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Assessment of Physico- Chemical Parameters to Govern the Ground Water Quality and Its Criteria in the Purlieu of the Industrial zone of Parawada, Visakhapatnam, A.P, India. - A Case Study

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Abstract:

The main objectives of this study are to investigate groundwater pollution and its remedial measures in the study area in order to ascertain the extent of health effects in industrialized areas and to evaluate groundwater quality and its suitability for drinking needs. For this study, groundwater samples were collected from tanam, pinamadaka, bottavanipalem, chintalagorlavanipalem, lankelapalem, jellalapalem, chinatadi, and parawada villages of rural Visakhapatnam, Andhra Pradesh, India during the period of pre-monsoon (March) and post-monsoon (September) seasons of 2018. To determine the quality of the water, physicochemical parameters like P^H, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Chlorides (Cl^-), Total Alkalinity (TA), Sulphates (SO_4-^{2}), Fluorides (F^-), Nitrates (NO_3^-), Phosphate (PO_4^-) and Turbidity were utilised. The results are compared with BIS (IS 10500:2012) and WHO drinking water standards. The mean concentration level of cat ions is in the following sequence: $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ and the mean concentration level of anions is in the following sequence: $Cl^- > SO4^{-2} > NO3^- > F^- > PO4^{-2}$. The dominant hydrochemical facies of groundwater are CaHCO3, mixed CaNaHCO3, mixed Ca^{+2}–Mg^{+2}–Cl^-, and Na^+–Cl^- water types. Because of the high concentrations, the water is unfit for drinking, and it must be protected from contaminants.

Keywords: Groundwater, Hazards, Hydro chemical facies, Physicochemical parameters, Industrial zone.

Introduction:

Water is an indispensable element of nature for the nourishment of Organisms and life on earth. Three fourth of the Earth's surface is covered with water. But, the major part of it is in the form of oceans. Which is not useful for drinking or agricultural purpose, and only sweet water is required but it is very little. Freshwater; is in the form of rivers, lakes, ponds, and groundwater. Groundwater is vital for human life is found only in selected provinces and it is very little. The problem with groundwater quality is primarily caused by geological and man-made errors, many researchers have made the same assertion in this regard[1-4] .Unlike many materials, and there is no substitute for water in many of its uses[5]. Groundwater supplies a significant portion of the water supply for both domestic and industrial use. Water scarcity and pollution are major issues in many parts of the world[6-8.] Almost half of the world's population lacks access to safe drinking water, and the demand for water doubles every 21 years[9]. Contaminated water can cause numerous infections and has been identified as the primary cause of certain diseases[10]. A child dies from a water-related disease every eight seconds around the world, 50% of people in developing countries suffer from one or more water-related diseases, and contaminated water causes 80% of diseases in developing countries [11].

Moreover, the influence of solid waste dumping sites, undignified drainage, aquifer material mineralogy, domestic wastewater together with semiarid weather, and unconscious anthropogenic activities have adversely affected the groundwater quality[12]. Before the industrial revolution, surface, as well as groundwater quality, is good enough with respect to quality and quantity. From the 18th century onwards, tremendous growth in industrial establishment causes to frantic growth of anthropogenic activities leading to water resources being vulnerable to contamination by various pollutants[13]. Groundwater is generally recharged by surface or river water and is used as a major source of drinking water as well as other uses such as agriculture, industry, and a variety of recreational activities. In recent days, there is strange pollutant contamination in groundwater is being observed due to the penetration of industrial wastewater, agricultural activities & runoffs, mining extracts, and urban sewages containing toxic chemical components[14], so it needs to be protected from the perils of contamination by avoiding abnormal concentrations major ions and parameters. Groundwater in several parts of India is contaminated with arsenic and fluoride as a result of both natural and anthropogenic contamination. A similar observation was made in the case of fluoride in groundwater in some areas of Kadapa District[15]; the groundwater in rural areas is getting polluted due to modern farming deeds. A surplus quantity of fertilizers and pesticides are utilized in village cropping to get high yields, and the excess concentration of residues may penetrate the groundwater and spoil the groundwater

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balance. The excessive use of nitrate fertilisers and related substances is the primary source of nitrate pollution of groundwater.

Materials and methods:

Visakhapatnam area is in a bowl shape. It has a geographical area of 681.96 km^2 (263.31 sq mi) and is located between the Eastern Ghats and the coast of the Bay of Bengal. It is located between 17° 15' and 18° 32' North latitude and 18° 54' and 83° 30' East longitude.

Material Used for the study:

Freshly purchased plastic cans, sterilised glass bottles, pipettes, burettes, beakers, measuring cylinders were used. AR-grade chemicals were used during analysis.

Study Area:

This is also a bumpy, slope area. The population density in this area is around 2500 per square kilometre. The gender ratio is 1120 females for every 1000 males. In November/December, the mean minimum temperature ranges from 28°C to 34°C recorded. In May/June, the mean maximum temperature ranges from 35°C to 42°C recorded. Every year, the southwest monsoon begins in the third week of April, and the northeast monsoon begins in October. The average annual rainfall ranges between 1100 and 1208 mm[16.] The photographic view of the study area is tabulated in the **Figure 1**.

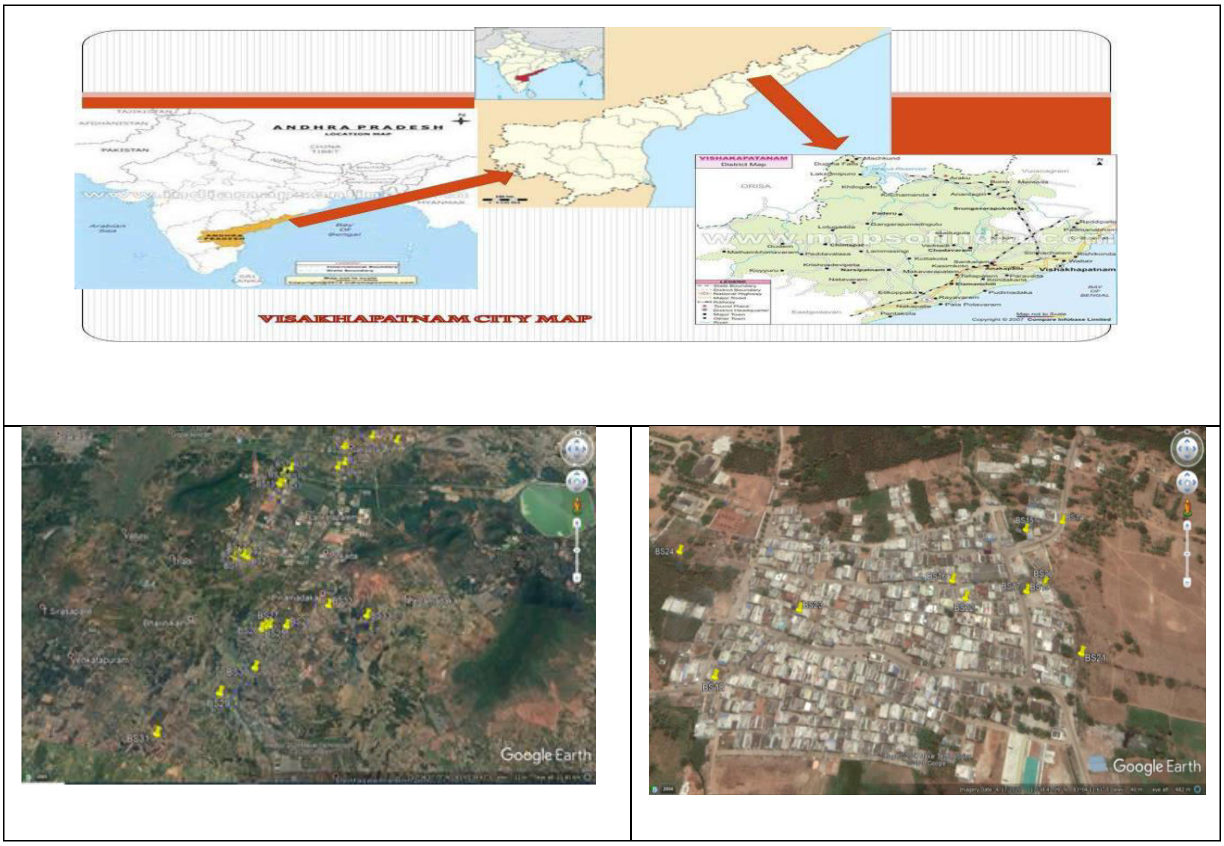

Figure 1. Study area map with geological locations covered 8 neighbouring villages.

