the amount of these parameters present in the ground water, and the results showed the allowable limits of these parameters as per the BIS (bureau of Indian standards) the maps of the following physio-chemical properties were generated using these interpolation techniques:

1. pH.

pH is the measurement of the hydrogen ion concentration, [H+]. Every aqueous solution can be measured to determine its pH value. This value ranges from 0 to 14 pH. Values below 7 pH exhibit acidic properties. Values above 7 pH exhibit basic (also known as caustic or alkaline) properties. Since 7 pH is the center of the measurement Scale, it is neither acidic nor basic and is, therefore, called "neutral."

In the study area the pH ranges from 6.2 to 8.9. When inverse distance weighted interpolation technique was applied to generate the map of pH, it was found that Sond village of Anantnag tehsil has the highest pH with 8.3pH, which as per BIS standards the water exceeds the permissible limits. The generated map is show in Fig.4 below.

2. TH

Total Hardness of water is primarily the amount of calcium and magnesium, and to a lesser extent, iron in the water. Water hardness is measured by adding up the concentrations of calcium, magnesium and converting this value to an equivalent concentration of calcium carbonate ($CaCO_3$) in milligrams per litre (mg/L) of water. Water hardness in most groundwater is naturally occurring from weathering of limestone, sedimentary rock and calcium bearing minerals. Hardness can also occur locally in groundwater from chemical and mining industry effluent or excessive application of lime to the soil in agricultural areas.

In the study area the total hardness was found ranging from 14 to 610. The following map Fig.5 generated from IDW (Inverse Distance Weighted Interpolation) results show that the total hardness ranges from 14 to 610 .The highest value of total hardness 610 was found at the Katriteng in the Bijbehara tehsil. As per the BIS water quality standards the value exceeds the permissible limits.

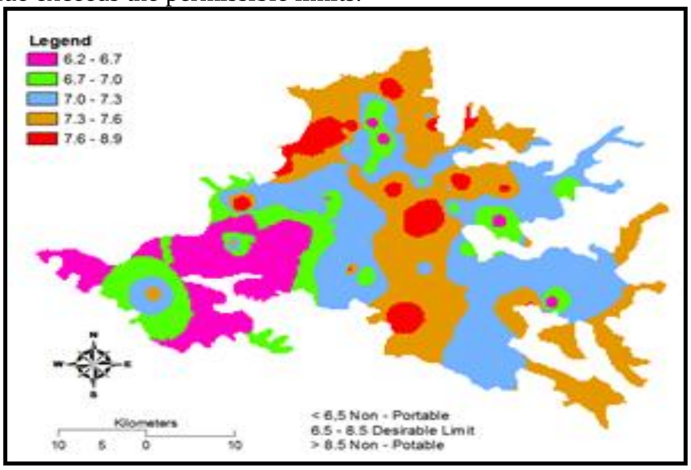

Fig. 4: pH Map

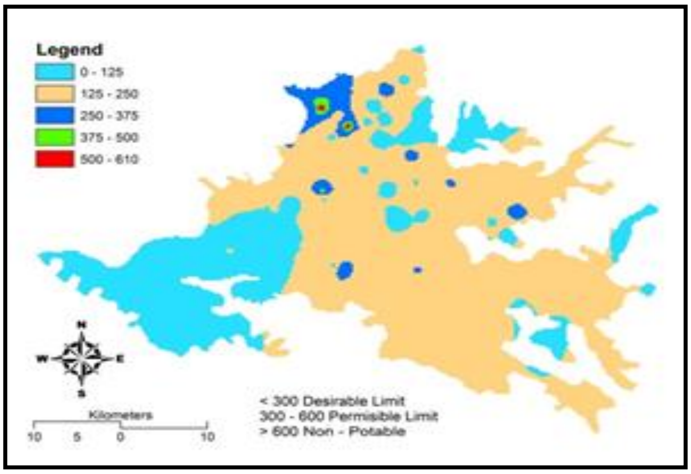

Fig. 5: Total Hardness Map

3. Sulphates

Sulphates (SO_4) can be found in almost all natural water. The origin of most sulphate compounds is the oxidation of sulfite ores, the presence of shales, or the industrial wastes. The Principle source of sulphates in groundwater is from evoporite minerals, gypsum and anhydrite. In the present study area the Sulphates concentration ranges from the 0.01 to 104. Interpolation results for sulphates Fig.6.

