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Groundwater Quality Status and Pollution Assessment of K.R.Puram Industrial Area by the Use of Nemerow's Pollution Index

B.S. Shankar

Department of Civil Engineering, East Point College of Engineering and Technology, Virgongar Post. Bidarahalli,
Bangalore- 560 049, Karnataka, India.

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ABSTRACT

Water quality monitoring is fast becoming a topic of utmost importance and concern as it deals the health and health issues faced by people. One of the widely employed approaches in water quality assessment is the Nemerow index method and this approach has been employed in the current study and the groundwater quality of K.R.Puram industrial area in Bangalore, India, has been assessed. The quality evaluation has been done by collecting thirty groundwater samples each, both during the pre-monsoon and post-monsoon periods of the year 2017, in and around the K.R.Puram area and subjecting the samples to a comprehensive physico-chemical analysis. To calculate the Nemerow index, ten critical parameters vital from the health point of view has been considered, namely, pH, calcium, magnesium, total hardness, nitrate, chloride, sulphate, total dissolved solids, fluorides and iron. The NPI analysis carried out for these thirty samples revealed that a whopping 93.33 % of the samples exceeded unity, the upper limit for drinking water. The high value of NPI at these stations is mainly due to the excessive concentrations of total dissolved solids, hardness, nitrate, iron, calcium and chlorides. The analysis reveals that most of the groundwater samples are unfit for drinking purposes, which calls for continuous monitoring of groundwater supplies and to adopt a systematic environment management plan to safeguard against the pollution of drinking water.

Introduction

One of the biggest issues affecting the world is the quality of our meager resource, the groundwater, due to population explosion, high rate of industrialization, haphazard urbanization, pollution flow from upstream to downstream, excessive usage of fertilizers as well as pesticides in agricultural activities (Joarder et al., 2008). 50% wastes from industries are directly released to rivers and seas. Hence the water quality also changes. As a result, it is absolutely necessary to analyze the water quality (Musalaiah et al., 2017). But groundwater contamination monitoring is not easy to assess, especially when the sample size is huge and involving a number of quality parameters. Thus, the contamination indices are employed, which minimize the volume of data considerably and thereby eases the methodology of contamination scenario (Prasoon Kumar Singh et al., 2014).

Researchers have used a number of groundwater quality evaluation methods such as fuzzy comprehensive evaluation method (Fu et al., 2011), artificial neural network (Zhang et al., 2013), gray clustering method (Zhou et al.,2007), analytic hierarchy process (Su at al.,1997), Nemerow index method (Li, et al., 2009). Among them, the Nemerow index method is simple and easy to operate, which is not available in other comprehensive assessment methods (Kou et al., 2012).

In the current work, Nemerow's Pollution Index (NPI) has been chosen to evaluate the groundwater quality with respect to important parameters causing pollution.

Nemerow's pollution index is a simplified pollution index introduced by Neme (Rathod et al.,2011) which is also known as Raw's pollution index. NPI provides information about extent of pollution for a particular water quality parameter with reference to its standard value. By calculating and analyzing the NPI values of water quality parameters for a region, principal pollutants of that region can be identified; which is a vital information regarding deteriorating water quality of the area as well as for the improvement of water quality in the area (Swati and Umesh, 2015).

The NPI, which is one of the most effective and simplified tools to communicate information on overall quality status of water to the concerned user community and policy makers.It is a powerful tool for processing analyzing, and conveying raw environmental information to decision makers, managers, technicians and the public (Caeiro et al., 2005). Nemerow pollution index, which combines the average value as well as maximum value of pollutants, was used to evaluate the water quality of M River by Li Ya-nan et al., 2008 and Guang et al. (2010).

Materials and methods of analysis

Details of the study area

The city of Bangalore is located between north latitude 12°52'21" to 13°6'0" and east longitude 77°0'45" to 77°32'25". K.R. Puram industrial area is the study area located in the heart of the city and forms a part of the topo sheet of Survey of India ,57 G/12. The area has a spread of 44 sqkm comprising of 850 industries of diversified category.

Tele: +91-08792531778
E-mail address: shanky5525@gmail.com

The area suffers from acute shortage of drinking water supplies. With no proper source to supply water, the 315 borewells and around 55 hand pumps struggle to meet the drinking water requirements. Poor sanitation still prevails, with the presence of percolation wells/soak pits resulting in the contamination of groundwater from both the community and disposal of industrial effluents (Bangalore Shankar and Latha Sanjeev, 2008).