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Sampling Locations:

For this study, 40 sampling locations were identified from 8 villages. The list of sampling stations and their details are tabulated in **Table 1**.

Table 1: List of sampling stations and its Geographical location in the study area:

Code	Location	Latitude	Longitude	Code	Location	Latitude	Longitude
Borewell sample at Lankelepalem village area (Area-01)				**BS19**	Anjaneya Swami temple	17° 38' 49.722"N	83° 4' 6.567" E
BS1	HP Gas go- Dom	17° 41' 18.85" N	83° 6' 40.215"E	**BS20**	K.Sanyarasirao house	17° 38' 52.623"N	83° 4' 17.173"E
BS2	Reddy mango garden	17° 41' 22.502" N	83° 6' 13.838"E	**BS21**	S.Kumari house	17° 38' 52.900" N	83° 4' 17.84" E
BS3	M. Srinivasa Rao house	17° 41' 7.926" N	83° 5' 45.765"E	**BS22**	B.Sannyasirao house	17° 38' 50.485" N	83° 4' 18.80" E
BS4	S. Raghavarao house	17° 41' 7.083" N	83° 5' 43.659"E	**BS23**	T. Gangaraju house	17° 38' 52.306"N	83° 4' 14.93" E
BS5	Shanti Talent School.	17° 40' 46.232"N	83° 5' 45.265"E	**BS24**	NTR statue	17° 38' 51.885"N	83° 4' 9.094" E
BS6	Kanakadurga temple	17° 40' 40.216"N	83° 5' 38.518"E	**BS25**	Z.P.High School	17° 38' 54.074"N	83° 4' 4.303" E
BS7	K.Ramullamma house	17° 41' 12.34 N	83° 5'41.35"E	**BS26**	T.Appala Naidu house	17° 38' 48.52 "N	83° 4' 08.77" E
Borewell sample at Chinatadi/ Kannur village area (Area-02)				**Borewell sample at Parawada village area (Area-04)**			
BS8	APGVB bank	17° 40' 29.143"N	83° 4' 42.679"E	**BS27**	Vinayaka temple	17° 37' 42.35" N	83° 04'39.68" E
BS9	House of S.Ramana.	17° 40' 35.583"N	83° 4' 49.807"E	**BS28**	Visakha Grameena Bank	17° 37' 44.85" N	83° 4'42.826" E
BS10	P.V. Lakshmi house	17° 40' 36.620"N	83° 04' 49.77"E	**BS29**	Main road	17° 37'45.886" N	83° 4'46.729" E
BS11	MPP School	17° 40' 19.992"N	83° 4' 43.108"E	**BS30**	Maridimamba CommunityHall	17° 37'46.452" N	83° 5'1.712" E
				BS31	Near K.Ramesh house	17° 37'43.24" N	83° 4'43.63" E
BS12	BC colony	17° 40' 16.320"N	83° 04' 41.04"E	**BS32**	Near Taviti Naidu house	17° 37'43.68" N	83° 4'47.66" E
				BS33	Near M. Sesha Rao house	17° 37'39.02" N	83° 4'44.92" E
BS13	Panchayat water tank	17° 40' 15.600"N	83° 04'39.07" E	**Borewell sample at Other village area (Area-05)**			
				BS34	Maridimamba temple Jallelapalem	17° 36'46.119" N	83° 4'12.457" E
BS14	Municipal Sub-Zonal Office	17° 40' 14.491"N	83°04' 40.46" E	**BS35**	Pydimamba temple-Atchutauram – Parawada road.	17° 37' 8.713" N	83° 4'38.769" E
Borewell sample at Tanam village area (Area-03)				**BS36**	Overhead water tank-Bottavanipalem	17° 36'11.660" N	83° 3'27.684" E
BS15	B.Nukaraju House.	17° 38' 55.402"N	83° 04' 18.86"E	**BS37**	Gowthulachanna Colony - Pinamadaka	17° 38' 7.922" N	83° 5'37.417" E
BS16	Overhead tank	17° 38' 55.15" N	83° 4' 17.44" E	**BS38**	Ramalayam – Chintalagorlavanipalem	17° 38' 1.017" N	83° 6'12.106" E
BS17	bore hole No.32/013	17° 38' 52.958" N	83° 4' 14.487"E				
BS18	M.Apparao house	17° 38' 52.648"N	83° 4' 17.166"E	**BS39**	Gollaveedhi	17° 38' 02.81" N	83° 6'09.68" E
				BS40	Near K. Sreenivas house	17° 38' 00.52" N	83° 5'58.09" E

BS1- Bore well sample collected at HP gas godown - Lankelapalem

BS2- Bore well sample collected at Reddy mango garden (near Indian Oil petrol bunk) Lankelapalem

BS3-- Bore well sample collected at the house of M. Srinivasarao. Lankelapalem

Figure - 02: Some photographic views of sampling in the study area.

Sampling:

After virtuous inventory, groundwater samples were collected from 40 locations for the period of pre-monsoon (March) and post-monsoon (September) seasons of 2018 in a simple random sampling method. In total, 80 samples were collected from 40 sampling locations in both seasons based on water consumption using the protocol and guidelines outlined in the Standards methods[17]. To avoid or minimise contamination, all practical precautions were taken at every stage, beginning with sample collection, adding preservatives, storage, transportation, analysis, and interpretation of the samples.

Parameters analysed:

The Analysis was carried out at the Zonal laboratory, APPCB, Kurnool, and Visakhapatnam by using standard methods and techniques (APHA 23rd edition). For this study, physicochemical parameters like P^H, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Chlorides (Cl^-), Total Alkalinity (TA), Sulphates (SO_4-^{2}), Fluorides (F^-), Nitrates (NO_3^-), Phosphate (PO_4^-) and Turbidity were utilised. Flame photometers, digital pH & conductivity metres (Hach), Spectrophotometers (DR6000), and calibrated glassware were among the sophisticated instruments used.

Scope of the Present Study:

The previous researchers have focused on urban agglomeration and some physicochemical characteristics in Visakhapatnam city by covering residential zones & some industrial zones and noticed some abnormalities. They are not focused on the suitability of groundwater for drinking needs. Moreover, the present study area is also close to the industrial hub. As per the author's knowledge, groundwater studies are yet to be carried out in the present study area. The local public uses the groundwater for drinking, cattle feeding, household, and irrigation purposes. Due to industrial activity, there might be chances to get contamination of groundwater. The study area has no scientific drainage system. Moreover, the local public in the area is frequently suffering from fever, diarrhoea, and gastrointestinal diseases. This forms the basis for groundwater quality study and an attempt has been made to evaluate the concentration levels of some physicochemical parameters.