The result shows that the Sulphates range from 0.01 to 102. The highest value 102 was found at the Bota Tachloo in the Kulgam Tehsil. The concentration was under desirable limits. As per the BIS standards the sulphates the sulphates range is under desirable limits.

4. Nitrates

Nitrate is a chemical compound of one part nitrogen and three parts oxygen (NO_3). It is the most common form of nitrogen found in water. Nitrate is usually introduced into groundwater through widespread or diffuse sources, commonly called non-point sources, which can be hard to detect. These sources can include leaching of chemical fertilizers leaching of animal manure, Groundwater pollution from septic and sewage discharges. Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern because it can harm infants by reducing the ability of blood to transport oxygen. In babies, especially those under six months old, methemoglobinemia, commonly called "blue-baby syndrome" can result from oxygen deprivation caused by drinking water high in nitrate. Death can occur in extreme cases.
In the present study area the Nitrates ranges from the 0.1 to 20 Fig.7.

Inverse Distance Weighted Interpolation Technique. The results show that the Nitrates range from the 0.1 to 20.As per the BIS standards the range is under desirable limits for the whole study area.

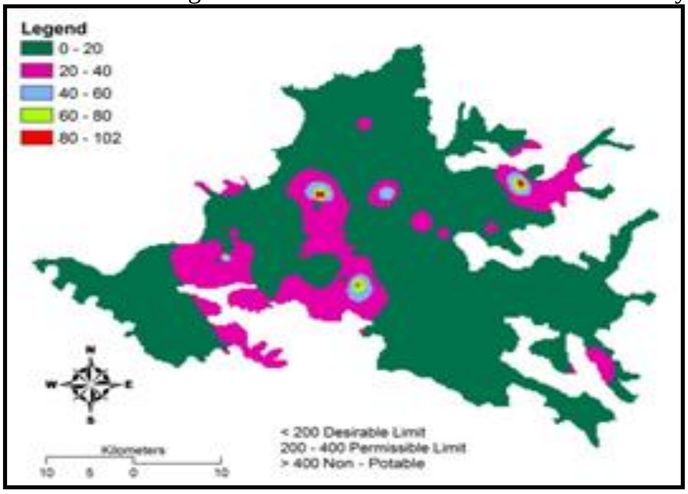

Fig.6: Total Sulphates Map

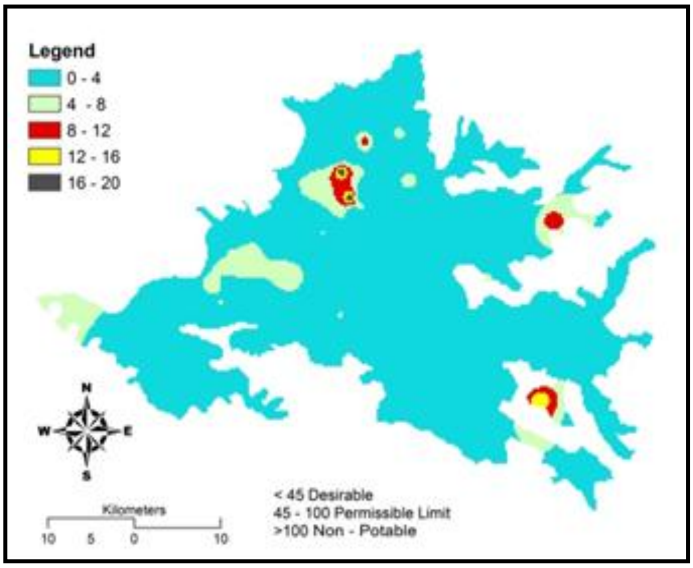

Fig. 7: Nitrates Distribution Map

5. Iron.

Iron is a common constituent in soils and groundwater. It readily participates in subsurface redox reactions and under some conditions can cause problems with groundwater remediation systems. Iron is generally derived from minerals contained within the underlying bedrock. Limestone, shale, and coal which often contain the iron-rich mineral pyrite, are large contributors of iron. Acidic rainwater releases iron ions into solution. Iron-bearing groundwater is often noticeably orange in colour, causing discoloration of laundry, and has an unpleasant taste, which is apparent in drinking and food preparation.