Sampling and analysis

The analysis was carried out by identifying 30 groundwater sampling stations and collecting samples from these stations comprising both the open wells as well as borewells during the pre-monsoon (April-May) as well as post-monsoon (October and November) seasons in two litre PVC containers. These were sealed properly, made airtight and later analyzed for the physico-chemical parameters, in compliance with the Standard Methods for the Examination of Water and Wastewater (APHA,2002). The analysis results obtained have been interpreted in accordance with the standards prescribed under ‘Indian Standard Drinking Water Specification IS 10500: 2003’ of Bureau of Indian Standards (BIS,2003). For computing NPI, however, 10 critical parameters from the health point of view have been considered. Fig 1 depicts the location map of K.R. Puram along with the sampling stations.

Evaluation of Nemerow Pollution Index (NIP)

Nemerow’s pollution index is evaluated with respect to the values of ten critical parameters, analyzed during the pre and post -monsoon seasons of 2017.

The NPI is computed using the equation 1.

NPI = Ci / Li ………………. (1)

Where Ci = observed concentration of i^{th} parameter

L_i=permissible limit of i^{th} parameter(Swati and Umesh, 2015)

Both the terms Ci and Li should bear the same units. Each value of NPI shows the relative pollution contributed by single parameter (Sudhakar Gummadi et al., 2015). NPS is an unitless quantity. Li values for different water quality parameters are indicated in Table 1.

Table 1. Standard values of water quality parameters for NPI computation.

Parameter	**Permissible/ Standard value as per BIS (L_i)**
pH	8.5
Total Hardness	300
Calcium	75
Magnesium	30
Chloride	250
Nitrate	45
Sulphate	200
TDS	500
Fluoride	1.5
Iron	0.3

