

Statistical Assessment of Underground Drinking Water Contamination and Effect of Monsoon at Hasanpur, J. P. Nagar (Uttar Pradesh, India)

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Water Quality Index (WQI) has been calculated for underground drinking water at Hasanpur in J. P. Nagar district, Uttar Pradesh, India at ten different sites in the pre-monsoon season as well as after the onset of monsoon. Water quality parameters were selected as per the WHO guidelines and seventeen water quality physico-chemical parameters were estimated following the standard methods and procedures. Drinking water at almost all the sites was found to be highly contaminated, except a few sites, where it was found moderately contaminated for both the periods during the year 2005. In general, to some extent water quality showed deterioration after the onset of monsoon. It was found that some effective measures are urgently required for water quality management in this region.

Key words: *Water Quality Index, physico-chemical parameters, assigned unit weight, quality rating*

Introduction

It is well known fact that potable safe water is absolutely essential for healthy living. Adequate supply of fresh and safe drinking water is a basic need for all human beings on the earth. The problem of drinking water contamination, water conservation and water quality management has assumed a very complex shape. Attention on water contamination and its management has become a need of hour because of far reaching impact on human health¹. Water Quality Index (WQI) is regarded as one of the most effective way to communicate water quality²⁻⁴. In a number of nationwide studies, water quality of different natural resources was assessed on the basis of calculated water quality indices⁵⁻⁷. The data obtained through quantitative analysis and WHO water quality standards⁸ were used for calculating water quality indices. The purpose of calculating WQI and comparing it with the standards is to assess drinking water contamination at Hasanpur, J. P. Nagar and variation of drinking water quality after the onset of monsoon on the basis of calculated values of water quality indices.

Jyotiba Phoolay Nagar (J. P. Nagar) is a 'C' class city of Uttar Pradesh (India) having population of about 14 lakh as per the 2001 census. According to Surveyor General of India, the total area of the district is 2147 km². J. P. Nagar is situated at an average altitude of about 200 meter from sea level and the slope of the surface is from north to south. J. P. Nagar is located at 28°20' and 29° 16' N and 78° 4', 79° 6' E. The boundaries of the district are Moradabad in east, Meerut and Ghaziabad in the

west, Bulandshahar and Badaun in the south and district Bijnor in the north of J.P. Nagar. The area is characterized by periodic occurrence of hot summers, moderate rains and dry winters. Its climate is affected by himalayan terrain.

Hasanpur is the tehsil headquarters of the district J. P. Nagar. In the recent past, Hasanpur has gone through rapid industrialization and population growth, during last few decades, though it is an agriculture based area. Some industries are causing pollution, especially water contamination in the area of concern. Therefore, the present study was urgently required to draw attention towards this region for taking necessary steps to minimize the adverse impacts likely to occur due to water pollution.

Materials and methods

Ten different sites at Hasanpur, J. P. Nagar were selected in order to study the physico-chemical characteristics of underground drinking water samples in the pre-monsoon period and after the onset of monsoon. The samples were collected during 2005 following the standard methods prescribed for sampling. The standard methods and procedures were used for quantitative estimation of water quality parameters^{9,10}. All the chemicals of anal R grade were used for this purpose. The standards prescribed by WHO were used for the calculation of water quality indices. Seventeen water quality physico-chemical parameters, whose standards are prescribed by WHO, were analysed quantitatively in all the

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Table 1: Details of the sampling locations