In the present study area the iron ranges from the 0.0001 to 7 Fig.8.

Inverse Distance Weighted Interpolation Technique: The results show that total iron value ranges from the 0.0001 to 7. As per the BIS standards the iron has exceeded the Permissible limits in the following areas 7 in the Damhal in the Dooru tehsil , 1.3 in Naushaher , 1.2 in Katriteng , 1.37 in the Thokerpora in the Bijbehara tehsil, 1.3, 1.6, and 3 in Lalan, Khandipher and Pushur in the Anantnag Tehsil.

6. Fluorides.

Fluoride is a chemical that occurs naturally within many types of rock. Fluoride is a naturally occurring toxic mineral present in drinking water and causes yellowing of teeth, tooth problems etc. Fluoride can also come from Runoff and infiltration of chemical fertilizers in agricultural areas, Septic and sewage treatment system discharge in communities with fluoridated water supplies, Liquid waste from industrial sources.

In the present study area the Fluorides Ranges from 0.002 to 2.5 Fig.9.

Inverse Distance Weighted Interpolation Technique. The results show that fluoride ranges from the 0.002 to 2.5. The highest value 2.5 was found at the Thokerpora in the Bijbehara tehsil. The rest of the study area has the con-centration under the desirable limits.

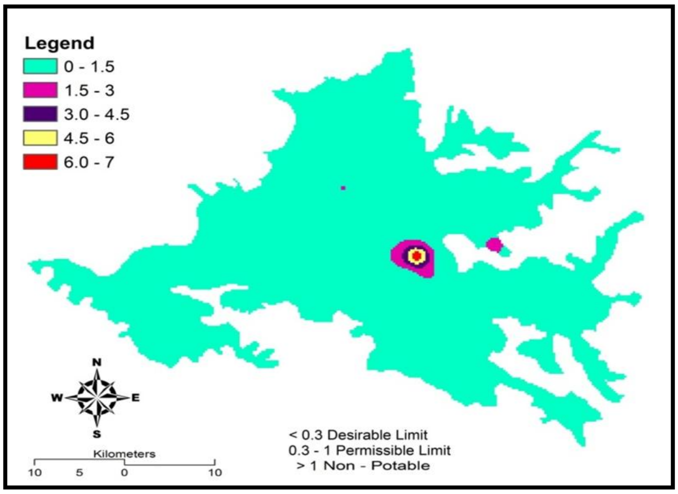

Fig. 8: Iron Distribution Map

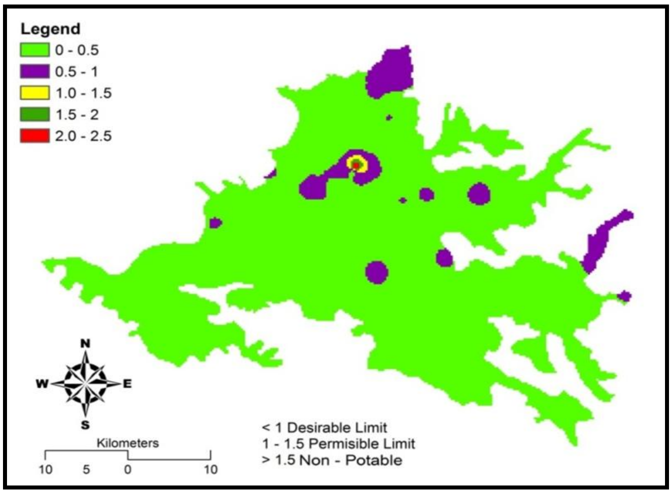

Fig.9: Fluorides Distribution Map

7. Calcium.

Calcium the most natural substance of natural water is calcium, being dominant in most of the minerals. Calcium is the fifth most abundant natural element, and magnesium the eighth. Both elements are present in all natural waters. In natural waters its concentration ranges from 10- 100 mg/l depending upon the rock type. Disposal of sewage and industrial wastes are important sources of calcium. At lower pH, calcium occurs as soluble $Ca(HCO_3)_2$. Calcium may block the absorption of heavy metals in the body and is thought to increase bone mass and prevent certain types of cancer. Very high concentrations of calcium may adversely affect the absorption of other essential minerals in the body.