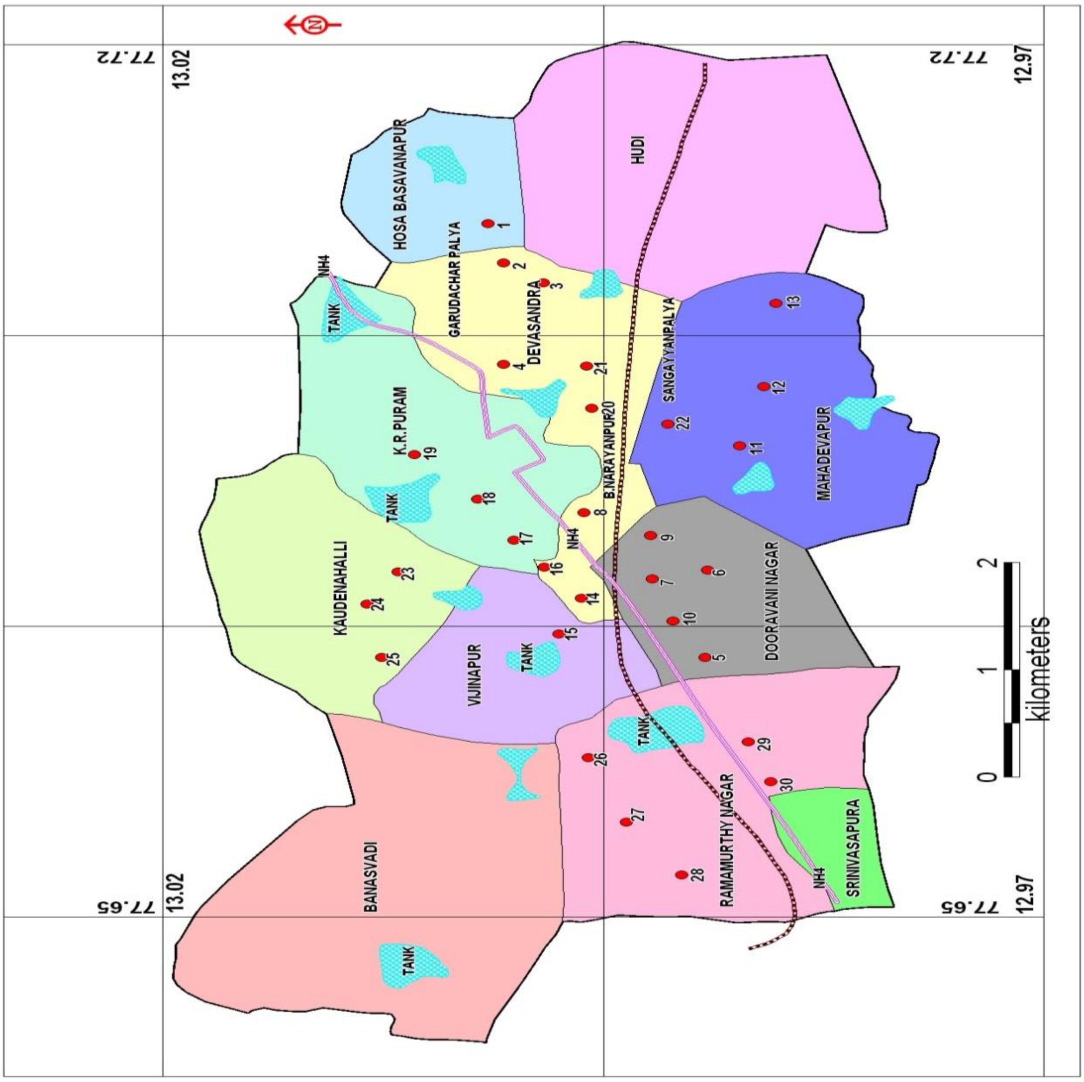

Fig 1. Location map of K.R.Puram industrial area showing the sampling stations.

Results and Discussion

Physico-chemical analysis

Thirty samples were collected from the groundwater of the study area comprising of all the water sources and were analyzed for ten critical physico-chemical parameters. The results of the physico-chemical analysis during pre and post monsoon seasons are presented in Table 2 and Table 3 respectively and the interpretations of the same has been pictorially represented results in figures 2 to 4.

Out of the thirty samples analyzed for physico-chemical parameters, 17 (56.67%) were found to be non-potable as per the maximum permissible BIS standards as depicted in Fig 2. Atleast one or more parameters such as nitrates, total hardness, calcium, total dissolved solids (TDS), pH, chlorides and iron accounted for the high percentage of non-potability of the thirty samples examined. The main causative constituent for the non-potability of the sample is nitrates, which has accounted for the non-potability of 46.67% and 53.33% of the samples tested during pre and post monsoon seasons respectively. Total hardness accounted for 26.67% and 30% non-potability respectively, calcium for 20% and 23.33%, and TDS for 13.33% and 10% of unsafe samples respectively, as per the potable water criteria norms laid down by the BIS.

The study area has shown excessive concentrations of nitrates. The maximum, minimum and average concentrations of nitrates are found to be 256 mg/l and 243 mg/l in the two seasons respectively, as presented in Tables 2 and 3, which also gives the concentrations for other critical parameters. Nitrates in several samples are quite high, when compared to a BIS permissible limit of 45 mg/l. In the study area, organic origin is probably the cause for most of such occurrences, which can be assigned fairly definitely to drainage of water through soil containing domestic and industrial wastes, vegetable and animal matter. Septic tanks and garbage dump disposal may also be responsible for the high nitrate content in the study area. Water with more than 45 mg/l of nitrate is not permissible for drinking as per BIS standards and the limit is mandatory as, excess ingestion of nitrates may cause various health hazards. Nitrates oxidize the hemoglobin to methemoglobin and cause a number of diseases, which are mostly dependent on the intensity and duration of nitrate consumption (Perlstein and Attala, 1976). The consumption of nitrate rich water causes a large number of diseases like dizziness, abdominal disorder, vomiting, weaknesses, high rate of palpitation, mental disorder and even stomach cancer etc. (Thind,1982., Burt et al., 1993).

The maximum concentration of total hardness during the pre and post-monsoons seasons is, 1410 mg/l and 1468 mg/l as $CaCO_3$ respectively. The maximum calcium concentrations are 432 mg/l and 440 mg/l respectively.

The high degree of hardness in the study area can definitely be attributed to the disposal of untreated / improperly treated sewage and industrial wastes. The maximum permissible limit of total hardness as per BIS is 600mg/l. Hard water leads to incidence of urolithiasis (WHO, 1984), anencephaly, parental mortality, some types of cancer and cardio-vascular disorders (Durvey,1991). Such waters can also develop scales in water heaters, distribution pipes and well pumps, boilers and cooking utensils, and require more soap for washing clothes (Todd, 1980., Karanth, 1997).

