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SEASONAL VARIATION OF GROUNDWATER QUALITY IN PERI-URBAN AREA OF SOUTH CHENNAI, TAMIL NADU

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ABSTRACT:
Groundwater is one of the important sources for drinking water in the world. The demand for groundwater has increased over the years due to intensive irrigation practices and population growth which in turn caused depletion of resources and deterioration of quality and this has led to water scarcity in peri-urban area. In view of this, quality studies have been undertaken on 24 groundwater samples collected from peri-urban villages of Chennai region and then tested in the laboratory for various physical as well as chemical parameters and using GIS techniques to identify out the temporal changes. In the present study the groundwater samples were located from different locations during pre-monsoon (2019) and post-monsoon (2020).The calculated water quality index results shows that 100% falls in the good water category. The Wilcox and USSL diagrams, SAR, Na% and RSC indicate that groundwater falls under the permissible category for irrigation purpose. Based on the physico-chemical analysis, the TDS, TH, calcium, magnesium, and chloride ions in most of the ground water samples of both pre monsoon and post monsoon are within the permissible limit values recommended by BIS.
Keywords: Physiochemical analysis, WQI, Irrigation water quality, Peri-urban area, Chennai.

INTRODUCTION:
Water is the essence of life and nearly 165 billion litres of water needed per day in India [1]. Climate change plays an important role in affecting groundwater quantity in arid and semi-arid regions through variation of groundwater recharge due to time, duration and magnitude [2]. In the present situation, in most of the cities in India, the daily water demand is met by groundwater utilization, as the surface water is either deficient or polluted. Groundwater is the main source that is commonly used for drinking and irrigation purpose in rural, urban and semi-urban areas [3.4]. It is estimated that about 45% of the irrigation water requirement is met from groundwater sources [5].Groundwater quality is generally assumed to be safe for consumption because it is located beneath the land surface and is not typically in contact with the atmosphere [6]. Due to the shortage and contamination of surface water, the dependency on groundwater has been increased within a few decades to meet water requirement for drinking, irrigation and other uses. The main source of life for many people in the world is the groundwater [7].The pollution of groundwater is a major problem due to rapid urbanization and industrialization [8].In developing countries like India; about 80% of all diseases are mainly associated with poor drinking water quality and unclean conditions [9]. The water demand is continuously increasing mainly due to population growth and raising needs in industrial uses and domestic purposes. Groundwater has become an essential resource over the past few decades due to the increase in its usage for drinking, irrigation and industrial uses etc. The quality of groundwater is equally important as that of quantity [10]. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer system. The rapid growth of urban area has two basic benefits of groundwater resources. Hydro-chemical characteristics of groundwater can also be analysed for the groundwater assessment [11]. Water quality index (W.Q.I) provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters [12]. A water quality index based on some very important parameters provides a single indicator of water quality. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that

rates the health of a water system with number [13].Water quality is very important for the growth of crops. An excess of dissolved ions in irrigation water affects the soil structure, reducing crop production capacity of the soil and affecting the quality of agricultural products. Excessive sodium levels in the water will result in soil permeability being reduced [14], which adversely affects crop quality and yield [15].Geological Information system mapping techniques is the best representative tool in the assessment of groundwater quality and its utilization for domestic and irrigation needs [`16] .There is a possibility of changes in groundwater quality due to hydrology and geologic conditions over a period of time [17]. During last decades, this is observed that groundwater get polluted drastically because of increased human activities. Consequently, number of cases of water borne diseases has been seen that is a cause of health hazards. To safeguard the groundwater, the quality of water must be monitored periodically. The groundwater samples from the study area were collected for two seasons viz, Pre-monsoon and Post-monsoon. The main objectives of the study are to analyse the groundwater quality and its suitability for drinking and agricultural purposes on the study area. Water quality is the measure of concentration of dissolved chemical constituents in water, which is due to natural and anthropogenic influences. The present study was carried out in the south peri-urban area of Chennai, Tamil Nadu. The major source of drinking and irrigation purposes is the availability of groundwater.

