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Hydro Chemical Evaluation of Groundwater in Pernampet Block in Palar River Basin at Vellore District, Tamilnadu, India

Tamilarasi V[1], Murugesan S[1] and Pugazhendi V[2]
[1]PG and Research Department of Botany, Pachaiyappa's College, Chennai, Tamil Nadu, INDIA
[2]Department of Hydrogeology, TWAD Board, Chennai, Tamil Nadu, INDIA

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Abstract

Seventy two number of groundwater samples were collected from 6 locations in Pernampet block in Palar river basin at Vellore District has been evaluated for hydro-chemical quality during 2009 to 2011. The collected samples were analysed for various water quality parameters such as electrical conductivity, total dissolved solids, turbidity, pH, alkalinity, hardness, iron, manganese, chloride, fluoride, nitrate, sulphate and chromium. Using water quality data, water quality Index (WQI) was calculated for the preparation of water quality rating. The present study reveals that the groundwater in Pernampet block, situated in the Palar river basin at Vellore district is contaminated by the parameters such as total dissolved solids, alkalinity, total hardness, calcium, magnesium, sodium, chloride, ammonia, nitrate and chromium.

Keywords: Hydro chemical parameters, groundwater quality, water quality index, water quality rating.

Introduction

Water is the primary natural resources, essential human need and a precious asset. It is required for all living things in all activities and health, for production of food, agriculture, industrial activities, energy generation and maintenance of the environment and development[1] .Water is the most essential commodity for the human consumption and it must be prevented from deterioration in quality[2]. Groundwater is one of the major renewable sources and is greatly affected by anthropogenic activities [3]. Quality of groundwater is declining due to heavy industrialization, disposal of industrial wastes both on land and surface of water bodies and also by human activities[4]. The factor affecting the hydro-chemical quality of groundwater are the developmental activities in industries, agriculture, geological formation, depth of water table , soil structure, infiltration rates etc.[5]. Hence, the studies of water pollution in water sources are essential through periodical monitoring of water quality.

Rivers are considered as main sources of water. All the rivers in India are getting polluted by the discharge of untreated and partially treated industrial effluents from paper mills, tanneries, agricultural runoff, photo industries, etc. In Tamilnadu, the Chennai basin receives the largest load of various pollutants generated from industrial effluents. Today good quality of water has become a precious commodity. The quality of water is getting contaminated due to untreated waste disposal, improper water management and negligence towards the environment protection. These situations lead to scarcity of safe drinking water [6]. Monitoring of drinking water quality is essential to avoid toxic effects on its consumption.

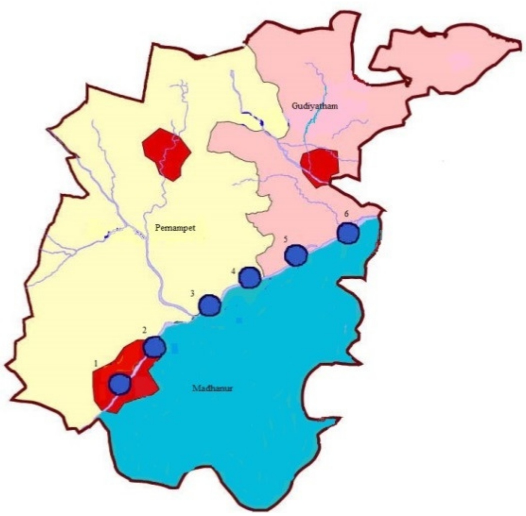
The Cauvery, Vellar and Palar rivers are also receiving pollution load from the industries. In Vellore district, in a stretch of 120 km from Vaniambadi to Walajah about 570 tanneries are functioning in the Palar river basin. Indiscriminate disposal of chemicals rich tannery effluent is causing the degradation of agricultural land, surface water and groundwater vastly. Inland rivers are polluted by indiscriminate disposal of sewage and other domestic waste also. The corporation of Vellore has been constantly trying to find new sources of water in addition to the existing one to cope up with the increasing industrial and domestic demands. People are forced to depend on groundwater for drinking and all other domestic purposes. There is an established fact that underground water is free from impurities and xenobiotic compounds which cannot harm its quality. But many recent studies on groundwater quality reveal that the quality of groundwater is deteriorating day by day. Hence, a regular monitoring of river has become an essential programme to safeguard public health and for the protection of valuable fresh water sources.