Sl. No.	No. and name of site	Location of site	Type of hand pump	Depth of boaring	Type of source	Apparent water quality	Usage of water
1	(I) IM2 Hand Pump at Kayasthan Chamunda Road	1 km west to the town	IM2	Approx. 33 meter	Only source of water	Neat and clear with good taste	Extensively used for drinking, washing and cooking etc.
2	(II) IM2 Hand Pump at Lal Masjid	1 km east	IM2 to site no. I	Approx. 35 meter	Complementary source of water	Water is turbid in both the	Moderately used for drinking, washing, bathing etc.
3	(III) Ordinary Hand Pump at Khewan Street	1.5 km south to site no. II	OHP	Approx. 20 meter	Only source of water till 2004 but now complementary	Water colour turns light yellowish orange on standing	Used for all domestic purposes including drinking.
4	(IV) IM2 Hand Pump at Kot Kala-Shaheed	1 km south to site no. III	IM2	Approx. 30 meter	Complementary source with municipal water supply	Water is hard and unfit for cooking	Extensively used for bathing etc. but not used for cooking.
5	(V) IM2 Hand Pump at Hasanpur-Rehra Road	Southern end of the town and 2 km south to site no. IV	IM2	Approx. 33 meter	Complementary source of water	Water becomes turbid on standing	Number of regular users is low but daily users are very high in number
6	(VI) IM2 Hand Pump at Sambhal-Kaneta Road	2 km east to town	IM2	Approx. 33 meter	Only source of water	Neat and clear water	Extensively used for all living purposes.
7	(VII) IM2 Hand Pump at Sambhal Bye Pass	Eastern end of the town and 1.5 km east to site no. VI	IM2	Approx. 35 meter	Only source of water	Clear water with no other relevant notice	Extensively used for drinking and household purposes.
8	(VIII) Ordinary Hand Pump at Lal Bagh Street	1 km west to site no. VII	OHP	Approx. 25 meter	Only source of water	Neat and clear water but some cases of recurrent diarrhoea and dental caries are noticed	Extensively used for all purposes including drinking.
9	(IX) Ordinary Hand Pump at Main Market	3 km west to site no. VIII	OHP	15-16 meter	Only source of water	Water is clear and good in taste but hard	Extensively used for drinking and other purposes.
10	(X) IM2 Hand Pump at Shiv Temple	Northern end of the town and 3 km North to site no. IX	IM2	Approx. 35 meter	Complementary source	Neat and clear	Moderately used for drinking, washing and bathing etc.

Note : IM2 - India Mark II, OHP - Ordinary Hand Pump

drinking water samples collected at Hasanpur, J. P. Nagar and water quality indices were estimated.

Details of the sampling sites are given in **Table 1** and a map indicating the sampling sites is depicted in **Fig.1**.

WQI of drinking waters, collected at ten different sites at Hasanpur, J. P. Nagar in the pre-monsoon period as well as after the onset of monsoon, were calculated using the methods proposed by Horton¹¹ and modified by Tiwari and Mishra¹². According to the role of various parameters on the basis of importance and incidence on the overall quality of drinking water, the rating scales were fixed in terms of ideal values of different physico-chemical parameters. Even if, they are present, they might not be the ruling factor. Hence, they were assigned zero values. For calculating WQI, the following four equations were used :

- Quality rating, $Q_n = 100 [(V_n - V_i) / (V_s - V_i)]$
 Where, V_n : actual amount of nth parameter
 V_i : the ideal value of this parameter
 $V_i = 0$, except for pH and D.O.
 $V_i = 7.0$ for pH ; $V_i = 14.6$ mg/L for D.O.
 V_s : recommended WHO standard of corresponding parameter
- Unit weight (W_n) for various parameters is inversely proportional to the recommended standard (S_n) for the corresponding parameter.

$$W_n = K/S_n$$

Where, S_n : world-widely accepted drinking water quality standard prescribed by WHO

K : constant

$n=17$

$\sum_{n=1}^{n=17} W_n = 1$, considered here

- Sub indices, $(SI)_n = (Q_n)^{W_n}$
- The overall WQI was calculated by taking geometric mean of these sub indices.

$$WQI = \sqrt[n=1]{\prod_{n=1}^{n=17} (SI)_n} = \sqrt[n=1]{\prod_{n=1}^{n=17} (Q_n)^{W_n}}$$

OR

$$WQI = \text{antilog}_{10} \left[\sum_{n=1}^{n=17} W_n \log_{10} Q_n \right]$$

To include the collective role of various physico-chemical parameters on the overall quality of drinking water, quality status is assigned on the basis of calculated values of water quality indices. On the basis of a number of water pollution studies, the following assumptions were made with reference to assess the extent of contamination or the quality of drinking water¹³. The assumptions were : WQI < 50 : fit for

human consumption ; WQI < 80 : moderately contaminated ; WQI > 80 : excessively contaminated and WQI > 100 : severely contaminated.

Results and discussion

The physico-chemical parameters with their WHO standards and unit weights (W_n) assigned with the help of equation No. 2 presented in the text are listed in **Table 2**. Site-wise and parameter-wise estimated values (V_n), and calculated quality rating (Q_n) for the pre-monsoon period are presented in **Table 3**. Site-wise and parameter-wise values of V_n and Q_n after the onset of monsoon are given in **Table 4**. Site-wise calculated values of WQI for the pre-monsoon period as well as after the onset of monsoon are presented in **Table 5**.