STUDY AREA:

The Southern part of the Chennai metropolitan area is chosen for conducting the study. It comes under the administrative boundary of the St. Thomas Mount, Tiruporur and Kattankulathur Blocks of Kancheepuram District, Tamil Nadu, and it is located immediately adjacent to the Chennai city boundary. The study area chosen as consequent nine villages of these blocks, and lies between the east longitudes 80°08′19.1″ to 80°12′11.52″ and the north latitudes lies between 12°49′35.59″ to 12°54′2.37″. The aerial extent of the study area is 30.9 km^2. It comprises nine village panchayats namely Madurapakkam, Koilancheri, Moolacheri, Agaramthen, Ottiyambakkam in the St. Thomas Mount Block, Moolacheri and Ponmar in the Tiruporur Block, and Vengadamangalam in the Kattankulathur Block. Fig.1 shows the location and the boundary map of the study area There are no major rivers or system tanks other than some medium and small tanks, and some of the tanks are well connected and form a drainage network. Most of the surplus during the heavy monsoon floods these areas, and finally goes to the Pallikaranai swamp, stretching from north to south. Almost all the drainage flows from west to east, except certain undulations due to topography, and finally end in the Bay of Bengal. Most of the precipitation in the Kancheepuram district occurs in the form of cyclonic storm caused due to the depressions in Bay of Bengal chiefly during northeast monsoon period.The normal annual rainfall over the district varies from 1105 mm to 1214mm.The minimum and maximum temperature are 20°C & 42°C. Rocks decide the quality of the ground water, charnockite rocks of the archaen age is the most widespread rock type of this area. The exposures of charnockite are found along the western and south-western periphery of the study area in the form of low hills and hillocks. Isolated outcrops of charnockite are also noted, and several quarries present in the area and well cuttings reveal the disposition of this rock type.Groundwater samples were collected in an open well from predetermined locations based on the land use practices. A total of 15 water samples were collected from different locations in the study area. Pre-cleaned polypropylene bottles were used to collect water samples for physical and chemical analysis. Some parameters like pH, TDS, EC, Temperature tested in-situ, in the sampling collection point itself. The ground water level in an Open Well is measured with the help of premeasured markings in the thread. The GPS coordinates of the locations were recorded by using handheld mobile GPS.

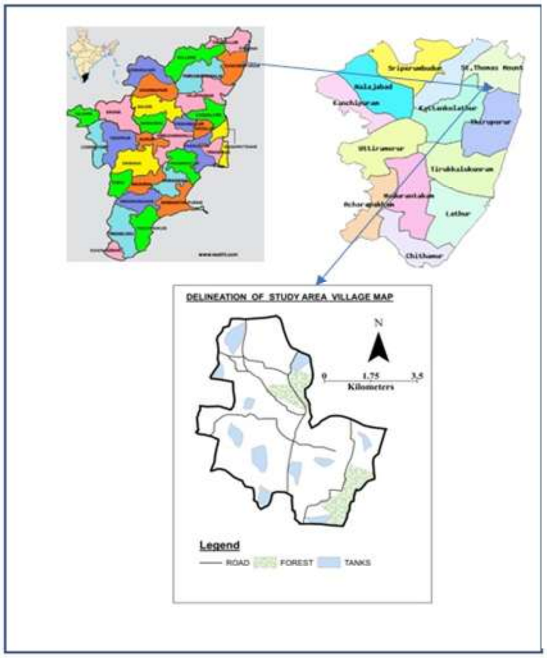

Fig.1 Location map of sampling point

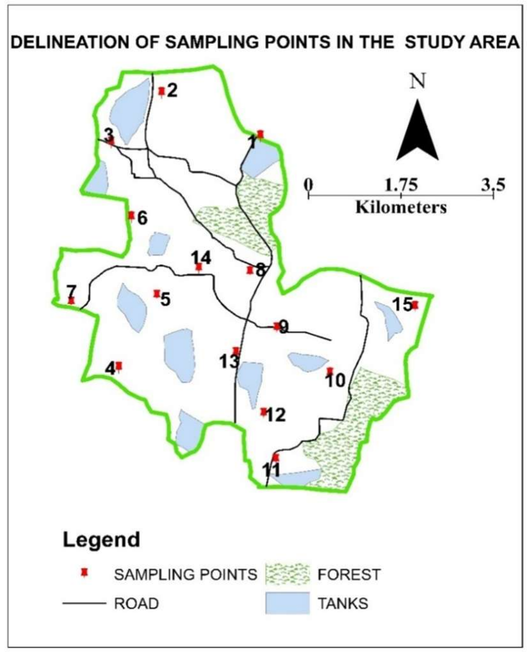

Fig.2 Location of the groundwater

MATERIAL AND METHODS:

Groundwater samples were collected in an open well from predetermined locations based on the land use practices. A total of 15 water samples (Fig.2) were collected from different locations in the study are during pre-monsoon 2019 and post-monsoon 2020. Pre-cleaned polypropylene bottles were used to collect water samples for physical and chemical analysis. Some parameters like pH, TDS, EC tested in-situ, in the sampling collection point itself. The ground water level in an Open Well is measured with the help of premeasured markings in the thread. The GPS coordinates of the locations were recorded by using handheld mobile GPS. Water quality parameters (chloride, sulphate, hardness, magnesium, calcium etc.,) were analyzed in the laboratory according to the methods given in the Standard Methods [18].