Total dissolved solids are found to have maximum concentration of 2590 mg/l during both the seasons. Waters with high total dissolved solids (>2000mg/l) are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer and gastrointestinal irritation (Dhembare et al.,2002). TDS signifies the inorganic pollution load of any water body (Sangeetha et al., 2000).

Iron concentrations revealed a high of 1.12 mg/l and 1.22 mg/l respectively in the two seasons. The higher value may be due to rusting of casing pipes, non-usage of borewells for long periods and disposal of scrap iron in open areas due to industrial activity (Shankar et al.,2008)

Only one sample had excess fluorides, with a high of 2.3 mg/l and 2.4 mg/l respectively in the two seasons. Fluorides in excess of 1.5 mg/l may lead to a crippling and painful disease called fluorosis, which may be in the form of dental fluorosis, skeletal fluorosis and non-skeletal fluorosis (Lakshmanan, and Rao,1994).

Chlorides in the groundwaters revealed a high of 1,165mg/l and 1,198 mg/l as against a B.I.S maximum limit of 1000mg/l and accounted for the non-potability of 6.67% of the samples. The higher value can definitely be attributed to the discharge of industrial effluents, which are contaminating the groundwater.

All these observations have been made against the maximum permissible limits and not the standard/allowable limits.

Table 2. Results of physico-chemical analysis of groundwater samples during pre-monsoon.

Sample no	p^H	Total Hardness, mg/l as CaCO3	Ca, mg/l	Mg, mg/l	Fe, mg/l	Cl, mg/l	NO_3, mg/l	SO_4, mg/l	TDS, mg/l	F, mg/l
1	8.2	170	52	10	0.64	110	16	66	590	1
2	7.2	314	96	18	1.02	200	32	70	670	2.3
3	8	514	160	28	0.88	400	70	96	1200	nil
4	7.92	302	88	20	0.16	320	22	80	810	nil
5	8.21	815	224	62	0.16	610	97	86	1600	nil
6	6.92	190	61	9	0.33	148	91	67	950	0.82
7	8.35	325	79	31	0.12	230	41	60	720	0.4
8	7.32	409	88	46	0.4	274	123	82	1110	0.22
9	7.9	813	260	40	0.12	740	186	242	2310	0.12
10	7.45	195	50	17	0.7	90	29	55	560	0.44
11	6.48	1410	432	81	0.23	1165	110	223	2590	0.46
12	6.56	323	80	30	0.46	258	6	116	920	0.46
13	7.9	654	203	36	0.22	462	44	60	1060	0.8
14	6.24	424	137	20	1.12	510	232	140	1800	0.38
15	7.51	454	162	12	0.12	532	155	180	2010	0.52

16	7.66	670	170	60	0.1	434	243	68	1470	0.48
17	7.2	584	186	29	0.26	420	137	144	1580	0.14
18	8.4	195	60	11	0.1	130	20	55	670	nil
19	7.51	494	94	63	0	512	242	192	1730	0.66
20	7.55	210	46	23	0.2	106	32	36	540	0.52
21	7.66	774	254	34	0.1	902	235	208	2410	0.25
22	8.2	116	40	4	0.08	70	34	50	410	nil
23	8	224	60	18	0.52	200	30	40	530	nil
24	6.5	1240	286	128	0.4	1060	122	22	1940	nil
25	7.3	530	140	44	0.08	490	32	130	1200	nil
26	6.88	354	107	21	0.22	224	152	155	1050	0.14
27	6.1	622	160	54	0.29	480	38	108	1370	1.3
28	7.9	240	76	12	0	180	20	49	720	1.4
29	6.9	150	44	10	0	90	12	33	410	1.4
30	7.1	290	80	22	0.08	240	36	102	750	nil

Table 3. Results of physico-chemical analysis of groundwater samples during post-monsoon.