Based on the above views, in the present study, an attempt was made on hydro chemical evaluation of groundwater in Pernampet block in Palar river basin at Vellore District.

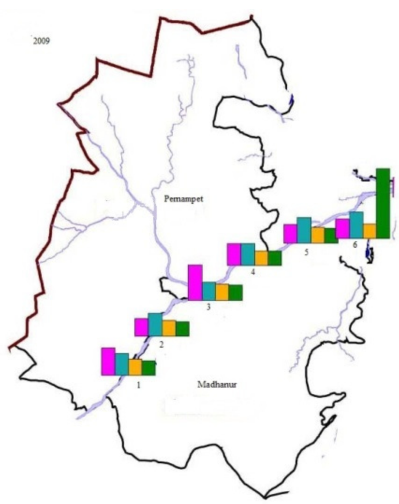
Study Area: From Pernampet block, Palar river basin, Vellore district, Tamilnadu, six numbers of groundwater sources are selected for water sample collection and are listed in the table-1 and figure-1. They are Marapattu near primary school, Kumaramangalam near community hall, Alinjikuppam-Rajakkalpudumani, Thuthipattu near mariammankoil, Devalapuram-Gangaiammankoil street and Pernampet town, Govt- Higher secondary school.

Table-1
Sample Locations

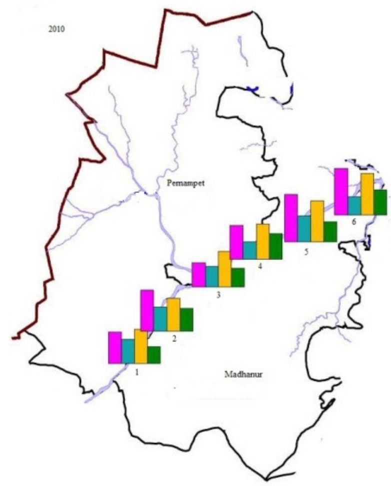
Station Code	Location of sampling	Block
S1	Marapattu, near primary school	Pernampet
S2	Kumaramangalam, near community hall, BW No: 06/29	Pernampet
S3	Alinjikuppam, Rajakkalpudumani, BW No: 06/42/40	Pernampet
S4	Thuthipattu, near mariammankoil	Pernampet
S5	Devalapuram, Gangaiammankoil street	Pernampet
S6	Pernampet town, Govt. Higher secondary school, B.W No:10/96	Pernampet



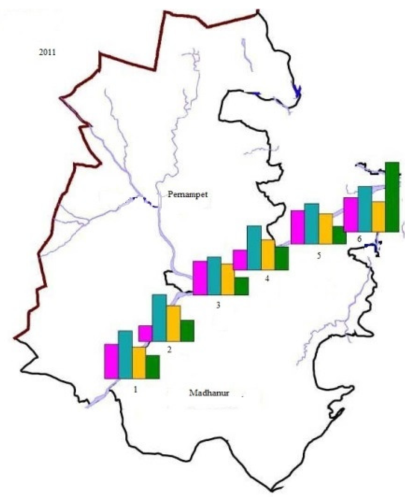
●Sampling location
●Tannery location
Figure-1
Sampling location with Tannery location



●January●April●July●October
Figure-2
Water quality index -2009



●January●April●July●October
Figure-3
Water quality index-2010



●January●April●July●October
Figure-4
Water quality index -2011

Methodology

Water samples are collected from the above said locations at Pernampet block during the month of January, April, July and October for a period of three years of 2009, 2010, and 2011. Totally seventy two samples were collected from six groundwater sources. Proper preservation was carried out before reporting to the laboratory. The water samples were analysed for drinking water quality parameters as referred in the Standard Methods, APHA[7] and the data were compared with the Drinking Water Specifications- BIS-10500-2012[8].

Water Quality Index: Water Quality Index (WQI) is playing key role in assessing the quality of any water sources. It is one of the effective, helpful parameter and provides information data which is important to public, Government and Public

Health Policies for improving the water quality programme [9]. WQI takes a predominant place in water quality management. It indicates water quality in terms of index numbers and offers useful representations of overall quality of water to public. WQI is one of the meaningful devices for groundwater and for all other types of water sources like river, lake and surface water quality analysis [10]. Water quality is the status of the water body or water resource in relation to its various kinds of uses.