Critical analysis of the data of the WQI presented in **Table 5** and its comparison with the standard assumptions reveals the following facts regarding the level of drinking water contamination and effect of monsoon over the quality of underground drinking water at Hasanpur, J. P. Nagar during the course of study.

The observed range of Water Quality Index is 72 - 124, except at site No. VIII (**Table 1**), where it is 211 for the pre-monsoon period and after the onset of monsoon, it is 69 -217,

Table 2 : Parameter-wise W.H.O. standards and their assigned unit weights

Sl. No.	Parameter	W.H.O. Standard	Assigned Unit Wt. (W_n)
1	pH value	7.0-8.5 (8.0)	0.016381
2	Turbidity (NTU)	5.00	0.026210
3	Conductivity (m S/cm)	0.300	0.436833
4	Total Alkalinity (mg/L)	100.00	0.001310
5	Total Solids, TS (mg/L)	500.00	0.000262
6	Total Dissolved Solids, TDS (mg/L)	500.00	0.000262
7	Dissolved Oxygen, DO (mg/L)	5.00	0.026210
8	Biological Oxygen Demand, BOD (mg/L)	6.00	0.021842
9	Chemical Oxygen Demand, COD (mg/L)	10.00	0.013105
10	Total Hardness (mg/L)	100.00	0.001310
11	Calcium (mg/L)	100.00	0.001310
12	Magnesium (mg/L)	30.00	0.004368
13	Free CO ₂ (mg/L)	10.00	0.013105
14	Chloride (mg/L)	200.00	0.000655
15	Zinc (mg/L)	3.00	0.043683
16	Iron (mg/L)	0.50	0.262100
17	Fluoride (mg/L)	1.00	0.131050

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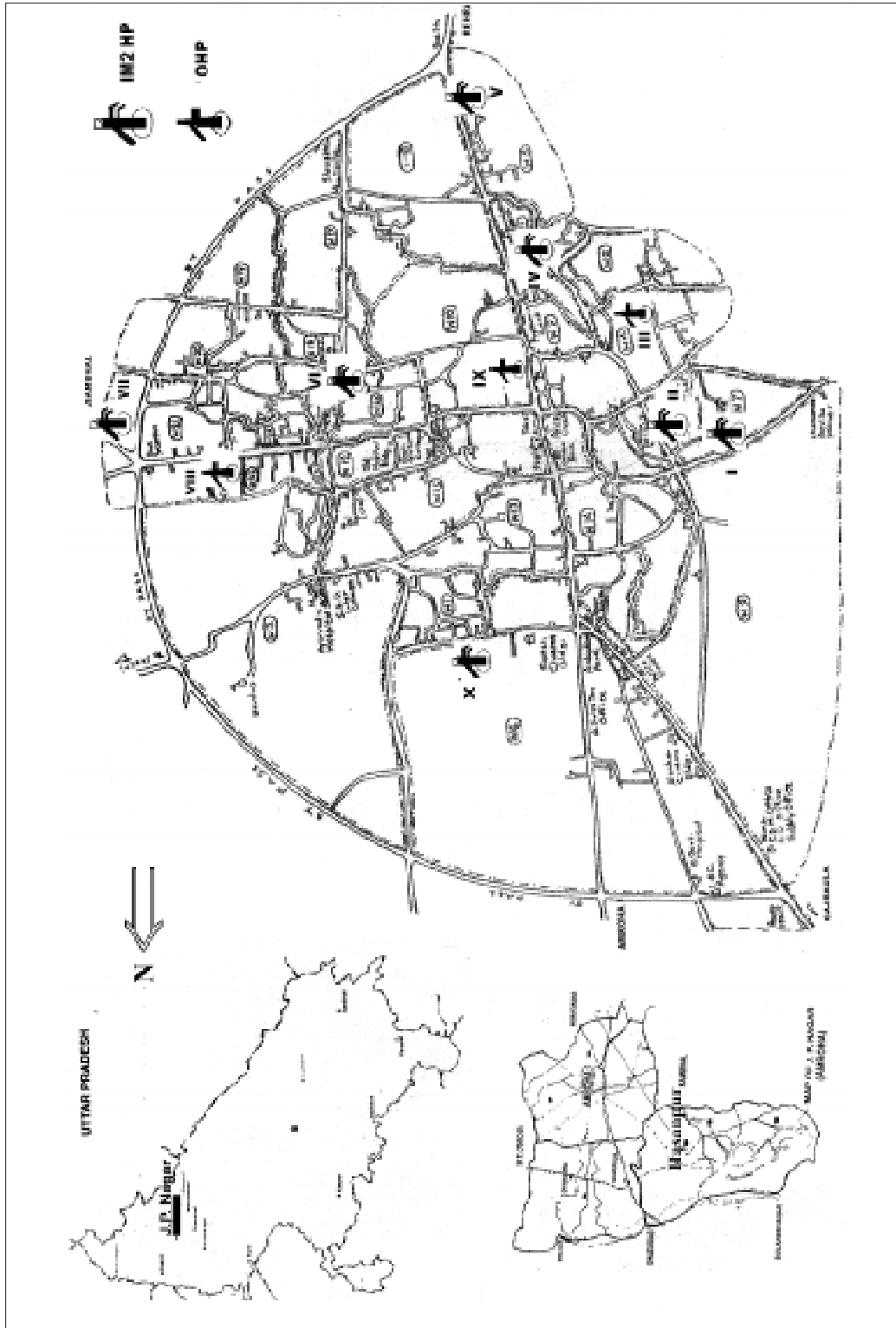