Sample no	P^H	Total Hardness, mg/l as CaCO3	Ca, mg/l	Mg, mg/l	Fe, mg/l	Cl, mg/l	NO_3, mg/l	SO_4, mg/l	TDS, mg/l	F, mg/l
1	8.2	200	50	18	0.56	140	22	80	520	1.1
2	7.2	330	100	20	1.14	240	38	80	670	2.4
3	8.1	502	152	30	0.72	432	88	104	1120	nil
4	7.94	330	96	22	0.28	360	30	86	800	nil
5	8.22	856	244	60	0.26	660	122	94	1540	nil
6	6.94	206	66	10	0.29	160	96	72	800	1.04
7	8.3	372	90	36	0	270	54	70	750	0.8
8	7.34	450	114	40	0.2	300	144	100	1050	0.42
9	8	920	280	55	0.22	820	214	260	2200	0.12
10	7.46	150	40	12	0.9	104	32	60	470	0.5
11	6.49	1468	440	90	0.38	1198	140	230	2590	0.24
12	6.56	288	76	24	0.38	266	10	130	790	0.66
13	7.9	710	212	44	0.36	520	60	80	1090	1
14	6.26	398	120	24	1.22	550	254	180	1730	0.44
15	7.52	464	150	22	0.12	564	172	222	1840	0.68
16	7.66	670	170	60	0.1	434	243	68	1330	0.48
17	7.22	666	214	32	0.34	482	144	170	1530	0.2
18	8.42	186	50	15	0.08	144	22	62	530	nil
19	7.53	524	78	80	0	604	256	212	1780	0.74
20	7.56	216	54	20	0.22	124	36	42	460	0.7
21	7.67	802	272	30	0.18	964	248	220	2380	0.42
22	8.22	100	30	6	0	76	30	55	340	nil
23	8	270	72	22	0.3	260	34	44	560	nil
24	6.52	1326	314	132	0.4	1124	140	28	1960	nil
25	7.31	516	128	48	0.07	510	36	126	1130	nil
26	6.89	360	100	27	0.28	240	168	170	980	0.22
27	6.11	640	174	50	0.32	512	40	118	1250	1.6
28	7.92	258	80	14	0	210	24	58	640	1.4
29	6.94	166	40	16	0	100	16	38	340	1.42
30	7.21	312	92	20	0	260	40	116	710	nil

Quality Assessment using NPI

Ten water quality parameters mentioned in Table 1 were considered for calculating the NPI values as explained earlier in this paper. The table also depicts the Li values for various quality parameters. NPI values exceeding 1.0 indicate the presence of contaminant in water.

As per Nemerow's Pollution Index (NPI), the pollution creating parameters at each station is calculated for both the pre-monsoon and post-monsoon seasons and presented in Tables 4 and 5, which also present the values of NPI. The predominant pollutants in the study area at each station during both seasons are identified and presented in Table 6.

On the basis of NPI, 28 out of 30 samples tested indicated pollution with TDS the largest contributor having NPI values greater than 1, equivalent to a massive 93.33% and 90% during the pre and post-monsoon respectively, clearly revealing the hazardous levels of TDS in groundwater. Total hardness was the second largest contributor of pollution with 66.67% of the samples exhibiting hardness values for NPI above 1. Chlorides were found to have excess NPI in 56.67% and 66.67% samples in pre and post-monsoon seasons respectively. Nitrate was next with 46.67% and 53.33% of the samples having higher NPI values. Iron also showed predominantly high NPI values with 33.33% and 36.67% of the samples exceeding the permissible value. The conventional analysis results as well as NPI analysis reveal considerable uniformity with respect to contributing to significant pollution in the study area.

Table 4. Results of NPI values computed for groundwater quality parameters during pre-monsoon.