Water quality of six sources has been presented, on the basis of calculated water quality indices[11,12]. The estimated quantitative values of water quality parameters and their standards as per the Drinking Water Specifications-IS-10500-2012 were used for WQI calculation.

Water quality index (WQI) has been computed using the formula: $n, \sum w_i q_{i,}\ i = 1$,

Where w_i= weightage factor of i^{th} parameter, qi = quality rating of i^{th} parameter, w_i is calculated from the following equation:
$w_i = (k/S_n)$

Where k = constant = $1 / (1/v_{s1}+ 1/v_{s2}\text{------}+1/v_{sn})$, Sn = standard value of i^{th} parameter, q_i is calculated from the following equation:
$q_i= (v_a-v_i / v_s-v_i) \times 100$

Where v_a = actual value obtained from analysis of i^{th} parameter, v_s = standard value of i^{th} parameter, v_i = ideal value (pH= 7 and 0 for all other parameters)

Results and Discussion

According to the hydro-chemical analytical data of the present study, the water quality index and the water quality ratings are calculated for the year 2009, 2010 and 2011.The water quality index is expressed in the form of bar charts in figure-2, figure-3 and figure-4.

The water quality index and the water quality ratings are tabulated in table-2.

Table-2
WQI and Ratings

Block: Pernampet		**Water Quality Index and Rating**					
Station Code		**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
2009	January,2009	93	43	135	64	48	52
		Severely Polluted	Good	Unfit	Moderately Polluted	Good	Moderately Polluted
	April, 2009	64	69	46	63	84	89
		Moderately Polluted	Moderately Polluted	Good	Moderately Polluted	Severely Polluted	Severely Polluted
	July, 2009	35	35	36	25	34	25
		Good	Good	Good	Excellent	Good	Excellent
	October,2009	27	28	31	25	30	309
		Good	Good	Good	Excellent	Good	Unfit
2010	January,2010	53	75	38	59	88	87
		Moderately Polluted	Moderately Polluted	Good	Moderately Polluted	Severely Polluted	Severely Polluted
	April, 2010	38	38	30	23	41	25
		Good	Good	Good	Excellent	Good	Excellent
	July, 2010	59	57	63	62	74	76
		Moderately Polluted	Moderately Polluted	Moderately Polluted	Moderately Polluted	Moderately Polluted	Severely Polluted
	October,2010	22	35	26	41	28	40
		Excellent	Good	Good	Good	Good	Good
2011	January,2011	37	15	36	20	36	37
		Good	Excellent	Good	Excellent	Good	Good
	April, 2011	53	52	41	49	44	50
		Moderately Polluted	Moderately Polluted	Good	Good	Good	Good
	July, 2011	34	39	33	32	32	32
		Good	Good	Good	Good	Good	Good
	October,2011	24	22	17	24	17	79
		Excellent	Excellent	Excellent	Excellent	Excellent	Severely Polluted

Note: 0 to 25 - Excellent; 26 to 50 - Good; 51 to 75 - Moderately Polluted; 76 to 100 - Severely Polluted; > 100 - Unfit.

The analysed samples were grouped into five classes as excellent (0-25), good (26-50), moderately polluted (51-75), severely polluted (76-100) and unfit for drinking (above 100), based on water quality index and the water quality ratings. In the present study, the WQI ranges from 22-93 in S1, 15-75 in S2,17-135 in S3, 20-64 in S4, 17-88 in S5 and 32-309 in S6. Overall about 58, 67, 83, 67, 75 and 50 percent of the samples are from excellent to good and about 42, 33, 17, 33, 25 and 50 percent of the samples are from moderately polluted to unfit in S1, S2, S3, S4, S5 and S6 respectively. It reveals that the level of water quality contamination is at 42% (minimum level) in S1and 50% (maximum level) in S6.

The guideline values suggested by the Bureau of Indian Standards are used for the above quality assessment. The station wise hydro-chemical data analyses of the present study for each parameter for the year 2009, 2010 and 2011 are tabulated in table-3 and table-4.