Results and discussion

Physicochemical parameters:

pH:

Normally the value of pH in drinking water is always neutral, if the value is increase or decreases can change the quality of water, and the recommended range is from 6.5 to 8.5as per IS 10500:2012 & WHO. This study ranged from 6.78 to 7.82 (mean of 7.32) and from 6.69 to 7.65 (mean of 7.13) for the 2018 monsoon and post-monsoon seasons, respectively. The maximum value is found at BS9. Compared the results, the pre-monsoon results are higher than the post monsoon seasons. The abnormal concentration of pH indirectly affects health in many ways. The water with its acidic nature can corrode the plumbing and lead to the leaching of metals like lead, manganese, iron, copper, zinc, etc. Excess levels of lead in drinking water can cause cancer, kidney disease, memory loss, high blood pressure, and other health problems in humans. The standard deviation is recorded as 0.19 & 0.15 respectively.

Dissolved Oxygen:

In groundwater investigations, the most important and perpetually considered parameter is DO. It is invariably regarded as a necessary and critical parameter. It varies greatly with water temperature and the partial pressure of oxygen in its gas phase [18]. The lower value of DO is an indicator of contamination and it may not be fit for direct consumption. If the Dissolved Oxygen levels are may be decreased, it may be an indication of bacteriological or chemical contamination and this may cause by the interaction of various constituents. The decrease in the DO of water in summer is due to its poor ability to hold O_2 at high temperatures as a result of the higher rate of microbial metabolism. This study ranged from 3.8 to 5.3 (mean of 4.4) and from 5.0 to 6.6 (mean of 6.14) for the monsoon and post-monsoon seasons of 2018, respectively. The maximum value is found at BS14 & BS30 and the minimum value is recorded at BS24. The standard deviation is recorded as 0.33 to 0.37 respectively. Among the results, very lower values were recorded during the pre-monsoon season due to high temperature.

Electrical conductivity:

The ability of water to carry an electrical current is referred to as conductivity. A sudden increase in water conductivity indicates the presence of pollutants in the water[19, 20]. The present study ranged from 401 to 2610 µS/cm (mean 1188), and 381 to 2519 µS/cm (mean 1072), during pre-monsoon and post-monsoon seasons, respectively. The maximum value is found at BS27. The standard deviation is recorded as 661 & 620 respectively.

Total Dissolved Solids:

Total dissolved solids, the concentration ranged from 262 mg/L to 1707 mg/L (mean 777), and 249 mg/L to 1647 mg/L (mean 701) at pre-monsoon and post-monsoon seasons, respectively. The maximum value is found at BS27. TDS levels in groundwater may be high due to nutrient-rich surface waters contaminating the groundwater [21]. A high level of TDS in groundwater is not a significant health risk to the general public but affects people with kidney and heart disease. The standard deviation is recorded as 432 & 405 respectively. Among the results, the higher values were observed at tanam and parawada areas.

Total Hardness:

Hardness is also one of the prime parameter in drinking water quality assessment it is mainly caused by the presence of cat ions such as Calcium and Magnesium, strontium, ferrous iron, and manganous ions and accompanied by anions such as chlorides, sulfates and bicarbonates nitrate and silicate respectively. Calcium and magnesium are responsible for the majority of the hardness found in natural waters[22, 23.] Hard water is water that necessitates a substantial amount of soap to develop foam or lather and start generating scale in hot-water pipes, heating systems, boilers, and other appliances. As per IS 10500: 2012, the acceptable limit in drinking water is 200 mg/L and the permissible limit in drinking water is 600 mg/L. The present study ranged from 80.9 to 767 mg/L (mean 210), and 54.5 to 563.6 mg/L (mean 151), during the pre- and post-monsoon seasons. The maximum value is found at BS27. The standard deviation is recorded as 152 & 116 respectively.

Calcium:

Calcium is a vital nutrient that has helped to form and develop bones and teeth. High concentration levels produced cardiovascular diseases, create kidney stones, weaken bones, and interfere with heart and brain work. The high deficiency of calcium is often called hypocalcemia in humans and may cause rickets, poor blood clotting, bones fracture, etc. In the present study, the concentration ranged from 14 mg/L to 163 mg/L (mean 47.5), and 10 mg/L to 124 mg/L (mean 35) during the pre- and post-monsoon seasons. The maximum value was found at the BS27 sampling station. The standard deviation is recorded as 32 & 26 respectively.

Magnesium:

Before and after the monsoon, magnesium concentrations ranged from 8 mg/L to 88 mg/L (mean 22.4) and from 4 mg/L to 62 mg/L (mean 15.5), respectively. The maximum value was found at the BS27. Magnesium is also a much-needed nutrient for plants and living organisms. It can help in the formation and development of organisms and flowering as well as in the process of photosynthesis. Excess magnesium intake in the form of supplements has also been linked to laxative effects. The standard deviation is recorded as 20.8 & 15.2 respectively.

Sodium:

Sodium is a dominant cat ion in groundwater. It is found alkaline in nature. It present in the groundwater is from the silicate mineral group, Ionic imbalance shows the ill health of humans. It is a very vital ion for the nervous stimulation of animals. In the human being, it plays a very critical role in Blood Pressure activities. In the coastal area, the concentration of Na^+ is very high in groundwater due to the intrusion of seawater. Abundantly, Sodium ions are presented in nature as Sodium Chlorides. Rock salt (NaCl) is a naturally occurring ionic compound that appears as white crystals. It is obtained through the mineral form halite or through seawater evaporation. Because NaCl has only one electron in its valence shell, it has weak metallic companionship and free electrons, which carry energy. The concentration levels of sodium in the present study varied from 59 mg/L to 550 mg/L (mean 208) and from 51 mg/L to 540 mg/L (mean 206) before and after the monsoon, respectively. The maximum value was found at the BS23. The standard deviation is recorded as 137 & 132 respectively.

Potassium:

The Occurrence of potassium ion in natural ground waters is very essential; as it is an important nutritional element and plays a crucial role in the human biological system. Potassium is commonly found in soils and rocks. There are no health-based drinking water standards, as it is not toxic. Potassium concentrations in shallow groundwater and deep aquifers may be elevated due to anthropogenic sources. Waste dump leachates are also significant contributors [24]. The concentration levels of potassium in the present study assorted from 0.36 mg/L to 3.2 mg/L (mean 1.06) and from 0.21 mg/L to 1.8 mg/L (mean 0.65) before and after the monsoon, respectively. The maximum value was found at the BS3. The standard deviation is recorded as 0.64 & 0.37 respectively.

Total Alkalinity:

Total alkalinity, the concentration ranged from 136 mg/L to 684 mg/L (mean 353) and 130 mg/L to 686 mg/L (mean 338) before and after the monsoon, respectively. The maximum value was found at the BS17 sampling station. Alkalinity can be caused by ammonia or hydroxides in some cases [25]. When water contains carbonates, it becomes more alkaline[26]. Alkalinity is not inherently harmful to human health [27]. The standard deviation is recorded as

155 & 144 respectively.

Chlorides:

During the pre-monsoon and post-monsoon seasons, chloride concentrations ranged from 22 mg/L to 425 mg/L (mean 155) and 18 mg/L to 400 mg/L (mean 130), respectively. The highest value was exposed at the BS27 sampling station. Weathering leaches chlorides from far most into the water and soil[28]. A higher result signifies that water pollution causes an unpleasant taste, is hazardous to human consumption, and contributes to health issues[29]. The standard deviation is recorded as 115 & 106 respectively.