Sample no	p^H	NPI	Total Hardness,mg/l as $CaCO_3$	NPI	Ca ,mg/l	NPI	Mg, mg/l	NPI	Fe, mg/l	NPI	Cl, mg/l	NPI	NO_3, mg/l	NPI	SO_4, mg/l	NPI	TDS, mg/l	NPI	F, mg/l	NPI
1	8.2	0.96	200	0.67	50	0.67	18	0.6	0.56	1.87	140	0.56	22	0.49	80	0.4	520	1.04	1.1	0.73
2	7.2	0.85	330	1.1	100	1.33	20	0.67	1.14	3.8	240	0.96	38	0.84	80	0.4	670	1.34	2.4	1.6
3	8.1	0.95	502	1.67	152	2.03	30	1	0.72	2.4	432	1.73	88	1.96	104	0.52	1120	2.24	0	0
4	7.94	0.93	330	1.1	96	1.28	22	0.73	0.28	0.93	360	1.44	30	0.67	86	0.43	800	1.6	0	0
5	8.22	0.97	856	2.85	244	3.25	60	2	0.26	0.87	660	2.64	122	2.71	94	0.47	1540	3.08	0	0
6	6.94	0.82	206	0.69	66	0.88	10	0.33	0.29	0.97	160	0.64	96	2.13	72	0.36	800	1.6	1.04	0.69
7	8.3	0.98	372	1.24	90	1.2	36	1.2	0	0	270	1.08	54	1.2	70	0.35	750	1.5	0.8	0.53
8	7.34	0.86	450	1.5	114	1.52	40	1.33	0.2	0.67	300	1.2	144	3.2	100	0.5	1050	2.1	0.42	0.28
9	8	0.94	920	3.07	280	3.73	55	1.83	0.22	0.73	820	3.28	214	4.76	260	1.3	2200	4.4	0.12	0.08
10	7.46	0.88	150	0.5	40	0.53	12	0.4	0.9	3	104	0.42	32	0.71	60	0.3	470	0.94	0.5	0.33
11	6.49	0.76	1468	4.89	440	5.87	90	3	0.38	1.27	1198	4.79	140	3.11	230	1.15	2590	5.18	0.24	0.16
12	6.56	0.77	288	0.96	76	1.01	24	0.8	0.38	1.27	266	1.06	10	0.22	130	0.65	790	1.58	0.66	0.44
13	7.9	0.93	710	2.37	212	2.83	44	1.47	0.36	1.2	520	2.08	60	1.33	80	0.4	1090	2.18	1	0.67
14	6.26	0.74	398	1.33	120	1.6	24	0.8	1.22	4.07	550	2.2	254	5.64	180	0.9	1730	3.46	0.44	0.29
15	7.52	0.88	464	1.55	150	2	22	0.73	0.12	0.4	564	2.26	172	3.82	222	1.11	1840	3.68	0.68	0.45
16	7.66	0.9	670	2.23	170	2.27	60	2	0.1	0.33	434	1.74	243	5.4	68	0.34	1330	2.66	0.48	0.32
17	7.22	0.85	666	2.22	214	2.85	32	1.07	0.34	1.13	482	1.93	144	3.2	170	0.85	1530	3.06	0.2	0.13
18	8.42	0.99	186	0.62	50	0.67	15	0.5	0.08	0.27	144	0.58	22	0.49	62	0.31	530	1.06	0	0
19	7.53	0.89	524	1.75	78	1.04	80	2.67	0	0	604	2.42	256	5.69	212	1.06	1780	3.56	0.74	0.49
20	7.56	0.89	216	0.72	54	0.72	20	0.67	0.22	0.73	124	0.5	36	0.8	42	0.21	460	0.92	0.7	0.47
21	7.67	0.9	802	2.67	272	3.63	30	1	0.18	0.6	964	3.86	248	5.51	220	1.1	2380	4.76	0.42	0.28
22	8.22	0.97	100	0.33	30	0.4	6	0.2	0	0	76	0.3	30	0.67	55	0.28	340	0.68	0	0
23	8	0.94	270	0.9	72	0.96	22	0.73	0.3	1	260	1.04	34	0.76	44	0.22	560	1.12	0	0
24	6.52	0.77	1326	4.42	314	4.19	132	4.4	0.4	1.33	1124	4.5	140	3.11	28	0.14	1960	3.92	0	0
25	7.31	0.86	516	1.72	128	1.71	48	1.6	0.07	0.23	510	2.04	36	0.8	126	0.63	1130	2.26	0	0
26	6.89	0.81	360	1.2	100	1.33	27	0.9	0.28	0.93	240	0.96	168	3.73	170	0.85	980	1.96	0.22	0.15
27	6.11	0.72	640	2.13	174	2.32	50	1.67	0.32	1.07	512	2.05	40	0.89	118	0.59	1250	2.5	1.6	1.07
28	7.92	0.93	258	0.86	80	1.07	14	0.47	0	0	210	0.84	24	0.53	58	0.29	640	1.28	1.4	0.93
29	6.94	0.82	166	0.55	40	0.53	16	0.53	0	0	100	0.4	16	0.36	38	0.19	340	0.68	1.42	0.95
30	7.21	0.85	312	1.04	92	1.23	20	0.67	0	0	260	1.04	40	0.89	116	0.58	710	1.42	0	0

Table 5. Results of NPI values computed for groundwater quality parameters during post-monsoon.