RESULT AND DISCUSSION:

Field work is conducted and groundwater samples are collected from various locations in pre and post monsoon season with the help of the map. The samples are tested using standard procedures in the laboratory. The water quality data is linked to the sampling location for preparing spatial maps in the study area using Arc GIS software. The seasonal variations of physico-chemical characteristics of the groundwater samples in the study area are discussed below and presented. The suitability of groundwater of this area for drinking and irrigation purposes was assessed by comparing the measured concentration of ions and other parameters with the recommended ranges given by [19].

HYDROGEN ION CONCENTRATION (PH):

The pH is considered as an important ecological factor and provides an important factor and information in many types of geological equilibrium or solubility calculation [20]. It has no direct effect on human health; it controls the quantity and chemical structure of a number of organic and inorganic matters which dissolved in the groundwater [21]. The permissible limit of pH a value for drinking water is specified a 6.5 to 8.5 [19]. Values of pH were measured a well site, which range between 6.9 to 8.2 and 7.3 to 8.1 during pre-monsoon 2019 and post monsoon 2020 respectively.

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Groundwater were found mildly acidic and alkaline in nature. Spatial distribution map of pH all the samples are within the permissible limit of drinking water standards (Fig.3). It has no direct adverse effect on health. If the pH is not within the prescribed, it damages mucous membrane present in eyes, nose, mouth, abdomen, anus etc.

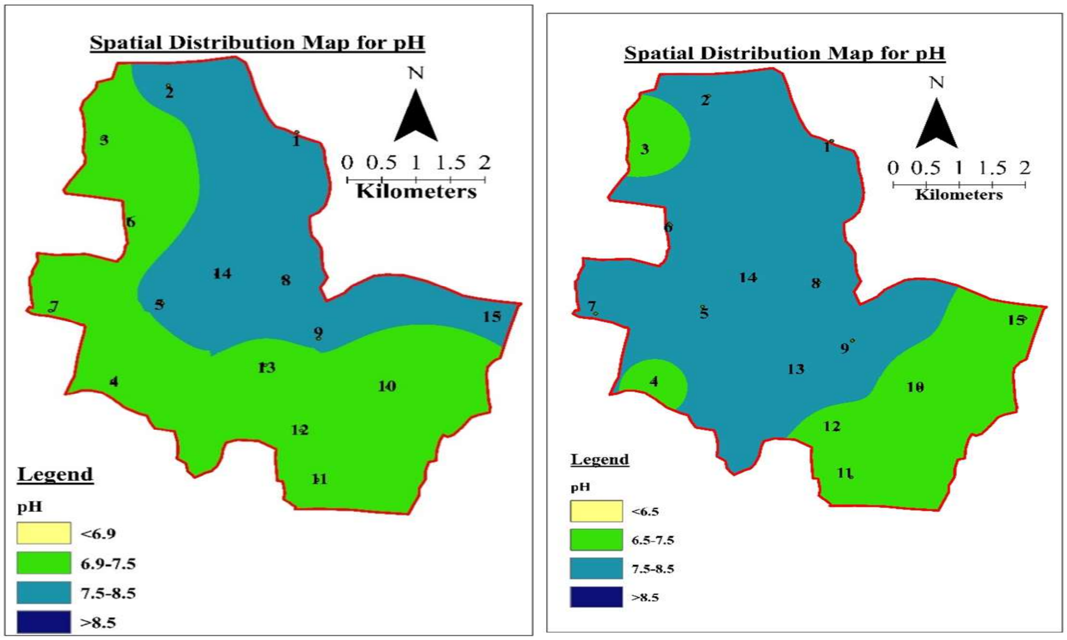

Fig.3 Spatial distribution map pH

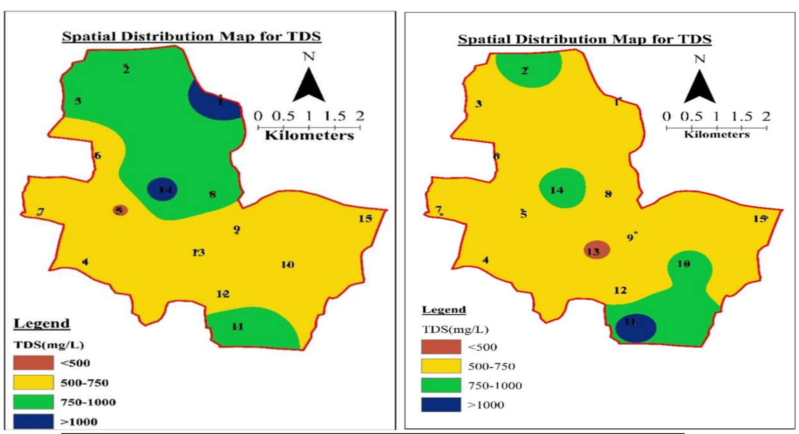

Fig.4 Spatial distribution map for TDS

TOTAL DISSOLVED SOLIDS (TDS):