Table-3
Station wise Water Quality Data Analyses

Block: Pernampet	**Station wise Water Quality Data Analyses - 2009 to 2011**					
Parameters	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
	Mean Value In mg/l except for pH					
Turbidity	1.01	1.68	1.59	1.02	1.27	3.26
Total dissolved solids	2862.24	2240.61	1738.01	3086.86	2577.23	3662
pH	7.75	7.55	7.759	7.75	7.762	7.84
Total alkalinity	464.52	430.87	352.40	377.68	379.50	440.48
Total hardness	961.45	777.20	613.91	994.51	920.50	1151.40
Calcium hardness	250.90	202.11	145.63	253.65	211.43	306.85
Magnesium hardness	82.64	73.66	54.88	99.27	75.04	94.24
Sodium	465.50	339.25	220.33	486.25	420.92	641.75
Potassium	53.75	32.00	20.00	44.33	35.58	61.00
Iron	0.07	0.07	0.08	0.05	0.08	0.18
Ammonia	0.27	0.32	0.14	0.26	0.32	1.45
Nitrate	90.07	65.22	51.53	79.32	90.55	98.85
Chloride	801.34	587.30	420.66	948.00	775.49	1182.89
Fluoride	1.01	0.88	0.91	1.00	0.98	1.05
Sulphate	265.58	191.59	129.43	285.54	221.95	316.05
Phosphate	0.127	0.07	0.08	0.10	0.11	0.135
Chromium	0.015	0.013	0.007	0.016	0.011	0.028

Table-4
Water Quality Data–Mean Value Analyses

Parameters	**Minimum Mean Value**		**Maximum Mean Value**	
	Value in mg/l except for pH	**Station Code**	**Value in mg/l except for pH**	**Station Code**
Total dissolved solids	1738	S3	3662	S6
pH	7.55	S2	7.84	S6
Total alkalinity	352	S3	465	S1
Total hardness	614	S3	1151	S6
Calcium	146	S3	307	S6
Magnesium	55	S3	94	S6
Sodium	220	S3	642	S6
Potassium	20	S3	61	S6
Iron	0.05	S4	0.18	S6
Ammonia	0.14	S3	1.45	S6
Nitrite	0.02	S3	0.31	S6
Nitrate	52	S3	99	S6
Chloride	421	S3	1183	S6
Fluoride	0.88	S2	1.05	S6
Suphate	129	S3	316	S6
Phosphate	0.07	S2	0.13	S6
Chromium	0.007	S3	0.028	S6

Total dissolved solids (TDS) indicate the inorganic pollution load of any water resource. It is the sum of all dissolved chemicals present in water and it reduces the solubility of oxygen in water. In the present study, the minimum TDS value of 1738 mg/l is recorded in S3 and the maximum value of 3662 mg/l is recorded in S6. The higher values indicated the effect of overland flow. The guideline value suggested by the Bureau of Indian Standards is 500–2000 mg/l. The high value of TDS produces aesthetically displeasing colour, odour and taste to water and causes gastro intestinal irritation on consumption[13]. It can be removed by distillation, solar evaporation and by reverse osmosis.

The pH value of drinking water is an index of acidity or alkalinity nature, which depends on the carbon-di-oxide, carbonate and bicarbonate equilibrium and is contributed by industrial waste. In the present study, it ranges from a minimum value of 7.55 in S2 and maximum value of 7.84 in S6 which is a safe range for drinking as well as for the growth of plants. The guideline value suggested by the Bureau of Indian Standards is 6.5–8.5. The similar observations were recorded by Suthan *et al.*[14]. Though the pH value has no direct effect on health, it can able to alter the taste of water[15].

The alkalinity in natural resource mainly includes carbonate, bicarbonate and hydroxide, which is derived from dissolution of mineral substances in soil and atmosphere[16]. Alkalinity of water is a measure of its capacity to neutralize acids [17]. The salts of carbonates and bicarbonates with hydroxyl ions in a free state constitute alkalinity[18]. In the present study, the minimum alkalinity value of 352 mg/l is recorded in S3 and the maximum value of 464 mg/l is recorded in S1. The guideline value suggested by the Bureau of Indian Standards is 200 –600 mg/l. Alkalinity values are providing guidance in applying proper doses of chemicals in water and wastewater treatment process, particularly, in coagulation, softening and operation control of anaerobic digestion process. It can be removed by distillation, solar evaporation and by reverse osmosis.