Fig. 1 : The sampling sites at Hasanpur (UP), India

Table 3 : Parameter-wise and site-wise estimated actual values (V_n) and calculated quality rating (Q_n) for pre-monsoon period

Sl. No.	Parameter	Site No. I		Site No. II		Site No. III		Site No. IV		Site No. V		Site No. VI		Site No. VII		Site No. VIII		Site No. IX		Site No. X	
		V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n
1	pH value	7.40	40.00	7.17	17.00	7.07	7.00	7.55	55.00	7.60	60.00	7.59	59.00	7.56	56.00	7.14	14.00	7.30	30.00	7.40	40.00
2	Turbidity (NTU)	2.47	49.40	3.08	61.60	5.11	102.20	2.84	56.80	2.94	58.80	3.11	62.20	3.27	65.40	4.93	98.60	4.17	83.40	3.47	69.40
3	Conductivity (m S/cm)	0.814	271.33	1.000	333.33	1.560	520.00	0.536	178.66	0.589	196.33	0.489	163.00	0.662	220.66	1.540	513.33	1.450	483.33	0.630	210.00
4	Total Alkalinity (mg/L)	195.0	195.0	205.0	205.0	340.0	340.0	190.0	190.0	170.0	170.0	185.0	185.0	185.0	185.0	340.0	340.0	290.0	290.0	175.0	175.0
5	Total Solids, TS (mg/L)	600.0	120.0	810.0	162.0	1250.0	250.0	428.0	85.6	420.0	84.0	360.0	72.0	491.0	98.2	1247.0	249.4	1140.0	228.0	714.0	142.8
6	Total Dissolved Solids, TDS (mg/L)	400.0	80.0	660.0	132.0	940.0	188.0	304.0	60.8	290.0	58.0	260.0	52.0	381.0	76.2	991.0	198.2	922.0	184.4	594.0	118.8
7	Dissolved Oxygen, DO (mg/L)	4.22	108.13	3.36	117.08	3.00	120.83	4.40	106.25	4.20	108.33	4.32	107.08	4.50	105.21	1.98	131.46	2.22	128.96	2.25	128.65
8	Biological Oxygen Demand, BOD (mg/L)	7.50	125.00	6.67	111.17	6.52	108.67	8.51	141.83	9.42	157.00	8.97	149.50	7.81	130.17	3.02	50.33	4.00	66.67	5.50	91.67
9	Chemical Oxygen Demand, COD (mg/L)	24.00	240.00	12.00	120.00	32.00	320.00	16.00	155.00	23.00	233.00	15.00	150.00	31.00	310.00	50.00	500.00	35.00	349.00	31.00	310.00
10	Total Hardness (mg/L)	270.0	270.0	450.0	450.0	580.0	580.0	150.0	150.0	176.0	176.0	152.0	152.0	250.0	250.0	560.0	560.0	522.00	522.0	278.0	278.0
11	Calcium (mg/L)	64.13	64.13	107.41	107.4	145.09	145.09	34.47	34.47	44.09	44.09	38.48	38.48	60.92	60.92	157.92	157.92	120.24	120.2	64.13	64.13
12	Magnesium (mg/L)	26.81	89.37	44.36	147.9	53.12	177.07	15.19	51.97	16.08	53.60	13.65	45.5	23.88	79.6	41.21	137.37	54.11	180.4	28.76	95.87
13	Free CO ₂ (mg/L)	24.20	242	37.40	374	44.00	440	19.80	198	17.60	176.00	17.60	176	30.80	308	44.00	440	44.00	440	22.00	220.00
14	Chloride (mg/L)	49.70	24.85	77.53	38.77	159.04	79.50	21.87	10.94	29.82	14.91	17.89	8.95	71.57	35.79	135.18	67.59	159.04	79.52	8.76	4.38
15	Zinc (mg/L)	0.58	19.33	0.56	18.67	1.88	62.67	1.22	40.67	0.78	26.0	0.21	7.0	0.70	2.33	0.87	29.00	0.50	1.67	0.12	4.0
16	Iron (mg/L)	0.23	46	0.13	26	0.70	14.00	0.57	114	0.18	36	0.11	22	0.09	18	0.67	134.00	0.14	28	0.22	44
17	Fluoride (mg/L)	0.40	40.00	0.78	78.00	1.24	124.00	0.51	51.00	0.43	43.00	0.79	79.00	0.84	84.00	1.02	102.00	1.11	111.00	0.33	33.00