Sulphates:

The presence of hydrogen sulphide causes pipe corrosion[30]. Drinking sulfate-rich water may result in diarrhea and dehydration. Sulfates are frequently more irritating to infants than to adults. In the present study, the concentration ranged from 12 mg/L to 223 mg/L (mean 61), and 10.2 mg/L to 208 mg/L (mean 52) at pre-monsoon and post-monsoon seasons, respectively. The maximum value was found at the BS24 sampling station. The standard deviation is recorded as 55.8 & 53 respectively.

Fluoride:

Fluoride concentration ranged from 0.42 mg/L to 1.49 mg/L (mean 0.99), and 0.24 mg/L to 1.29 mg/L (mean 0.8) during pre-monsoon and post-monsoon seasons, respectively. The maximum value was found at the BS29 sampling station. It is regarded as a vital component though either a deficiency or an excess amount can cause health problems[31]. A concentration of 0.4 ppm in drinking water causes a mild form of dental fluorosis [32]. Enamel hypo mineralization is triggered by an excessive intake of fluoride during tooth growth and mineralization as results a white spot or severe brown staining may appear. The standard deviation is recorded as 0.29 & 0.32 respectively.

Nitrate:

Nitrogenous fertilisers, domestic waste disposal, and animal wastes are the most common sources of nitrate in the aquatic system. Nitrogenous fertiliser used in intensive agriculture trickles down to groundwater and is likely one of the causes of the high nitrate concentration. Improper septic tank construction can also contribute to nitrate contamination in groundwater in urban areas. Organic pollution is triggered by the presence of nitrate in water. The WHO nitrate standard is 50mg/L, and levels above this limit can cause cyanosis ailment or blue baby syndrome in infants under 3 months old [33-35].Nitrate concentration ranged from 6.3

mg/L to 168 mg/L (mean 30.9), and 3.5 mg/L to 144 mg/L (mean 23.9) during pre-monsoon and post-monsoon seasons, respectively. The maximum value was found at the BS27 sampling station. The values are compared with standards specified[36].The standard deviation is recorded as 31 & 27.5 respectively.

Phosphates:

Phosphates in water bodies, even in small quantities of around 25 mg/L, can fledged growth of algae and aquatic vegetation, resulting in eutrophication of the aqueous system [33], as well as odour and taste problems. No amount of phosphate in water is thought to have any effect on human health (EPA, 1995). WHO and BIS have not specified acceptable limits for phosphates in drinking water. The Canadian Department of National Health and Welfare (1969) recommends a maximum concentration of PO4 in water of 0.2 mg/L, while the European Economic Community [32] recommends 0.54 mg/L. In the study area, phosphates concentration ranged from 0.03 mg/L to 0.42 mg/L (mean 0.17), and 0.01 mg/L to 0.28 mg/L (mean 0.1) during pre-monsoon and post-monsoon seasons, respectively. The maximum value was found at the BS27 sampling station. The standard deviation is recorded as 0.1 & 0.07 respectively.

Biological Oxygen Demand:

The Biological Oxygen Demand is the amount of oxygen required to break down a contaminant or organic residue biologically. It is frequently used to determine the extent of pollutants in normal and wastewater, as well as to assess the potency of waste such as sewage and industrial effluent, as well as seepage of contaminated wastewater. It is a water quality indicator parameter that represents the quality of freshwater ecosystems. An increased level indicates organic matter contamination [34] .Improper septic tank constructions can also contribute to nitrate contamination in groundwater in urban areas that gives rise to increase concentration of micro organisms, and leads to high BOD values. The concentration ranged from 0.4 mg/L to 5.04 mg/L (mean 1.56), and 0.6 mg/L to 5.9 mg/L (mean 2.0) during pre-monsoon and post-monsoon seasons, respectively in the present study area. The maximum value was found at the BS23 sampling station. The standard deviation is recorded as 1.12 & 1.29 respectively.

Turbidity:

The turbidity of water is determined by the amount of solid matter suspended in it; it appears cloudy or gloomy in nature. Turbidity, on the other hand, has no direct impact on health but can aid in the growth of infectious organisms. In the present study, the concentration ranged from 0.38 NTU to 5.36 NTU (mean 1.05), and 0.35 NTU to 6.84 NTU (mean 1.11) during pre-monsoon and post-monsoon seasons, respectively. The maximum value was found at the BS27 sampling station. The standard deviation is recorded as 0.96 & 1.33 respectively.

Hydro chemical facies:

The results of major cations (Na+,K+,Mg2+,Ca2+) and major anions (Cl-,HCO3-,SO42- ,F-) are represented on the piper line diagram. Piper diagram was drawn by using the software GW chart (version1.260.0). The comparative concentration of the anions and cat ions are plotted in the lower triangles (left-side angle cat ions and right-side angle anions) and the resulting two points are drawn-out into the central field to represent the total ion concentration using the analytical data. In the present study 4 major hydrochemical facies were identified in the pre & post monsoon seasons, they are mixed Ca-Mg-Cl, mixed Ca-Na-HCO3, NaCl, and Ca-HCO3. But in post-monsoon season mixed Ca-Mg-Cl, were not recorded, instead of that $NaHCO_3$ recorded. This may be due to temporary hardness, high alkalinity, and salinity.

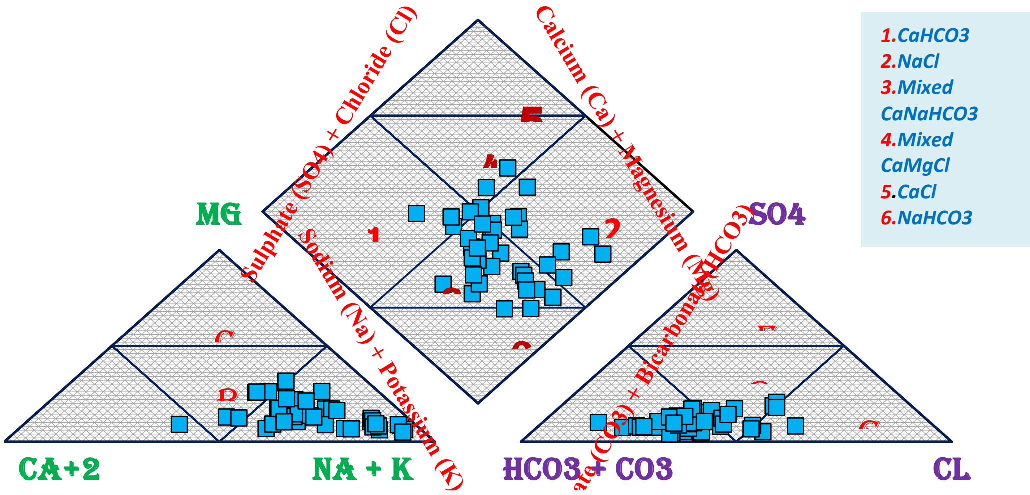

Figure 3. Piper diagram is showing pre-dominant hydro chemical facies in the study area during pre-monsoon season 2018.