In the present study area the calcium ranges from the 0.1 to 127 Fig.10.

Inverse Distance Weighted Interpolation Technique. The results show that calcium ranges from the 0.1 to 127. The highest value 127 was found at the Rambelpur in the Anantnag tehsil. The whole study area has the concentration of calcium under the desirable limits as per the BIS standards.

8. Chlorides.

Chloride (Cl) is one of the major inorganic anions in water and wastewater. The Cl content normally increases as the mineral content increases. It is generally in the form of sodium, potassium, and calcium salts. In many areas, the level of chlorides in natural waters is an important consideration in the selection of supplies for domestic, industrial, agricultural use. Chloride‘s source in groundwater may be seawater, evaporates, precipitation and atmosphere.

In the present study area the chlorides range from 0.03 to 184.3 Fig.11.

Inverse Distance Weighted Interpolation Technique. The results show that chlorides range from the 0.03 to 184.3. The highest value 184.3 was found at the Soput in the Kulgam tehsil. As per the BIS Standards the whole study area has the concentration of chlorides under the desirable limits.

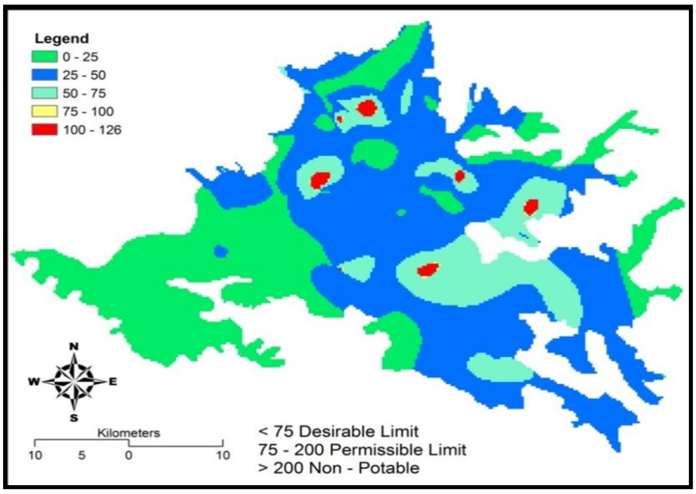

Fig.10: Calcium Distribution Map

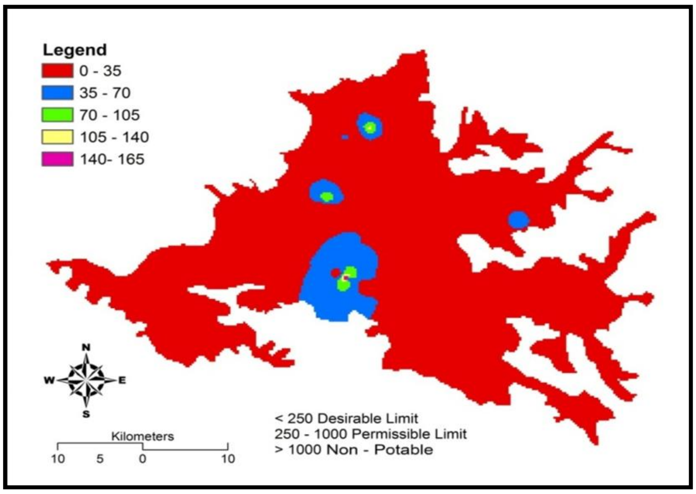

Fig.11: Chlorides Distribution Map

9. Magnesium

All waters contain magnesium but in lesser concentration than calcium, sewage and industrial wastes are important contributors of magnesium. Natural softening of water occurs during percolation through soil by exchange with sodium ions. Like calcium, magnesium is also important element for human metabolism. Magnesium is an essential element in cardiac and vascular functions, but in drinking water may have a laxative effect, particularly with magnesium sulphate concentrations above 700 mg/l. However, the human body tends to adapt to this laxative effect with time.
In the present study area the magnesium ranges from 0.1 to 75 Fig.12.
Inverse Distance Weighted Interpolation Technique. The results show that magnesium ranges from the 0.1 to 75. The highest value 75 was found at the Wopazan in the Bijbehara tehsil and Bota Tachloo having the value 36.6. As per the BIS standards the range exceeds the desirable limits and is under permissible limits. The rest of the study area has the concentration of magnesium under desirable limits.

