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Assessment of Groundwater Quality for Drinking Purpose in Tehsil Bah, Agra District, India

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The increasing dependence on groundwater for domestic, irrigation, industrial and other purposes is giving adverse impact on the aquifers and environment of the area. The present study is focused on the physico-chemical analysis of groundwater quality of Tehsil Bah, located in Agra district of India. A total 84 samples of groundwater were collected from different locations throughout the area of the tehsil Bah. Total 16 test parameters were analyzed to assess the quality of groundwater by adopting methodology and techniques given in the American public health association (APHA), 2017. Total dissolved solids are not meeting the requirements of acceptable limit in all the locations as per Bureau of Indian standard IS 10500:2012. Total hardness, total alkalinity, chloride, calcium and magnesium values are also not met the requirements in most of the locations. Sodium and fluoride concentrations also exceed the prescribed limits of Indian standard in some places.

Keywords: Groundwater, Water quality, IS 10500:2012, Contamination.

INTRODUCTION

Water is a natural resource essential for the existence of life and is a basic human entity. Water resources are harnessed for various purposes like drinking, agricultural, industrial, household, recreational and environmental activities, *etc*. Groundwater is one of the major sources of drinking water all over the world [1]. The past decade has seen a remarkable impact of man on the environment due to an unprecedented increase in population and rapid rate of urbanization as well as the intensification of the use of fragile and marginal ecosystems. This has led to progressive and continual resources degradation especially surface and groundwater. The quality, quantity and availability of drinking water are one of the most important environmental issues [2-4].

Groundwater is an important source for India as 70% population of India lives in villages and 85% of rural population depend on groundwater for drinking and domestic purposes. Groundwater from deep and confined aquifers is usually microbially safe and chemically stable in the absence of direct contamination [5]. However, shallow or unconfined aquifers can be subject to contamination from discharges or seepages assoc-iated with agricultural practices (*e.g.* pathogens, nitrates and pesticides), onsite sanitation and sewerage (*e.g.* pathogens and nitrates) and industrial wastes [6].

In India, 85% of drinking water and 60% of irrigation water requirements are fulfilled by groundwater [7]. The devastating effects of water pollution not only on humans, birds, animals but also on aquatic animals by reducing their reproductive ability [8]. The groundwater source contains a variety of substances either in suspension or in solution. These water samples contain alkali & alkaline earth metal cations such as sodium & potassium and calcium & magnesium [9]. The exponentially increasing rate of urbanization and industrialization is directly proportional to the availability and the quality of groundwater [10].

In India, rice and wheat are two major staple crops facing severe water scarcity. Water resource management is the only way to achieve food security in population prediction. In the light of population prediction in India by 2030, food security and water management are the major challenges need to be addressed [11]. In India, more than 50% of the urban population and about 80% of the rural population directly depend on groundwater for the domestic water uses [12]. The alarming statistics of macro-water availability in India is population driven scarcity [13,14]. Scarcity and declining trends of groundwater are imposing a high level of risk to the gross domestic products (GDP). As per the NITI Aayog report, it is estimated annual usable water resources in our country is 690 billion cubic meters (BCM) from surface sources and 447 BCM from groundwater [11]. In spite of possessing surplus surface water resources, India is highly dependent on groundwater resources for day-to-day survival. The per capita water storage capacity in India is about 209 m^3, which is meagre in comparison to per capita storage capacities in countries like Australia (3223 m^3), The USA (2193 m^3), Brazil (2632 m^3) and China (416 m^3) [15].

Agra city is surrounded by many leather tanneries and small-scale dying industries. These industrial effluents are discharged into the Yamuna river causing impacts on the quality of the underground water [16]. About 80% population in Agra district of Uttar Pradesh province use groundwater for drinking and other purposes [17]. Agra district has varied continental sub-tropical climate with long hot summers from end of March to mid of September, temperature touches in the month of May and June up to 46 ºC. During the monsoon months from July to September, about 700 mm of rainfall occurs. The maximum temperature during summer is 46 ºC and the minimum temperature is about 21 ºC and during winter maximum temperature goes up to 32 ºC and the minimum temperature goes up to 2 ºC.

EXPERIMENTAL

Study area: The Agra district occupies the western part of the Uttar Pradesh. The boundaries of district are shared with Rajasthan and Madhya Pradesh states in the west & south and by Mathura, Etah, Firozabad, Mainpuri and Etawah district from north to east, respectively. It encompasses an area of 4027 Km^2 and lies between latitude 26º 44′10″ to 27º 24′30″ North and longitude 77º 30′15″ to 78º 51′′30″. The Agra city universally renowned place because of Taj Mahal. The Agra district is divided into six tehsils (sub divisions) namely Bah, Fatehabad, Agra, Kiraoli, Etmadpur, Khairagarh.Tehsil Bah comes under district Agra and divided in to three blocks namely Bah, Jaitpur and Pinahat (Fig. 1).

The district of Agra occupies a part of the Indo-Gangetic plain and its major part is underlain by alluvial sediments of quaternary age comprising mainly a sequence of clay, silt, sand of different grades, gravels and kankar in varying propor-tions. The alluvium was deposited over the slopes of the basement of Vindhyan rocks. The main objective of the present study is to analyse the ground water of Tehsil Bah, located in Agra district for drinking purpose.