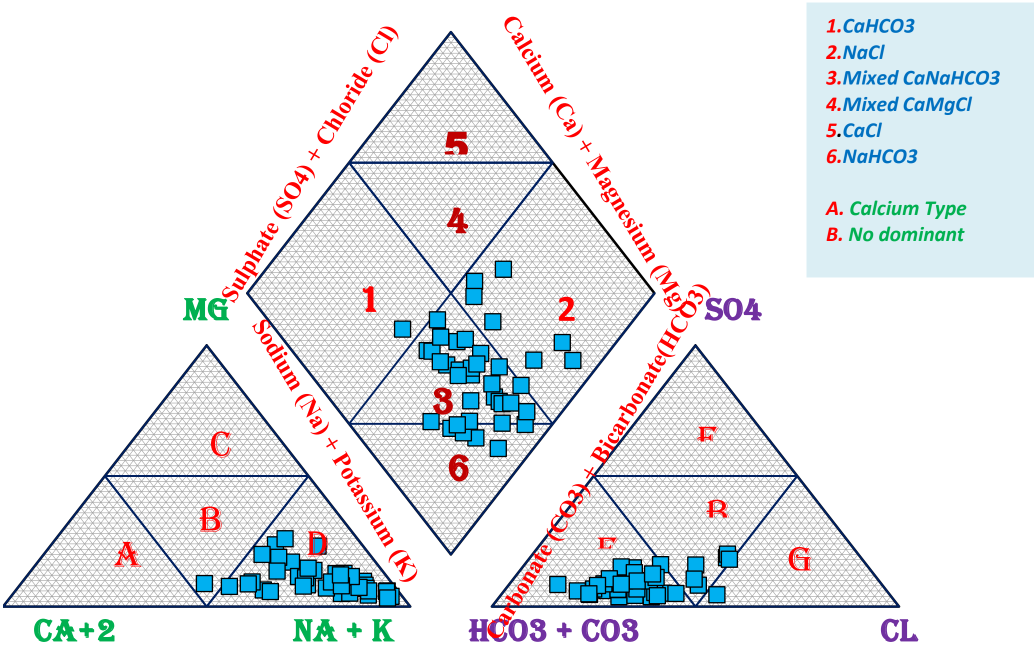

Figure 4. Piper diagram is showing pre-dominant hydro chemical facies in the study area during post-monsoon season 2018.

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Table 2: The results of physicochemical parameters during the pre-monsoon season of 2018.

Location	Code	pH	DO	EC	TDS	TH	Ca+2	Mg+2	Na	K	TA	Cl-	SO42-	F-	NO3	BOD	PO4	Turbidity
HP Gas go- Dom	**BS1**	7.12	4.2	1091	713	255.1	86	10	158	1.2	321	120	74.5	0.65	36.3	0.8	0.28	0.62
Reddy mango garden	**BS2**	7.09	4.3	969	633	352.9	122	12	92	1.2	362	89	32.6	0.82	36.5	1.0	0.22	0.63
Manyam Srinivasa Rao house	**BS3**	7.23	4.0	1133	741	342.0	68	42	146	3.2	402	136	28.3	0.94	40.3	1.2	0.11	0.58
S. Raghavarao house	**BS4**	7.25	4.6	1247	815	310.6	62	38	186	1.3	374	184	47.3	0.86	32.6	1.6	0.12	0.74
Shanti Talent School.	**BS5**	7.35	4.2	1966	1286	219.7	42	28	402	2.3	489	368	47.6	0.99	40.2	0.8	0.09	0.69
Kanakadurga temple	**BS6**	7.42	4.5	1726	1129	235.0	68	16	336	1.9	562	210	65.3	0.98	39.7	0.6	0.14	0.74
K. Ramulamma house	**BS7**	7.23	4.1	1325	866	168.8	48	12	265	0.6	436	178	26.7	0.68	32.5	0.5	0.12	0.82
APGVB bank	**BS8**	7.56	4.6	639	418	152.3	48	8	96	0.8	226	64	26.0	1.02	18.6	1.2	0.04	0.82
Sala Ramana house	**BS9**	7.82	4.2	929	608	180.1	36	22	162	1.2	312	128	22.3	0.42	19.5	1.8	0.04	0.74
P.Venkata Lakshmi house	**BS10**	7.35	4.5	1103	721	204.0	39	26	196	0.6	396	118	36.2	1.02	32.6	0.6	0.03	0.62
MPP School	**BS11**	7.32	5.2	516	337	117.5	34	8	84	0.6	236	22	24.0	0.65	6.4	1.6	0.04	0.53
BC colony	**BS12**	7.15	5.3	680	444	145.6	42	10	113	0.8	256	76	14.3	1.12	12.5	1.7	0.08	0.42
Panchayati water tank	**BS13**	7.36	5.1	654	428	148.9	40	12	106	1.3	254	74	12.3	1.08	8.2	0.8	0.07	0.58
Municipal Sub-Zonal Office	**BS14**	7.56	4.8	661	432	211.1	65	12	80	0.9	236	82	22.3	1.32	6.5	2.0	0.09	0.74
Batti Nukaraju house.	**BS15**	7.54	4.2	1454	951	129.0	32	12	314	1.1	487	168	62.5	1.32	22.3	2.3	0.21	0.72
Overhead tank	**BS16**	6.89	4.6	1322	864	155.2	26	22	272	0.9	458	136	84.0	1.28	6.3	2.5	0.06	0.69
bore hole No.32/013	**BS17**	7.25	4.2	1690	1105	117.1	14	20	384	0.6	632	153	82.0	1.26	18.4	2.2	0.16	0.68
Mullapaka Apparao House	**BS18**	7.35	4.7	2112	1382	118.9	18	18	486	0.4	684	253	96.4	1.02	32.6	4.2	0.23	1.86
Anjaneya Swami temple	**BS19**	7.42	4.3	2251	1472	506.6	68	82	361	0.6	583	398	92.5	1.32	48.6	0.6	0.32	0.72
Katta Sanyarasirao House	**BS20**	7.65	4.1	1797	1176	196.5	36	26	366	1.2	514	224	136.0	1.36	20.6	1.8	0.33	0.38
Sambangi Kumari House	**BS21**	7.36	4.5	1515	991	155.4	36	16	322	0.6	536	168	62.0	1.02	16.3	0.4	0.12	0.48
Burra Sannyasirao House	**BS22**	7.24	4.1	1544	1010	108.9	14	18	340	0.8	425	210	86.3	1.33	36.5	1.2	0.19	1.02
Thigiripalli Gangaraju House	**BS23**	7.25	3.9	2511	1642	130.5	26	16	550	0.6	462	410	210.3	1.32	72.5	5.0	0.26	3.64
NTR statue	**BS24**	7.23	3.8	2504	1637	223.9	47	26	499	0.6	423	396	223.5	1.26	112.3	4.1	0.26	3.12
Z.P.High School	**BS25**	7.25	4.2	972	636	166.3	47	12	180	0.5	415	64	32.5	1.32	19.2	0.8	0.22	1.05
Near T.Appala naidu house	**BS26**	7.25	4.6	779	510	81.0	16	10	166	0.4	312	58	28.6	0.98	18.3	0.6	0.22	1.32
Vinayaka temple	**BS27**	7.32	4.0	2610	1707	767.6	163	88	296	2.6	462	425	204.6	1.23	168.2	4.2	0.42	5.36
Visakha Grameena Bank	**BS28**	6.78	4.2	2248	1470	680.8	143	79	264	1.6	554	314	178.2	1.24	86.5	1.2	0.29	0.86
Main road -Parawada	**BS29**	7.53	4.4	1540	1007	453.1	68	69	206	1.2	468	236	70.0	1.48	26.5	0.6	0.18	1.02
Maridimamba Community Hall	**BS30**	7.36	4.6	570	373	130.7	36	10	84	1.4	168	58	44.7	0.96	19.0	0.8	0.36	0.69
Near govt.school	**BS31**	7.25	4.2	479	313	137.4	42	8	59	0.6	142	48	36.5	0.96	18.3	1.2	0.15	2.12
SC colany	**BS32**	7.36	4.1	504	330	129.0	32	12	72	0.5	174	46	29.5	1.12	16.5	1.3	0.16	1.23
BC Colany	**BS33**	7.23	4.3	509	333	110.8	28	10	80	0.4	162	52	30.2	0.86	18.2	1.6	0.23	0.87
Maridimamba temple -	**BS34**	7.34	4.6	661	432	129.0	32	12	107	0.6	168	88	41.6	0.74	28.9	1.2	0.19	0.74
Pydimamba temple -	**BS35**	7.42	4.5	675	441	170.3	42	16	96	1.0	136	146	26.8	0.45	10.6	2.3	0.16	0.68
Overhead water tank-	**BS36**	7.21	4.6	709	464	160.6	48	10	110	0.9	187	125	22.3	0.58	12.5	1.0	0.14	0.65
Gowthulachanna Colony	**BS37**	7.33	4.7	535	350	94.2	18	12	97	1.2	212	42	18.3	0.62	16.8	1.0	0.09	0.78
Ramalayam - Pinamadaka	**BS38**	7.63	4.5	561	367	110.8	28	10	96	2.3	223	46	20.3	0.69	12.3	0.4	0.16	0.62
Near Golla veedhi	**BS39**	7.23	4.6	402	263	94.2	18	12	63	1.3	144	42	18.4	0.58	8.6	1.3	0.09	0.76
SC -Colany - Pinamadaka	**BS40**	7.36	4.5	448	293	117.3	24	14	64	0.9	142	58	22.3	0.65	10.3	2.2	0.06	0.65
	Min	6.78	3.80	401.83	262.79	80.95	14.00	8.00	59.00	0.36	136.00	22.00	12.30	0.42	6.30	0.40	0.03	0.38
	Max	7.82	5.30	2610.28	1707.12	767.61	163.00	88.00	550.00	3.20	684.00	425.00	223.50	1.48	168.20	5.04	0.42	5.36
	Avg	7.32	4.42	1188.46	777.25	210.46	47.55	22.40	208.90	1.06	353.38	155.33	61.00	0.99	30.99	1.56	0.17	1.05