Sample no	p^H	NPI	Total Hardness,mg/l as $CaCO_3$	NPI	Ca ,mg/l as Caco3	NPI	Mg, mg/l as CaCO3	NPI	Fe, mg/l	NPI	Cl, mg/l	NPI	NO_3, mg/l	NPI	SO_4, mg/l	NPI	TDS, mg/l	NPI	F, mg/l	NPI
1	8.2	0.96	170	0.57	52	0.69	10	0.33	0.64	2.13	110	0.44	16	0.36	66	0.33	590	1.18	1	0.67
2	7.2	0.85	314	1.05	96	1.28	18	0.6	1.02	3.4	200	0.8	32	0.71	70	0.35	670	1.34	2.3	1.53
3	8	0.94	514	1.71	160	2.13	28	0.93	0.88	2.93	400	1.6	70	1.56	96	0.48	1200	2.4	0	0
4	7.92	0.93	302	1.01	88	1.17	20	0.67	0.16	0.53	320	1.28	22	0.49	80	0.4	810	1.62	0	0
5	8.21	0.97	815	2.72	224	2.99	62	2.07	0.16	0.53	610	2.44	97	2.16	86	0.43	1600	3.2	0	0
6	6.92	0.81	190	0.63	61	0.81	9	0.3	0.33	1.1	148	0.59	91	2.02	67	0.34	950	1.9	0.82	0.55
7	8.35	0.98	325	1.08	79	1.05	31	1.03	0.12	0.4	230	0.92	41	0.91	60	0.3	720	1.44	0.4	0.27
8	7.32	0.86	409	1.36	88	1.17	46	1.53	0.4	1.33	274	1.1	123	2.73	82	0.41	1110	2.22	0.22	0.15
9	7.9	0.93	813	2.71	260	3.47	40	1.33	0.12	0.4	740	2.96	186	4.13	242	1.21	2310	4.62	0.12	0.08
10	7.45	0.88	195	0.65	50	0.67	17	0.57	0.7	2.33	90	0.36	29	0.64	55	0.28	560	1.12	0.44	0.29
11	6.48	0.76	1410	4.7	432	5.76	81	2.7	0.23	0.77	1165	4.66	110	2.44	223	1.12	2590	5.18	0.46	0.31
12	6.56	0.77	323	1.08	80	1.07	30	1	0.46	1.53	258	1.03	6	0.13	116	0.58	920	1.84	0.46	0.31
13	7.9	0.93	654	2.18	203	2.71	36	1.2	0.22	0.73	462	1.85	44	0.98	60	0.3	1060	2.12	0.8	0.53
14	6.24	0.73	424	1.41	137	1.83	20	0.67	1.12	3.73	510	2.04	232	5.16	140	0.7	1800	3.6	0.38	0.25
15	7.51	0.88	454	1.51	162	2.16	12	0.4	0.12	0.4	532	2.13	155	3.44	180	0.9	2010	4.02	0.52	0.35
16	7.66	0.9	670	2.23	170	2.27	60	2	0.1	0.33	434	1.74	243	5.4	68	0.34	1470	2.94	0.48	0.32
17	7.2	0.85	584	1.95	186	2.48	29	0.97	0.26	0.87	420	1.68	137	3.04	144	0.72	1580	3.16	0.14	0.09
18	8.4	0.99	195	0.65	60	0.8	11	0.37	0.1	0.33	130	0.52	20	0.44	55	0.28	670	1.34	0	0
19	7.51	0.88	494	1.65	94	1.25	63	2.1	0	0	512	2.05	242	5.38	192	0.96	1730	3.46	0.66	0.44
20	7.55	0.89	210	0.7	46	0.61	23	0.77	0.2	0.67	106	0.42	32	0.71	36	0.18	540	1.08	0.52	0.35
21	7.66	0.9	774	2.58	254	3.39	34	1.13	0.1	0.33	902	3.61	235	5.22	208	1.04	2410	4.82	0.25	0.17
22	8.2	0.96	116	0.39	40	0.53	4	0.13	0.08	0.27	70	0.28	34	0.76	50	0.25	410	0.82	0	0
23	8	0.94	224	0.75	60	0.8	18	0.6	0.52	1.73	200	0.8	30	0.67	40	0.2	530	1.06	0	0
24	6.5	0.76	1240	4.13	286	3.81	128	4.27	0.4	1.33	1060	4.24	122	2.71	22	0.11	1940	3.88	0	0
25	7.3	0.86	530	1.77	140	1.87	44	1.47	0.08	0.27	490	1.96	32	0.71	130	0.65	1200	2.4	0	0
26	6.88	0.81	354	1.18	107	1.43	21	0.7	0.22	0.73	224	0.9	152	3.38	155	0.78	1050	2.1	0.14	0.09
27	6.1	0.72	622	2.07	160	2.13	54	1.8	0.29	0.97	480	1.92	38	0.84	108	0.54	1370	2.74	1.3	0.87
28	7.9	0.93	240	0.8	76	1.01	12	0.4	0	0	180	0.72	20	0.44	49	0.25	720	1.44	1.4	0.93
29	6.9	0.81	150	0.5	44	0.59	10	0.33	0	0	90	0.36	12	0.27	33	0.17	410	0.82	1.4	0.93
30	7.1	0.84	290	0.97	80	1.07	22	0.73	0.08	0.27	240	0.96	36	0.8	102	0.51	750	1.5	0	0