Table 4 : Parameter-wise and site-wise estimated actual values (V_n) and calculated quality rating (Q_n) after the onset of monsoon

Sl. No.	Parameter	Site No. I		Site No. II		Site No. III		Site No. IV		Site No. V		Site No. VI		Site No. VII		Site No. VIII		Site No. IX		Site No. X	
		V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n	V_n	Q_n
1	pH value	7.80	80.00	7.90	90.00	7.80	80.00	7.82	82.00	7.60	60.00	7.65	65.00	7.70	70.00	8.12	112.00	8.10	110.00	7.65	65.00
2	Turbidity (NTU)	2.5	50.00	3.67	73.40	5.32	106.40	3.12	62.40	3.25	65.00	2.23	44.60	2.98	59.60	5.2	104.00	4.75	95.00	3.77	75.40
3	Conductivity (m S/cm)	0.800	266.67	0.988	329.33	1.522	507.33	0.520	173.33	0.574	191.33	450.0	150.00	0.625	28.33	1.450	483.33	1.390	463.33	0.614	204.67
4	Total Alkalinity (mg/L)	210.0	210.0	210.0	210.0	300.0	300.0	200.0	200.0	180.0	180.0	160.0	160.0	164.0	164.0	340.0	340.0	280.0	280.0	160.0	160.0
5	Total Solids, TS (mg/L)	755.0	151.0	901.0	180.2	1100.0	220.0	484.0	96.8	418.0	83.6	380.0	76.0	550.0	110.0	1270.0	254.0	1118.0	223.6	700.0	140.0
6	Total Dissolved Solids, TDS (mg/L)	575.0	115.0	690.0	138.0	850.0	170.0	404.0	80.8	290.0	58.0	310.0	62.0	390.0	7.80	1014.0	202.8	914.0	182.8	592.0	118.4
7	Dissolved Oxygen, DO (mg/L)	4.78	102.29	3.62	114.37	3.00	120.83	4.80	102.08	4.85	101.56	5.50	94.79	5.20	97.91	2.02	131.04	2.31	128.02	4.00	110.42
8	Biological Oxygen Demand, BOD (mg/L)	9.00	150.00	7.80	130.00	7.80	130.00	11.50	191.67	10.80	180.00	11.53	192.17	10.08	168.00	5.21	86.83	4.20	70.00	8.00	133.33
9	Chemical Oxygen Demand, COD (mg/L)	24.00	240.00	12.00	120.00	38.00	380.00	20.00	200.00	25.00	250.00	15.00	150.00	30.00	300.00	54.00	540.00	46.00	460.00	28.00	280.00
10	Total Hardness (mg/L)	230.0	230.0	260.0	260.0	500.0	500.0	114.0	114.0	158.0	158.0	128.0	128.0	220.0	220.0	532.0	532.0	536.00	536.0	244.0	244.0
11	Calcium (mg/L)	55.31	55.31	86.57	86.57	120.24	120.24	34.47	34.47	37.68	37.68	30.46	30.46	52.91	52.91	127.45	127.45	86.57	86.57	58.52	58.52
12	Magnesium (mg/L)	22.42	74.73	35.09	116.97	48.74	162.47	14.14	47.13	15.60	52.00	12.19	40.63	21.44	71.47	51.67	172.23	65.32	217.7	23.4	78.00
13	Free CO ₂ (mg/L)	37.40	374	44.00	440	55.00	550	17.60	176	22.00	220.00	19.80	198.0	33.00	330.00	52.80	528.00	44.00	440	16.50	165.00
14	Chloride (mg/L)	55.66	87.83	79.52	39.76	161.03	80.51	19.88	9.94	29.82	14.91	15.90	7.95	59.64	29.82	147.11	73.55	174.94	87.47	12.00	6.00
15	Zinc (mg/L)	0.70	23.33	0.5	16.67	2.20	73.33	1.1	36.67	0.90	30.00	0.20	6.67	1.00	33.33	0.90	30.00	0.60	20.00	0.20	6.67
16	Iron (mg/L)	0.27	54	0.11	22	0.92	184.00	0.6	120	0.20	40.00	0.11	22.00	0.11	22.00	0.61	122.00	0.18	36.00	0.20	40.00
17	Fluoride (mg/L)	0.31	31.00	0.98	98.00	1.57	157.00	0.58	58.00	0.56	56.00	0.81	81.00	0.87	87.00	1.26	126.00	1.23	123.00	0.59	59.00