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	SD	0.19	0.33	661.95	432.91	152.04	32.60	20.87	137.04	0.64	155.42	115.50	55.82	0.29	31.07	1.12	0.10	0.96

Table 3: The results of physicochemical parameters during the post-monsoon season of 2018.

Location	Code	pH	DO	EC	TDS	TH	Ca^{+2}	Mg^{+2}	Na	K	TA	Cl-	$SO4^{2-}$	F^{-}	NO3	BOD	PO4	Turbidity
HP Gas go- Dom	**BS1**	7.02	6.2	933	610	202.1	68	8	144	0.8	308	84	62.3	0.42	28.9	1.2	0.24	0.72
Reddy mango garden	**BS2**	7.01	6.5	804	526	255.1	86	10	96	0.6	324	68	22.5	0.65	22.4	1.3	0.18	0.68
Manyam Srinivasa Rao house	**BS3**	7.06	6.0	1036	677	273.4	52	35	154	1.2	412	104	18.6	0.68	32.4	1.4	0.09	0.66
S. Raghavarao house	**BS4**	7.05	5.9	1178	771	254.5	56	28	194	0.9	392	162	28.5	0.74	28.6	2.0	0.09	0.68
Shanti Talent School.	**BS5**	7.23	6.1	1673	1094	155.4	36	16	354	1.6	423	306	35.2	0.84	38.4	1.2	0.04	0.58
Kanakadurga temple	**BS6**	7.15	6.2	1450	948	158.1	47	10	302	0.8	501	168	42.8	0.76	31.2	0.8	0.08	0.72
K. Ramulamma house	**BS7**	7.02	6.3	1152	754	112.5	32	8	247	0.4	398	146	20.4	0.42	24.8	0.6	0.06	0.61
APGVB bank	**BS8**	7.32	6.4	504	330	106.0	36	4	82	0.6	190	43	21.0	0.86	12.4	1.4	0.01	0.74
Sala Ramana house	**BS9**	7.65	6.2	798	522	102.4	18	14	161	0.8	276	104	20.3	0.36	13.2	1.9	0.02	0.72
P.Venkata Lakshmi house	**BS10**	7.12	6.5	1028	672	143.7	28	18	204	0.4	396	96	30.5	0.86	24.8	1.2	0.01	0.65
MPP School	**BS11**	7.08	6.2	451	295	79.4	22	6	84	0.5	214	18	18.0	0.47	3.5	1.8	0.01	1.03
BC colony	**BS12**	7.01	6.4	452	295	114.2	36	6	68	0.6	179	42	14.0	1.02	6.4	1.9	0.06	0.46
Panchayati water tank	**BS13**	7.06	6.3	492	322	95.1	25	8	88	0.5	189	56	10.2	1.02	4.5	1.2	0.03	0.48
Municipal Sub-Zonal Office	**BS14**	7.35	6.6	571	374	145.7	47	7	85	0.5	214	64	18.7	1.08	4.2	2.4	0.04	0.72
Batti Nukaraju house.	**BS15**	7.36	6.3	1326	867	92.6	24	8	298	0.8	486	124	60.2	1.2	18.2	2.6	0.09	0.84
Overhead tank	**BS16**	6.69	6.2	1204	787	110.6	18	16	262	0.5	426	118	74.2	1.23	4.1	2.8	0.03	0.62
bore hole No.32/013	**BS17**	7.12	6.2	1691	1106	82.5	10	14	403	0.4	686	134	68.9	1.05	10.3	2.4	0.09	0.74
Mullapaka Apparao House	**BS18**	7.25	6.4	1926	1259	71.0	12	10	459	0.2	647	218	88.2	0.98	22.8	5.1	0.12	2.14
Anjaneya Swami temple	**BS19**	7.14	6.5	1922	1257	377.0	49	62	334	0.4	536	320	76.3	1.25	32.5	1.3	0.24	1.12
Katta Sanyarasirao House	**BS20**	7.25	6.4	1628	1065	136.3	25	18	351	0.8	488	186	122.3	1.28	16.8	2.2	0.24	0.65
Sambangi Kumari House	**BS21**	7.22	6.5	1265	827	101.6	21	12	280	0.4	426	147	58.3	1.01	12.4	0.9	0.08	0.65
Burra Sannyasirao House	**BS22**	7.14	6.4	1555	1017	74.3	10	12	362	0.4	496	184	80.4	1.05	20.8	1.6	0.18	1.05
Thigiripalli Gangaraju House	**BS23**	7.05	6.2	2394	1566	90.9	20	10	540	0.3	453	384	203.4	1.12	60.5	5.9	0.21	5.62
NTR statue	**BS24**	7.05	6.1	2372	1551	163.6	36	18	496	0.4	423	365	208.6	1.02	98.3	5.0	0.10	3.87
Z.P.High School	**BS25**	7.09	6.4	809	529	112.5	32	8	163	0.2	362	48	22.4	1.15	12.0	1.2	0.11	1.12
Near T.Appala naidu house	**BS26**	7.02	6.4	589	385	54.5	12	6	130	0.2	246	42	18.2	0.68	10.4	1.2	0.14	0.85
Vinayaka temple	**BS27**	7.11	5.3	2519	1648	563.6	124	62	362	1.8	456	400	200.1	1.09	144.5	5.7	0.16	6.84
Visakha Grameena Bank	**BS28**	7.02	5.0	2003	1310	515.8	118	54	274	1.2	489	284	146.3	1.08	75.6	1.4	0.21	1.02
Main road -Parawada	**BS29**	7.14	5.3	1313	859	331.9	54	48	196	0.8	369	210	68.0	1.29	18.3	1.2	0.09	0.65
Maridimamba Community Hall	**BS30**	7.02	6.6	532	348	86.9	25	6	96	0.8	186	42	36.8	0.62	12.3	1.2	0.28	0.71
Near govt.school	**BS31**	7.03	6.1	382	250	103.5	35	4	51	0.4	130	36	22.8	0.52	10.2	1.8	0.06	0.96
SC colany	**BS32**	7.12	5.4	423	277	95.1	25	8	67	0.3	162	32	20.6	0.98	12.3	1.8	0.08	1.25
BC Colany	**BS33**	7.10	5.6	420	275	72.7	16	8	76	0.2	145	43	18.9	0.45	12.3	2.4	0.14	0.36
Maridimamba temple	**BS34**	7.12	6.1	541	354	92.6	24	8	94	0.3	162	57	29.3	0.45	26.9	1.4	0.06	0.62
Pydimamba temple	**BS35**	7.08	6.2	842	550	114.9	28	11	167	0.7	270	128	20.4	0.24	6.8	2.6	0.08	0.48
Overhead water tank	**BS36**	7.11	6.2	741	484	127.4	38	8	136	0.5	256	100	14.6	0.32	10.4	1.2	0.06	0.56
Gowthulachanna Colony	**BS37**	7.25	6.4	497	325	57.8	10	8	105	0.9	214	36	10.5	0.41	10.5	1.2	0.04	0.69
Ramalayam - Pinamadaka	**BS38**	7.36	6.1	543	355	64.5	16	6	112	1.2	223	40	20.1	0.45	8.6	0.8	0.12	0.54