TDS values represent the various types of minerals present in water in terms of the mineral contamination, which in turn reflects the nature of salinity water [22]. Higher the ionisable solids, greater will be the TDS. The most important among these is effect on taste. TDS generally tells the quality of the water. In natural water, TDS is usually less than about 600 mg/l considered to be good, whereas the TDS level greater than about 1000 mg/l is not acceptable for drinking [19]. The low content of soluble salts in groundwater samples which can be used for drinking without any health

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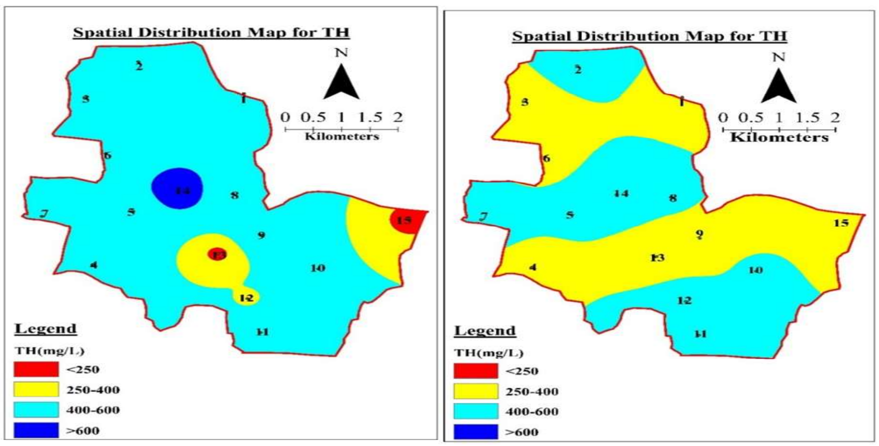
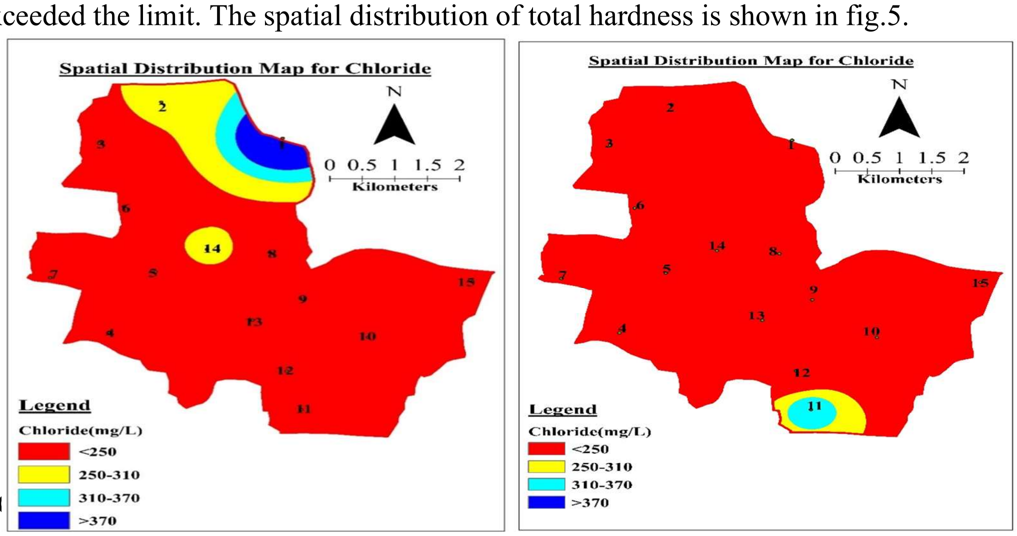
risk. Weathering or dissolution of soils and rocks generated ions in water [23]. The classification of groundwater of the study region based the range of TDS as recommended by [24] falling under fresh water (<1000 mg/l) and very few samples are brackish water (1000-10000 mg/l). The desirable limit of TDS of drinking water is 500 mg/l and 2000 mg/l as the maximum permissible limit has been suggested for drinking water [19]. The TDS of groundwater of the study region were varies from 475 to 1176 mg/l in pre monsoon 2019 and 460 to 1115 mg/l in post monsoon 2020.Almost all the groundwater sample had TDS within maximum permissible limit (<2000 mg/l) of [19]. The spatial distribution of TDS is presented in maps (Fig.4) majority of the location are fresh water (TDS<1000 mg/l).