Table 6. Pollutants present (NPI>1) at the sampling sites as per NPI in pre- monsoon and post-monsoon seasons.

Sampling station	Pollutants (pre-monsoon)	Pollutants (post-monsoon)
1	Fe, TDS	Fe, TDS
2	TH, Ca, Fe, TDS, F	TH, Ca, Fe, TDS, F
3	TH, Ca, Fe, TDS, Cl, NO$_3$	TH, Ca, Fe, TDS, Cl, NO$_3$
4	TH, Ca, TDS, Cl	TH, Ca, TDS, Cl
5	TH, Ca, TDS, Cl, NO$_3$, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg
6	TDS, Fe, NO$_3$,	TDS, NO$_3$,
7	TH, Ca, TDS, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg
8	TH, Ca, Fe, TDS, Cl, NO$_3$, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg
9	TH, Ca, TDS, Cl, NO$_3$, Mg, SO$_4$	TH, Ca, TDS, Cl, NO$_3$, Mg, SO$_4$
10	TDS, Fe	Fe
11	TH, Ca, TDS, Cl, NO$_3$, Mg, SO$_4$	TH, Ca, Mg, TDS, Cl, NO$_3$, Mg, SO$_4$
12	TH, Ca, TDS, Cl, Fe	TH, Ca, TDS, Cl, Fe
13	TH, Ca, TDS, Cl, Mg	TH, Ca, TDS, Cl, NO3, Fe, Mg
14	TH, Ca, TDS, Fe, Cl, NO$_3$,	TH, Ca, TDS, Fe, Cl, NO$_3$,
15	TH, Ca, TDS, Cl, NO$_3$	TH, Ca, TDS, Cl, NO$_3$, SO$_4$
16	TH, Ca, TDS, Cl, NO$_3$, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg
17	TH, Ca, TDS, Cl, NO$_3$	TH, Ca, TDS, Fe, Cl, NO$_3$, Mg
18	TDS	TDS
19	TH, Ca, TDS, Cl, NO$_3$, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg, SO$_4$
20	TDS	None
21	TH, Ca, TDS, Cl, NO$_3$, Mg, SO$_4$	TH, Ca, TDS, Cl, NO$_3$, SO$_4$
22	None	None
23	TDS, Fe	TDS, Cl
24	TH, Ca, TDS, Cl, NO$_3$, Mg	TH, Ca, TDS, Cl, NO$_3$, Mg, Fe
25	TH, Ca, TDS, Cl, Mg	TH, Ca, TDS, Cl, Mg
26	TH, Ca, TDS, NO$_3$,	TH, Ca, TDS, NO$_3$
27	TH, Ca, TDS, Cl, Mg	TH, Ca, TDS, Cl, Mg, Fe, F
28	TDS	TDS
29	None	None
30	Ca, TDS	TH, Ca, TDS, Cl

Conclusion

The chief causative pollution parameters in the study area are principal pollutants (pollution causing parameters) observed in the present study are nitrates, total hardness, calcium, total dissolved solids (TDS), pH, chlorides and iron.

Based on the Nemerow index method to evaluate the groundwater quality of K.R.Puram, the results show that the NPI values of TDS, nitrate, total hardness, calcium, iron and chloride are quite high , well above the max limit of 1, and hence in concurrence with the conventional characterization analysis .

The results thus indicate that the status of groundwater quality in K.R. Puram is quite poor and the groundwater of most of these locations is unfit for drinking purposes, which calls for continuous monitoring of groundwater supplies and to adopt a systematic environment management plan to safeguard against the pollution of drinking water. Boiling, filtering and techniques such as reverse osmosis are recommended to Based on these results and analysis of water samples, it is also recommended to reduce the pollution levels and thus prevent the adverse health effects that it may cause to the consumers of the said water.

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