Near Golla veedhi	**BS39**	7.04	6.2	464	303	62.8	12	8	95	0.9	204	34	10.5	0.32	5.8	2.2	0.03	0.35
SC -Colany - Pinamadaka	**BS40**	7.01	6.3	487	319	90.9	20	10	87	0.6	186	46	19.5	0.38	8.5	2.6	0.02	0.45
	MIN	6.69	5.00	381.98	249.82	54.54	10.00	4.00	51.00	0.20	130.00	18.00	10.20	0.24	3.50	0.60	0.01	0.35
	MAX	7.65	6.60	2519.18	1647.54	563.60	124.00	62.00	540.00	1.80	686.00	400.00	208.60	1.29	144.50	5.92	0.28	6.84
	AVG	7.13	6.17	1072.72	701.56	151.14	35.08	15.53	206.48	0.65	338.58	130.48	52.07	0.80	23.95	2.00	0.10	1.11
	SD	0.15	0.37	620.25	405.65	116.52	26.03	15.21	132.27	0.37	143.99	106.30	53.73	0.32	27.50	1.29	0.07	1.33

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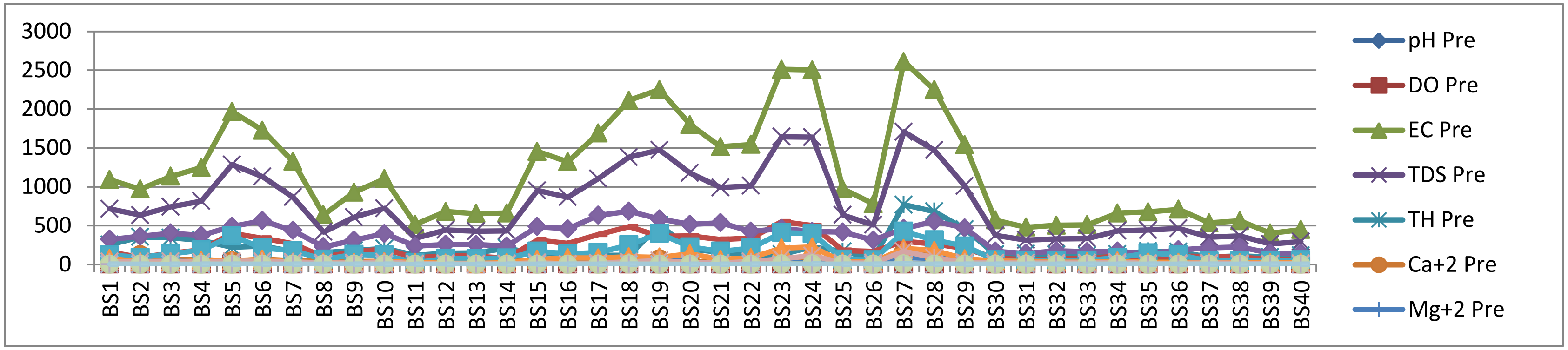

Figure 5: Graphical value of physicochemical parameters during Pre monsoon season- 2018

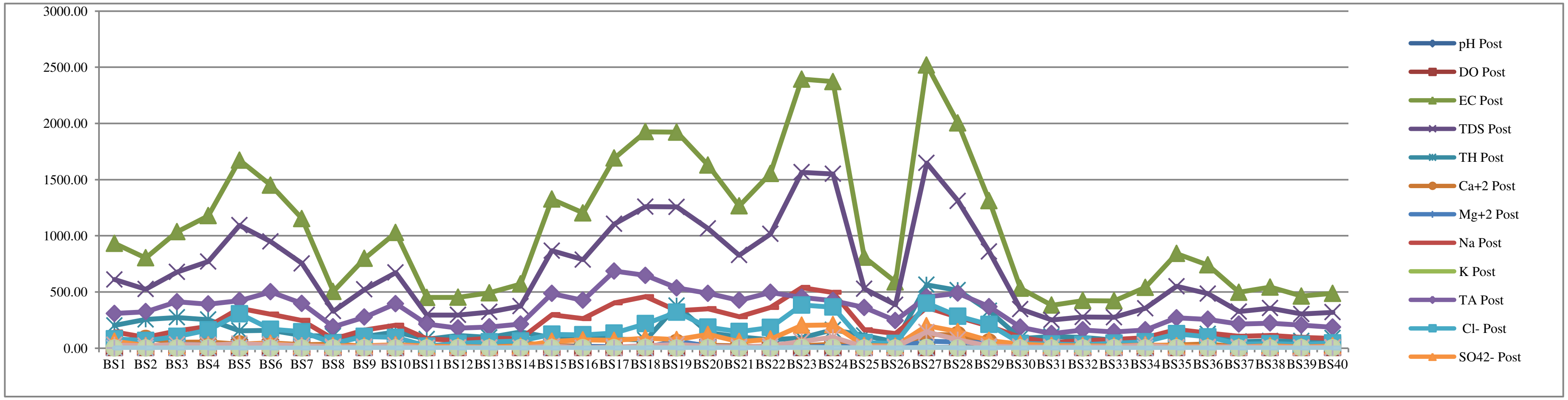

Figure 6: Graphical value of physicochemical parameters during Post- monsoon season- 2018.