TOTAL HARDNESS (TH) :

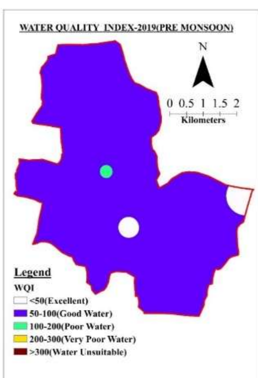
The hardness is the important characteristic of groundwater because the use of water depends upon hardness values. Hardness in groundwater is derived largely from contact with soil and rocks [25]. TH can be divided into two type Carbonate hardness is the amount of carbonate and bicarbonate in solution that can be removed by boiling, while non-carbonate hardness is presence of sulphates, chlorides and nitrates. When Ca and Mg can be removed by boiling water called permanent hardness [26]. The major cations that contribute to the hardness are calcium and magnesium ions in groundwater. Hard water might lead to the cause's alkali taste, scales in pipes and in boilers and also increases incidence of Urolithiasis and also causes heart diseases and kidney stones in human beings. Total hardness in groundwater varies in the pre monsoon (2019) from 220 to 745 mg/l and in the post monsoon (2020) varies from 250 to 525 mg/l. The most desirable limit of TH in water use for drinking purpose is 300 mg/l and the maximum permissible limit is 600 mg/l based on [19]. Almost majority of groundwater samples is below the maximum permissible limit and very few samples exceeded the limit. The spatial distribution of total hardness is shown in fig.5.

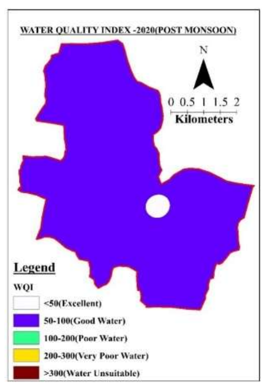


CHLORIDE (CL):

In natural freshwater high concentration of chlorides is indicator of pollution. Chloride in excess imparts a salty taste to water, and people who are allergic to high chloride are subjected to laxative effects. Excess of chloride is due to anthropogenic activity like septic tanks effluents, usage of bleaching agents by people nearby borewell.The higher concentrations of chloride in the groundwater may be attributed to the percolation of domestic sewage and irrigated land water [27].Chloride gives salty taste to water and higher consumption of chloride rich drinking water cause hypertension, stroke, left ventricular hypertension, renal stones and asthma in human beings. Surface water often has low concentration of chlorides as compare to groundwater. The concentration of chloride in groundwater in the study area varies from 74.97 mg/L to 499.845 mg/L in the pre monsoon (2019) and it varies from 92 to 357 in the post monsoon (2020). Chloride content above 250 mg/l makes water salty in taste; however, within the maximum permissible limit is 1000 mg/l [19]. The spatial variation and distribution of chloride ions in groundwater in the study area is shown in Fig.6.

DRINKING WATER QUALITY INDEX :





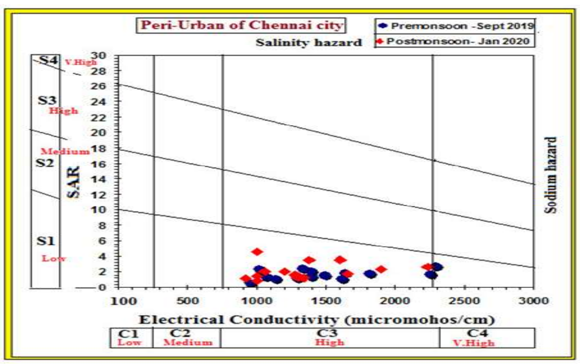
The WQI is commonly used for the detection and evaluation of water pollution level of water. It is one of evaluation techniques of water quality. Based on the WQI, five categories of drinking water quality have been established: excellent (<50) acceptable (50-100), bad (100-200), extremely poor (200-300) and not appropriate for drinking (>300). WQI is one of the most effective tools to communicate information on overall quality status of water to the concerned user community and policy makers. The values of selected parameters of groundwater quality data and BIS water quality standards were used for calculating water quality indices. WQI was calculated by using the Weighted Arithmetic Index method as described by [28, 29]. The water quality standard values, corresponding weight, relative weight was presented in the table. WQI values of the year 2010 and (2019- 2020) pre-monsoon and post monsoon are calculated. In 2010 both pre and post monsoon are found to be good water (Fig.7), but in 2019 pre-monsoon shows excellent to poor categories and in 2020 post monsoon it shows excellent to good water. Quality status is assigned on the basis of calculated values of water quality indices to include the collective role of various physicochemical parameters on the overall quality of drinking water is good.