10. Sodium

It is also important naturally occurring cation in all waters but having lesser concentration than magnesium and calcium, its major source is silicate weathering from various rocks. Sodium is the sixth most abundant element on Earth and is widely distributed in soils, plants, water and foods. Most of the world has significant deposits of sodium-containing minerals, most notably sodium chloride (salt). Sodium is an essential nutrient and adequate levels of sodium are required for good health. However, too much sodium is one risk factor for hypertension (high blood pressure). Other risk factors for hypertension include family history and being overweight.
In the study area the sodium ranges from 0.001 to 53.6 Fig.13.

Inverse Distance Weighted Interpolation Technique. The results show that the sodium ranges from the 0.001 to 53.6 .the highest value 53.6 was found in the Maliknag in the Anantnag tehsil. As per the BIS standards the sodium range exceeds that the desirable limits. The rest of the study area has the concentration of sodium under the desirable limits.

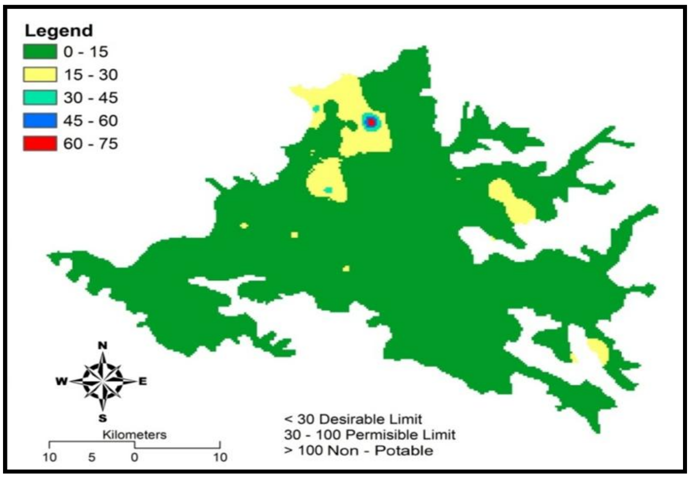

Fig.12: Magnesium Distribution Map

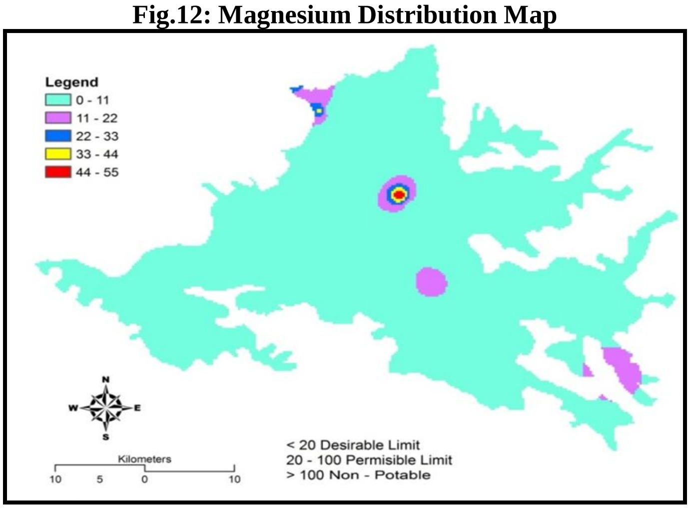

Fig.13: Sodium Distribution Map

11. Potassium

Potassium is slightly less abundant than sodium and similar in behaviour to sodium. Potassium is an important naturally occurring cation in all waters; it is added to the groundwater mainly by fertilizers and other agricultural wastes. Potassium occurs in various minerals, from which it may be dissolved through weathering processes. Examples are feldspars (orthoclase and microcline), which are however not very significant for potassium compounds production, and chlorine minerals carnalite and sylvite, which are most favourable for production purposes. Some clay minerals contain potassium. It ends up in seawater through natural processes, where it mainly settles in sediments.