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Correlation Analysis:

In both seasons, the correlation coefficient matrix between the various groundwater parameters in the study area revealed both positive and inverse relationships. Some parameters were strongly correlated and some were weakly correlated with others, and some parameters were negatively correlated with others (Tables 4 & 5). A strong correlation was observed among EC to TDS (0.999) followed by TA (0.850), Cl (0.967), and SO4-2 (0.912). TDS is strongly correlated with Mg+ (0.674), TA (0.850), Cl (0.969), SO4-2 (0.922). Calcium & Magnesium were moderately correlated with other parameters but strongly correlated with TH (0.858) & (0.921). Total Alkalinity is strongly correlated with EC (0.846), TDS (0.846), and F- (0.669). SO4-2 is strongly correlated with EC (0.922), TDS (0.922) and Cl-(0.894). pH is negatively correlated with other parameters. Turbidity, DO and Phosphates were weakly correlated with other parameters.

Table 4. The Correlation coefficient matrix among physicochemical parameters in the Study area during the pre- monsoon season of 2018.

	pH	DO	EC	TDS	TH	Ca+2	Mg+2	Na	K	TA	Cl-	SO42-	F-	NO3	BOD	PO4	Turbidity
pH	1																
DO	0.0317	1.0000															
EC	-0.1395	-0.5429	1.0000														
TDS	-0.1395	-0.5429	0.9999	1.0000													
TH	-0.2130	-0.3077	0.5602	0.5602	1.0000												
Ca+2	-0.2794	-0.2386	0.3787	0.3787	0.9049	1.0000											
Mg+2	-0.1131	-0.3194	0.6341	0.6341	0.9157	0.6576	1.0000										
Na	-0.0532	-0.4792	0.9154	0.9154	0.1839	0.0035	0.3222	1.0000									
K	0.0688	-0.1700	0.1566	0.1566	0.4698	0.4704	0.3874	-0.0417	1.0000								
TA	-0.1029	-0.3587	0.8520	0.8520	0.3965	0.2261	0.4884	0.8474	0.0852	1.0000							
Cl-	-0.0812	-0.5350	0.9515	0.9515	0.5972	0.3985	0.6809	0.8347	0.2085	0.6932	1.0000						
SO42-	-0.2310	-0.5615	0.8666	0.8666	0.5088	0.3836	0.5384	0.7556	0.0705	0.5655	0.8293	1.0000					
F-	-0.0860	-0.2625	0.5741	0.5741	0.3118	0.1509	0.4095	0.5397	-0.0841	0.5798	0.4749	0.5397	1.0000				
NO3	-0.2224	-0.5454	0.7492	0.7492	0.7217	0.6587	0.6556	0.5092	0.3311	0.4020	0.7732	0.8203	0.3214	1.0000			
BOD	-0.0562	-0.2507	0.4940	0.4940	0.0869	0.0338	0.1219	0.5118	-0.0904	0.2208	0.4903	0.6598	0.2420	0.5098	1.0000		
PO4	-0.1278	-0.4903	0.5254	0.5254	0.4787	0.4314	0.4401	0.3723	0.0819	0.3083	0.5067	0.6496	0.3772	0.6004	0.2836	1.0000	
Turbidity	-0.0857	-0.4414	0.5394	0.5394	0.3809	0.3374	0.3556	0.4155	0.0846	0.1712	0.5732	0.7080	0.2913	0.8111	0.7162	0.4973	1.0000

Table 5. The Correlation coefficient matrix among physicochemical parameters in the Study area during the post- monsoon season of 2018.

	pH	DO	EC	TDS	TH	Ca+2	Mg+2	Na	K	TA	Cl-	SO42-	F-	NO3	BOD	PO4	Turbidity
pH	1																
DO	0.1265	1.0000															
EC	-0.0227	-0.2448	1.0000														
TDS	-0.0227	-0.2448	0.9999	1.0000													
TH	-0.1343	-0.5896	0.5270	0.5270	1.0000												
Ca+2	-0.1648	-0.5258	0.3704	0.3704	0.9179	1.0000											
Mg+2	-0.0795	-0.5535	0.5978	0.5978	0.9119	0.6742	1.0000										
Na	0.0303	-0.0414	0.9435	0.9435	0.2205	0.0619	0.3463	1.0000									
K	0.1702	-0.3879	0.2365	0.2365	0.5473	0.5396	0.4606	0.0550	1.0000								
TA	0.0261	-0.0258	0.8464	0.8464	0.3397	0.1741	0.4523	0.8671	0.1013	1.0000							
Cl-	-0.0100	-0.3159	0.9540	0.9540	0.5847	0.4216	0.6523	0.8619	0.3060	0.6859	1.0000						
SO42-	-0.1127	-0.3267	0.8800	0.8800	0.4749	0.3766	0.4944	0.8025	0.1686	0.5709	0.8544	1.0000					
F-	-0.0375	-0.1006	0.5771	0.5771	0.3338	0.1897	0.4252	0.5449	-0.0455	0.5704	0.5017	0.5367	1.0000				
NO3	-0.0896	-0.4888	0.7534	0.7534	0.7037	0.6646	0.6223	0.5641	0.4490	0.3881	0.7964	0.8139	0.2815	1.0000			
BOD	-0.0647	-0.1709	0.5819	0.5819	0.1363	0.0845	0.1664	0.5862	0.0058	0.3078	0.5730	0.7265	0.2798	0.5786	1.0000		
PO4	-0.1459	-0.0826	0.4242	0.4242	0.3653	0.3339	0.3346	0.3416	0.0800	0.3249	0.3862	0.4921	0.2626	0.3361	0.1394	1.0000	
Turbidity	-0.0591	-0.2812	0.6708	0.6708	0.3885	0.3510	0.3601	0.5848	0.1764	0.3012	0.7014	0.8142	0.3191	0.8252	0.8212	0.2866	1.0000

Remedial measures:

This study area is a highly mineralized area. Some parameters are showing higher values. Hence, the following water purification methods are recommended to minimize the abnormal concentration of the above-mentioned parameters. They are ultra filtration, flocculation, precipitation, reverse osmosis, ion exchange technique, slow sand filtering, and membrane filtering. Moreover, flotation ion exchange and electrochemical deposition are some best useful techniques for the removal of pollutants and contaminants to purify groundwater.

Conclusions:

The majority of health problems are caused by contaminated water with high concentration levels. This study found that the concentration levels of electrical conductivity, total dissolved solids, total hardness, sodium, potassium, total alkalinity, and chlorides were higher at most of the sampling stations when compared to BIS and WHO standards. At some sampling stations, the remaining parameters have also recorded higher values. The concentration levels were higher in the pre-monsoon season than in the post-monsoon season. DO and turbidity levels were higher in post monsoon season. Sulfate concentrations were slightly higher at a few sampling stations due to sewers, seepage and unsanitary practises. Tanam and Parawada samples had the highest concentrations in the study area among all stations. As a result, the water is unfit for drinking. If no other source is available, it is recommended that the water be treated before consumption. During the monsoon season, pay close attention to this area.

Scope for further study:

From the present study, it is understood that the local ground water is affected. Further, it is suggested to carry out studies to establish sources of impact on ground water in this area viz to see whether sea water intrusion is occurring; to see if any industrial activity is influencing the ground water quality in the area; to see if any percolation is taking place from septic tanks; The current study will aid in the proper planning and management of available drinking water resources.

Recommendations:

Ground water in the study area is showing slightly higher values. Hence, it is recommended that, alternate drinking water sources shall be provided to these villagers.

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Author contribution:

M. Bujjibabu conceptualised, methodology, formal analysis and investigation, and draught preparation. Dr. B. Hari Babu conducted the investigation, supervision, review, and editing.

Data availability:

The author analysed the data and used it in the current study.

Testimonies:

Ethics approval- This article contains no studies with human or animal participants conducted by any of the authors, and permission to publish. The authors declared that all authors reviewed, authorised, and consented to the publication of the final draft of the manuscript.

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