IRRIGATION WATER QUALITY :

Irrigation system has a significant role in the quantity and intensity of crop production and largely depends on groundwater in India. Good quality of irrigation water is essential for achieving plant growth, crop yield, soil quality and human health, it is essential to assess the water quality for irrigation utilizes in the agriculture areas. Concentrations of dissolved salts mainly control the quality of irrigation water. High salt content in water used for irrigation may affect the soil structure together with the permeability rate and aeration. Groundwater suitability for irrigation purpose in this study area was assesses using sodium percentage (Na%), Sodium adsorption ratio (SAR), Residual sodium carbonate (RSC) and United States Department of Agriculture classification. Groundwater in most of the study area was found to be suitable for irrigation.

US SALINITY DIAGRAM :

A more detail information of the analysis with respect to SAR can be obtained from US salinity laboratory diagram [20]. It can be used to identify potential sources of contamination from surface runoff, such as urban or agricultural activities. Based on the SAR the quality of groundwater may be classified into four types (Fig.8). The SAR value in the study area ranges from 0.56 to 2.67 with an average of 1.59 in the pre monsoon and in the post monsoon it varies from 0.84 to 4.59 with an average value of 2.09. All the groundwater samples contain SAR less than 10,so they come under the excellent water quality types for irrigation[31]. The plot of US salinity diagram [30], in which EC is taken as a salinity hazard and SAR as an alkalinity hazard shows that majority of the groundwater samples in the study area during both the seasons fall in C3S1 indicating high salinity and low sodium water, which can be used for irrigation in almost types of soil with little danger of exchangeable sodium. Even with adequate drainage, special management or salinity control may be required and good salt tolerance crops like cotton, sunflower, chilly, cotton etc. may be selected. Very few samples fall in C4S1 indicating water suitable for plants having good salt tolerance but unsuitable for irrigation in soils with restricted drainage.



WILCOX DIAGRAM:

For suitability of irrigation water, classes of relative stability generally express quality of water. Sodium concentration is important in classifying the water for irrigation purposes because sodium concentration can reduce the soil permeability and soil structure[32,33] and this help little or no plant growth. Soil containing a large proportion of sodium with carbonate as the predominant anion is termed alkali soils with chloride or sulphate as the predominant anions are saline soils. Both the types of soil do not support plant growth. So, sodium is concentrated as a main factor for determining groundwater suitability for irrigation purposes. According to wilcox [34] classification of irrigation water with respect to sodium percentage (Na%) and Electrical conductivity (EC) a shown in diagram. All the samples are suitable for irrigation purposes.

The %Na in the study area ranges from 11.57% to 43.42% with an average of 26.5% in the pre monsoon and in the post monsoon it varies from 17.31% to 59.31 %with an average value of 33%.

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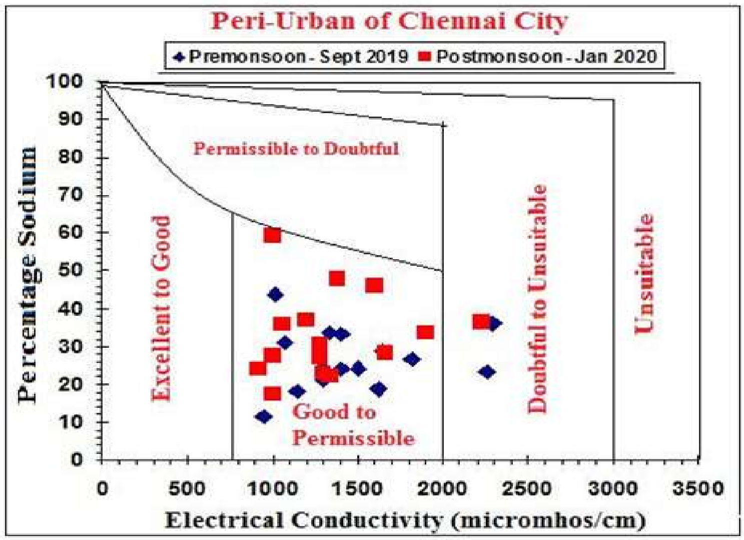
According to the Indian Standard, maximum of 60% sodium is permissible for irrigation water. From the percent sodium calculation, it was observed that 20% samples were excellent, 73.33% samples were good, 6.67% samples were permissible in pre monsoon Samples and in the post monsoon it was observed that 6.67% samples were excellent, 73.33% samples were good, 20% samples were permissible (Fig.9).