Total hardness of water is the sum of total concentration of alkaline earth metals such as calcium and magnesium ions present in water. In the present study, the minimum hardness value of 614 mg/l is recorded in S3 and the maximum value of 1151 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 300 – 600 mg/l. Hardness has no adverse effect on human health. However, some evidence has attributed about its role in heart disease[19]. It causes scale formation, skin irritation, consume more time and fuel for cooking. It can be removed by distillation, solar evaporation and by reverse osmosis.

High content of calcium is contributed from the soil. In the present study, the minimum calcium value of 146 mg/l is recorded in S3 and the maximum value of 307 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 75–200 mg/l. The high level of calcium may be imparted from the rock soil in the study areas[20]. Excessive calcium causes concretions in the human body and may cause gastro-intestinal problem. It can be removed by distillation, solar evaporation and by reverse osmosis.

The tolerances level of magnesium by human body is lower than that of calcium. In high concentration it works as laxative and give objectionable taste to the water. Magnesium contributes to hardness in the water. In the present study, the minimum magnesium value of 55 mg/l is recorded in S3 and the maximum value of 94 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 30–100 mg/l. It can be removed by distillation, solar evaporation and by reverse osmosis.

The iron content is contributed by soil and rocks. In the present study, the minimum iron value of 0.05 mg/l is recorded in S4 and the maximum value of 0.18 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 0.3-1.0 mg/l. Iron provides unpleasant taste and stains cloths, plumbing fixtures and dishes. Iron causes indigestion and constipation in human beings[21]. It can be removed by precipitation by aeration and filtration through activated charcoal is suggested for water having a higher concentration of iron depending upon the iron concentration and pH value.

Sodium concentration in the present study were observed minimum value of 220 mg/l in S3 and maximum value of 642 mg/l in S6 and potassium as minimum value of 20 mg/l in S3 and maximum value of 61 mg/l in S6. Sodium in water is a parameter computed to evaluate the suitability for irrigation. Excess of sodium with carbonate will forms alkaline soil, while with chloride and sulphate will form saline soils, which are not suitable for irrigation[22].

The presence of ammonia in waters is accepted as the chemical evidence of very recent organic pollution by sewage. Ammonia is formed as a result of the decomposition of nitrogenous organic materials. In the present study, the minimum ammonia value of 0.14 mg/l is recorded in S3 and the maximum value of 1.45 mg/l is recorded in S6. Ammonia is toxic to aquatic life and it can be removed by a biological oxidation method.

Nitrate content is due to organic and sewage pollution. Increased agricultural activities and application of fertilisers will also increase the nitrate content. In the present study, the minimum nitrate value of 52 mg/l is recorded in S3 and the maximum value of 99 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 45 mg/l. The presence of excess nitrate causes health hazards to humans[23]. This will cause methaemoglobinemia[24] (Blue baby disease) and it influences the growth of algae. The removal of nitrate is not an easy process, but it can be possible by the reverse osmosis system with softeners can remove nitrate contamination[25].

The salty taste produced by chloride concentration is variable depending on other chemical composition of water. Chloride concentration is used as an indicator of pollution by sewage [26]. Disposal of sewage and industrial wastes are the greatest source of chloride in fresh water [20]. Its concentration will be highest where the temperature is high with less rainfall. Chloride might be derived from natural processes in the earth, industrial effluent of soda ash, refineries and tanneries. In the present study, the minimum chloride value of 421 mg/l is recorded in S3 and the maximum value of 1183 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 250–1000 mg/l. Chloride content affects the taste of water and corrosive nature. Chloride can be removed by installing chloride removal unit in the sources by local functionaries.

Fluoride content is contributed from the soil and rocks. It is also derived from fertiliser effluent and fluoride based industries. In the present study, the minimum fluoride value of 0.88 mg/l is recorded in S2 and the maximum value of 1.05 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 1.0 - 1.5 mg/l. Fluoride concentration less than 0.5 mg/l is harmful and may cause dental carries. High fluoride concentration greater than 1.5 mg/l will cause both dental and skeletal fluorosis and other non-skeletal manifestation. Removal of fluoride from drinking water is suggested through various de-fluoridation techniques, including quick reverse osmosis, electro-dialysis and precipitation followed filtration by using alum and lime and also by the adsorption method by using activated alumina based on ion exchange resin. The Nalgonda technique is an economical way of de-fluoridation.