In the present study area the potassium ranges from the 0.0015 to 6.8 Fig.14.

Inverse Distance Weighted Interpolation Technique results show that potassium ranges from the 0.0015 to 6.8 .the highest values 6.8 was found at the Maliknag in the Anantnag tehsil. As per the BIS standards the study area has the potassium range is under desirable limits.

By analysing and interpreting the above mentioned water quality parameters the results for the whole study area were classified as per BIS standards into Portable water with desirable limits, Portable water with Permissible limits and Non-Portable water, using the Inverse Distance Weighted interpolation

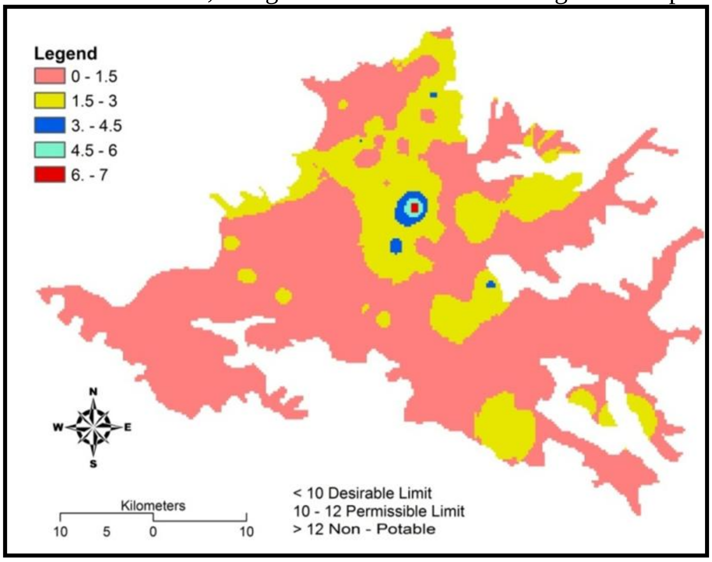

Fig.14: Potassium Distribution Map

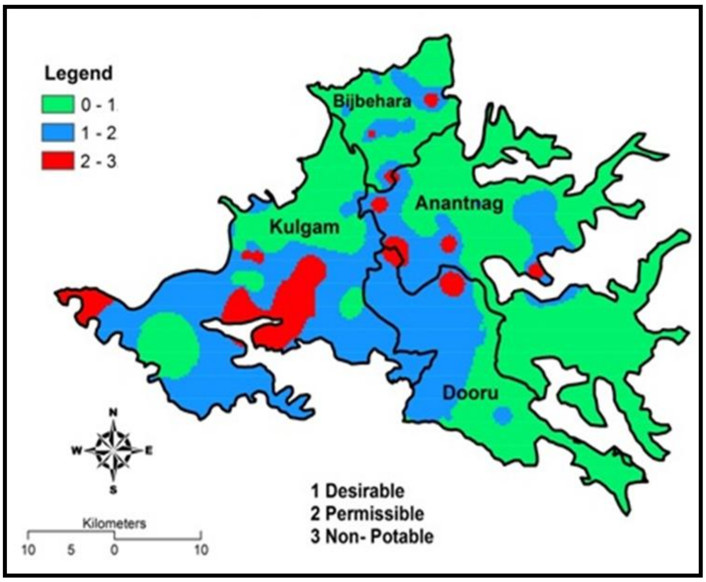

Fig.15: Water Quality Map

The groundwater Quality maps prepared based on GIS inverse Distance Weighted technique is shown in the Fig.15. The Quality zones are represented in terms of following zones:

- Potable with Desirable Limits
- Potable with permissible Limits
- Non- Potable

V. CONCLUSIONS

Groundwater is one of the most valuable natural re-sources, which supports human health, economic development and ecological diversity. Groundwater is a valuable dynamic and replenishable natural resource in present day and limited in extent. GIS is one of the most important tools for integrating and analysing spatial information from different sources or disciplines. It helps to integrate, analyse and represent spatial information and database of any resource, which could be easily used for planning of resource development, environmental protection and scientific researches and investigations. Although its importance is widely known and implemented in many countries in the world, in India especially in our Jammu & Kashmir State except some applications for specific projects it is not well implemented for planning, resource management and environmental protection at a national or regional levels.