RESIDUAL SODIUM CARBONATE (RSC):

Residual Sodium Carbonate (RSC) is to identify the alkalinity hazard for soil and to find suitability of water for irrigation [35]. The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black colour of the soil and affects crop yields[36].The RSC value <2.5 safe for irrigation, a value between (2.5-4.0) is marginal and value >4.0 is unsuitable for irrigation. Further the value of RSC is negative indicating that there is no complete precipitation of calcium and magnesium.RSC values of groundwater encountered in the present study at different locations was always found to be less than 1.25. Hence, groundwater at all the surveyed locations is quite safe for irrigation use. It is observed that 100% samples were safe for irrigational uses on the basis of RSC value

CONCLUSIONS:

In the present study, from analysis of pre and post monsoon data, the thematic maps for spatial distribution of water quality parameters in the study area are generated by Arc. GIS software 9.3. Based on the physic-chemical analysis, the pH, TDS, TH and chloride ions in most of the ground water samples of both pre monsoon and post monsoon are within the permissible limit values are recommended by BIS (IS10500:2012). Groundwater in the study area is relatively fresh and has not been subjected to strong water-rock interactions. The water quality index varies from excellent to poor water categories over the study area .During 2020 the WQI values in the post monsoon varies from 52 to 64 with a mean value of 58.2 , and in the pre monsoon varies from 60 to 75 with a mean value of 66.8, and in the year (2019-20) pre monsoon varies from 42 to 105 with a mean value of 70.67 and in the post monsoon varies from 44 to 87 with a mean value of 62.2.Comparing pre and post monsoon samples between the years 2019 and 2020, the WQI which indicate that though recent water quality is good for both the seasons and overall the post monsoon samples are good due to dilution because of the rainfall. Suitability of ground water for irrigation was evaluated based on

USSL diagram and Wilcox diagram and RSC. All these factors reveal that the groundwater quality was safe for irrigational uses, good to medium categories. At most of the surveyed locations, groundwater has low dissolved chemical load and meets the norms of good quality drinking water and is quite safe for irrigation use.

REFERENCES:

[1].Gupta, R.; Misra, A.K. (2018). Groundwater quality analysis of quaternary aquifers in Jhaijar district, Haryana, India: focus on groundwater fluoride and health implications. Alexandria Eng Journal., 57, 375-381. https://doi.org/10.1016/j.aej.2016.08.031

[2].Subba Rao, N. (2017). Hydrogeology: problems with solutions. Prentice Hall of India, New Delhi.

[3].Shrestha,S.;Bach, T.V.; Pandey, V.P. (2016). Climate change impacts on groundwater resources in Mekong Delta under representative concentration pathways (RCPS). Environmental Science Policy. 61, 1-13.

[3].Kumar, A.; Bhawsar, N.G.;Khandelwal, S.S.; Ahuja, S. (2013). Physico-Chemical parameters apply to analysis of drinking water from some selected area of Betual district, Madhya Pradesh. International Journal of Pharmaceutica, Biologicall and Chemical Sciences. 3:1109-1114.

[4].Magesh, N.;Krishakumar, S.;Chandrasekar, N.;Soundranayagam, J.P.(2013). Groundwater quality assessment using WQI and GIS techniques, DIndigul district, Tamil Nadu, India. Arabian Journal of Geosciences. 6:4179-4189. doi: 10.1007/s12517-012-0673-8.

[5].Ranjit Singh, A.J.A.;Ajithkumar,T.T.(2004). Water quality analysis of drinking water resources in selected villages Tirunelveli district. Indian Journal of Environmental Protection. 24(12):921-924.

[6].Quist,L.G.;Bannerman, R.R.;Owusu,S.(1988).Groundwater in rural water supply in Ghana, Report of the West African Sub-Regional Workshop, Accra, Ghana, 20-24.

[7].Shylasree, G.;Indirani, B.(2013). Physio-Chemical parameters of groundwater and pond water samples in and around Nagercoil town, Kanyakumari district, Journal of Chemical Pharmaceutical research, 5(2), 202-207.

[8]Mophin Kani, K.;Murugesan, A.G.(2011). Evaluation and classification of water quality of Perennial River Tamirabarani through Aggregation of water quality index, International Journal of Environmental Protection, 1(2),24-33.

[9].Olajire, A.A.;Imeokparia, F.E. (2001). Water quality assessment of Osun River Studies on inorganic nutrients, Environmental Monitoring Assessment, 69(1), 17-28.

[10].Asadi,S.S.;Padmaja Vuppala, Anji Reddy, M.(2007). Remote sensing and GIS technique for evaluation of groundwater quality in Muncipal Corporation of Hyderabad (Zone-V), International Journal of Resi. And Public Health, 4(1), 42-45.

[11].Ranjan, R.K.;Ramanathan.A.L.;Parthasarathy.P;Kumar.A.(2013). Hydrochemical characteristics of groundwater in the plains of Phalgu River in Gaya, Bihar, India, Arabian Journal of Geosciences, 6, 3257-3267.

[12].Chauhan, N.B.;Thakor,F.J.(2012). A study of water quality index (WQI) of Heranj Lake, Kheda district, Gujarat, Asian Journal of Experimental Biological Sciences. 3(3), 582-588.