Sulphate ions are derived from the solution of calcium and magnesium ions. The sulphate ion can produce bitter taste at high concentration. In the present study, the minimum sulphate value of 129 mg/l is recorded in S3 and the maximum value of 316 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 200–400 mg/l. The sulphate contents are within admissible limit. The results of this study are on par with the observations of Rao *et al.*, 2004. The biochemical and anthropogenic sources and industrial process contribute the sulphate content to the water[27]. Sulphate content affects the taste of water also. It can be removed by solar evaporation method and by the reverse osmosis method. Aeration is very effective in removing H_2S.

Phosphate content is of great importance in the determination of biological productivity in water [15]. In natural water the phosphate content gets increased due to degradation and decomposition of organic matter [28]. The presence of phosphate is caused by pollution by infiltration of waste water from domestic and industrial sources. In the present study, the minimum phosphate value of 0.07 mg/l is recorded in S2 and the maximum value of 0.13 mg/l is recorded in S6. Agricultural run-off containing phosphate fertiliser as well as the waste water containing the detergents tends to increase pollution in water [29]. It can be removed by precipitation method by using poly aluminium chloride.

High chromium content may be contributed from tanneries, pharmaceuticals, pigments, metal works or a combination of all[30]. In the present study, the minimum chromium value of 0.007 mg/l is recorded in S3 and the maximum value of 0.028 mg/l is recorded in S6. The guideline value suggested by the Bureau of Indian Standards is 0.5 mg/l. Though the minimum value of chromium is recorded, it is affecting the cultivation land on accumulation. The high dose of chromium causes liver and kidney damages and chromium dust is reported as carcinogenic[31]. It can be removed by the chemical reduction method by using sodium bisulphate and also by chemical precipitation by using lime and caustic soda.

A greater number of tannery units are located in the western part of Erode and most of these units carrying out process of animal hides requiring a considerable amount of water. The effluents from various tanneries are discharged without treatment through nearby the drain, which finally join the downstream on the Cauvery. In addition, Erode has a cluster of textile units. The small units generate a significant amount of effluent per day. Most of these effluents are discharged into the Bhavani and Cauvery rivers. In the long run, this may result in the reduction of dissolved oxygen and affects aquatic life in the mainstream rivers[32].

Conclusion

The water quality is directly proportional to the human health. The development of cost effective pollution control strategies are the challenge for developing countries [33] and the analytical cost involved could be a limiting factor for water quality assessments with scarce budgets [34]. In this situation, the usage of WQI, with few simple parameters will be an advantage process.

In the present study, the WQI ranges from 22-93 in S1, 15-75 in S2,17-135 in S3, 20-64 in S4, 17-88 in S5 and 32-309 in S6. Overall 58, 67, 83, 67, 75 and 50 percent of the samples are from excellent to good and 42, 33, 17, 33, 25 and 50 percent of the samples are from moderately polluted to unfit in S1, S2, S3, S4, S5 and S6 respectively. From the above it is observed, that the groundwater quality in Pernampet block is affected by the level of 42% in S1 and 50% in S6. Both S1 and S6 are situated near tannery location, whereas S2, S3, S4 and S5 are in the midway. It clearly indicates that the high level contamination of groundwater is by the discharge of tannery effluent without proper treatment.

Further, the maximum value for TDS, alkalinity, total hardness, calcium, magnesium, sodium, chloride, ammonia, nitrate and chromium is also recorded in S6. So, both WQI and water quality data are clearly indicating that the groundwater quality in the Pernampet block area situated in a Palar river basin at Vellore district is deteriorated and requires some degree of treatment before consumption. Therefore, the periodical water quality monitoring has become essential. The administration of corporation should seriously deal with the drinking water supply and monitor the quality continuously. This information will be of great value to water users like people, planners, water suppliers and the policy makers. It also needs an integrated approach of public and private sector to protect the groundwater from contamination. The regular water quality monitoring can be undertaken seasonally and spatially to identify the source of toxic pollution and adoption of proper disposal of waste to protect the quality of the groundwater.

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