Table-5 : Site-wise calculated values of Water Quality Index for pre-monsoon period and after the onset of monsoon

Sl. No.	No. and name of site	Water Quality Index	
		Pre-monsoon	Onset of monsoon
1	(I) IM2 Hand Pump at Kayasthan Chamunda Road	104	107
2	(II) IM2 Hand Pump at Lal Masjid	106	107
3	(III) Ordinary Hand Pump at Khewan Street	124	264
4	(IV) IM2 Hand Pump at Kot Kala-Shaheed	117	120
5	(V) IM2 Hand Pump at Hasanpur-Rehra Road	87	93
6	(VI) IM2 Hand Pump at Sambhal-Kaneta Road	72	69
7	(VII) IM2 Hand Pump at Sambhal Bye pass	76	88
8	(VIII) Ordinary Hand Pump at Lal Bagh Street	211	217
9	(IX) Ordinary Hand Pump at Main Market	123	150
10	(X) IM2 Hand Pump at Shiv Temple	84	90

except at site No. III, where it is exceptionally high (264). The drinking water is severely contaminated at almost all the sites, except at site Nos. V, VI, VII and X for both the periods as the observed values of WQI are more than 100. Drinking water is found to be moderately contaminated at site Nos. VI and VII with WQI values less than 80 for pre-monsoon period, whereas, it is excessively contaminated at site Nos. V and X with WQI values more than 80 for the pre-monsoon period. Drinking water is observed to be excessively contaminated with WQI values more than 80 at site Nos. V, VII and X and it is moderately contaminated with WQI values less than 80 at site No. VI after the onset of monsoon. A comparison of the values of WQI for two seasons reveals that in general, drinking water quality is deteriorated or contamination of drinking water is increased after the onset of monsoon which is quite alarming. A comparison of values of WQI of ordinary hand pumps and IM2 hand pumps shows that the water quality of IM2 hand pumps is better.

Conclusion

On the basis of the above discussion, it may be concluded that the underground drinking water at almost all the sites at Hasanpur, J. P. Nagar is highly polluted as indicated by WQI. At a few sites, it is moderately polluted in the catchment study area. The drinking water is polluted with reference to almost all the water quality physico-chemical parameters studied. The quality of IM2 water was found better than the water of ordinary hand pumps. Therefore, the use of ordinary hand pumps should be discouraged. The drinking water quality was found to start deteriorating after the onset of monsoon. People dependent on this water are often prone

to health hazards due to polluted drinking water. Therefore, some effective measures are urgently required to enhance the drinking water quality by delineating an effective water quality management plan for the region-Hasanpur, J. P. Nagar (Uttar Pradesh, India).

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