GIS can be used as an effective tool for water quality mapping and land cover mapping essential for monitoring, modelling and environmental change detection. Monitoring of pollution patterns and its trends with respect to urbanization is an important task for achieving sustainable management of groundwater. The spatial distribution analysis of groundwater quality in the study area indicated that many of the samples collected are not satisfying the drinking water quality standards prescribed by the BIS. The overall results obtained from Inverse Distance Weighted interpolation technique showed that in the study area, most area falls under the Potable with Desirable Limits followed by the Potable with Permissible Limits and Non-Potable as per the BIS standards for water quality because in this technique the results are not greater than the highest and less than the lowest input value. The Inverse Distance Weighted Interpolation technique is based on the principle of linear combination of known points, weighted inversely by distance. One of the advantages of this technique it is easy to use and works well with noisy data but the disadvantage of this technique is that spatial arrangement of samples does not affect weights. The best suited scenario for this technique is moderately dense sampling with regard to local variation.

The results obtained gave the necessity of making the public, local administrator and the government to be aware on the crisis of poor groundwater quality prevailing in the area. The government needs to make a scientific and feasible planning for identifying an effective ground-water quality management system and for its implementation. For this, public awareness on the present quality crisis and their involvement and cooperation in the actions of local administrators are very important. Since, in future the groundwater will have the major share of water supply schemes, plans for the protection of groundwater quality is needed. Present status of groundwater necessitates for the continuous monitoring and necessary groundwater quality improvement methodologies implementation.

VI. RECOMMENDATIONS

Following recommendations are proposed in light of the present study on the ground water resources, and needs to be taken for preventing futher deterioration and strategy for there protection for future generations.

1. In valley areas, in addition to the traditional ground water structures like dug wells and springs, shallow to medium depth tube wells can be constructed for developing the ground water resources. Ground water resources can also be developed by constructing infiltration galleries (Percolation wells).
2. In hilly terrain, springs and perennial nallahs are the major sources of water. Medium to shallow bore holes and hand pumps are useful ground water structures for meeting the domestic needs.
3. Monitoring of water levels and chemical quality at representative areas is required to keep a watch on any ad-verse effect that ground water development may have in future.
4. Traditional resources like springs need to be revived, developed & protected on scientific lines for various use. The discharge of such springs can be sustained by construction of small check dams or subsurface dykes across the nallahs/tributaries in the downstream at favourable locations.
5. Small ponds/tanks can be utilized for recharging ground water. These structures can be constructed for harvesting water and utilized for both recharging and meeting the domestic needs.
6. Roof top rainwater harvesting practices must be adopted in hilly areas since the district receives precipitation in the form of snow and rain programme.
8. Quantifying the domestic sewage that enters into the different water bodies located in the city, will help in planning for effective sewage treatment plant and minimizing groundwater pollution by sewage.
9. Identification of groundwater recharging locations and structures. For this purpose, Geographical Information System (GIS) with the required spatial and non-spatial data can be used very well as the tool. Designing recharging structures is to be done.
10. Groundwater recharging structures are to be formed at different parts of the city. Formation of storm water drains leading to groundwater recharging structures, to increase their recharging potentials.
11. Continuous monitoring of groundwater table level along with quality study will minimize the chances of further deterioration.

The role of the Geographic Information Science in this part of the world is still in its infancy stage. For the proper resource management, although its importance is widely known and implemented in many countries in the world, in India especially in our Jammu & Kashmir State except some applications for specific projects it is not well implemented for planning, resource management and environmental protection at national or regional levels. Taking into consideration the wealth of the water resources of our Kashmir valley we have plenty of water resources so the proper planning and management is the utmost concern for everyone, because when we are talking about water resources every one is a stakeholder.

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