[13].Sharma,P.;Sharma,H.P.(2011). Groundwater quality assessment of Pachim Nalbari block of Nalbari district, Assam based on major ion chemistry, International journal of ChemTech Research, 3(4), 1914-1917.

[14].Bob,M.;Abd Rahman,N.;Elamin,A.;Taher,S.(2016) Assessment of groundwater suitability for irrigation in Madinah city, Saudi Arabia, Arabian Journal of Geosciences, 9,38.

[15].Guan,L.S.;Gul,H.R.;Kang,Z.Y.;Zhao,H.H;Li,J.(2018). Hydrochemical characteristics and water quality assessment of goaf water of Kouquangou mining area in Datong, Shanxi, China, Fresenius Environmental Bulletin, 27(12A), 9315-9324.

[16].Ravikumar,P.;Somashekar,R.K.(2013) A geochemical assessment of cioastal groundwater quality in the Varahi river basin, Udupi district, Karnataka state, India, Arabian Journal of Geoscience, 6, 1855-1870.
[17].Pandey,S.K.;Tiwari,S.(2009) Physico-chemical of groundwater of selected area of Ghazipur city, A case study, Natural Science, 7, 17-20.
[18].Americal Public Health Association (APHA). (1995). Standard methods for analysis of water and wastewater, 18th edition, port city press, Baltimore.
[19].Bureau of Indain Standards (BIS).(2012) Indian Standard (IS 10500, 2012) Drinking Water Specification, New Delhi.
[20].Shymala,R.;Shanthi,M.;Lalitha,P.(2008).Physicochemical analysis of borewell water samples of Telungupalayam area in Coimbatore district, Tamil Nadu, India, Indian E-Journal of Chemistry, 1.5(4), 924-929.
[21].Hem,J.D.(1985). Study and interpretation of the chemical characteristics of natural water (3rd edn). US Geological Survey Water –Supply paper 2254, University of Vigінia, Charlottesville.
[22].Mitra, B.;Sasaki,C.;Enari,K.;Matsuyama, N.;Fujita, M.(2007).Suitability assessment of shallow groundwater for agriculture in sand sune area of northwest Honshu Island Japan, Applied Ecology Environmental Research, 5, 177-188.
[23].Singh,S.K.;Srivastava, P.K.;Pandey,A.C.;Gautam, S.K.(2013).Integrated assessment of groundwater influenced by a confluence river system: Concurrence with remote sensing and geochemical modelling, Water Resource Management, 27(12), 4291-4313. https://doi.org/10.1007/s11269-013-0408-y
[24].Freeze,R.A.;Cherry,J.A.(1979). Groundwater.Prentice Hall, Inc.,604 p.Englewood Cliff.New Jersey. USA.
[25].Arumugam.K.(2010) Assessment of Groundwater Quality in Tirupur Region, Ph.D.Thesis (Unpublished) Anna University, Chennai.
[26].Sawyer, C.N.;McCarty, D.L.(1967). Chemistry of Sanitary Engineers, 2nd edn.McGraw-Hill, New York, 518.
[27].Bhatia,H.S.(1998) A textbook on environmental pollution and control. Galgotia Publicaitons Pvt.Ltd.,India.
[28].Cude,C.(2001).Oregon water quality index:A tool for evaluating water quality management effectiveness, Journal of the American Water Resources Associations, 37, 125-137.
[29[.Brown,R.M.;McClelland,N.I.;Deininger,R.A.;Tozer,R.G.(1970). A water quality index-do we dare? Water sewage works, 117, 339-343.
[30]United States Salinity Laboratory (USSL). (1980). Diagnosis and improvement of saline and alkali soils. Agricultural Handbook No.:60.USDA.
[31].Richards, L.A.;(1954). Diagronosis improvement of saline and alkali soils. United States Department of Agriculture, 60.
[32].Todd, D.K.(1980). Groundwater hydrology[M], 2nd edn.Wiley, New York.
[33].Domenico, P.A.; Schwartz, F.W.(1990). Physical and chemical hydrogeology, John Wiely and Sons.
[34].Wilcox, L.Y.(1955).Classification and Use of Irrigaiton Water, US.Department of Agriculture, Circular 969, Washington DC.
[35].Ghobadi, A.;Cheraghi,M.;Sobhanardakani,S.;Lorestani,B.;Merrikhpour, H.(2020).Hydro geochemical characteristics, temporal and spatial variations for evaluation of groundwater quality of Hamedan-Bahar plain as a major agricultural region, West of Iran, Environmental Earth Science, 79, 428.
[36].Eaton,F.M.(1950). Significance of carbonate in irrigation water Soil Science, 69(2), 123-133.