Samples collection: Groundwater samples were collected from 84 different locations throughout the area of the tehsil Bah in which 79 samples were collected from the villages and 5 samples were collected from semi-urban areas. The pH and electrical conductivity were measured immediately in the field after sampling. Water samples collected in polyethylene bottles [18] and stored at 10 ºC to analyze various major anionic, cationic concentrations and heavy metals in the laboratory by following standard guidelines and procedures [19].

The accuracy of chemical analysis was examined using the ion-balance error [20] as given in eqn. 1:

$$\varepsilon = \frac{(r_c - r_a)}{(r_c + r_a)} \times 100$$

where r_c and r_a are the sum of the major cations and anions, respectively, expressed in milliequivalents per liter and ε is the error percent. The ionic balance for all the analyses was within a limit of less than ± 10% [21]. The results were evaluated in accordance with the Bureau of Indian Standards Specifications for drinking water (BIS 2012) and World Health Organization guidelines for Drinking Water Quality (WHO 2004) [22,23]. The water quality assessment parameters are presented hereunder.

pH: pH meter is required to be equipped with temperature compensation adjustment at 25 ºC if not equipped with temperature compensation adjustment as it is required to correct manually prior to obtain the result. Range of pH is 0-14 in which 7.0 at 25 ºC is neutral.

Total dissolved solids: TDS gives an approximate idea about the presence of minerals in the sample. A well-mixed water filtered through a filter paper and put into pre-weighed dish at 180 ºC, sample will be dried till the constant weight of dish in the specified temperature as per APHA method [19]. The difference between post-weight and pre-weight divided by the volume of the sample is known as total dissolved solids.

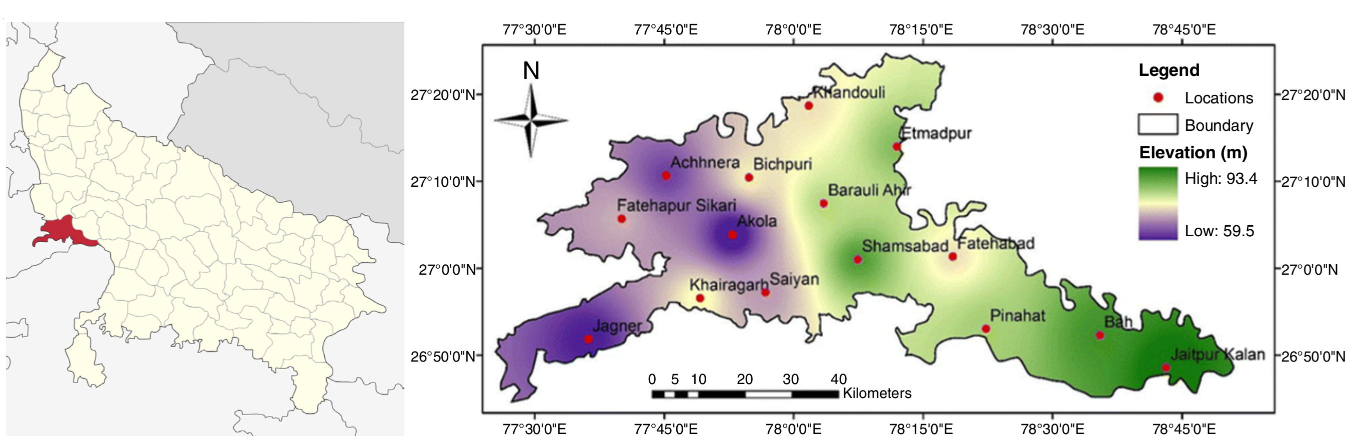

Fig. 1. Map of Agra district in Uttar Pradesh province of India showing various tehsil

$$\text{Total dissolved solids (mg/L)} = \frac{\text{Weight of dried sample (A)} - \text{Weight of empty dish (B)}}{\text{Sample volume in mL}} \times 1000$$

Electrical conductivity: Conductivity is the measurement of electric current of an aqueous solution at 25 ºC or the conductivity meter should be equipped with temperature compensation adjustment.

Total hardness, calcium and magnesium: EDTA method is used for the determination of total hardness in the groundwater. In this method, Eriochrome black T indicator was added to the sample at pH 10. If the sample contains calcium and magnesium ions, sample becomes wine red after the addition of indicator. Sample is titrated with EDTA solution, resulted in chelated soluble complex of calcium and magnesium. The endpoint of the titration is identified by the blue colour.

Calcium was also analyzed by EDTA titrimetric method in which pH raise by NaOH between 12-13 followed by the addition of murexide as indicator and then titrate slowly with EDTA till the endpoint obtained. Magnesium was calculated based on the difference of total hardness and calcium by estimating the values as calcium carbonate.

Total alkalinity: The total alkalinity was measured using titrimetric method in which acid titration in the presence of mixed indicators of bromocresol green & methyl red.

Chloride: Chloride is major inorganic ions present in the groundwater. The salty taste of water produced by chloride is variable and depends on the chemical composition and the concentration of chloride in water. Some water samples with the concentration of 250 mg/L may have detectable salty taste if the cation is sodium. On the other hand, the typical salty taste may be absent in water having concentration as much as 1000 mg/L when the predominant cations are calcium and magnesium [24]. Potentiometric titration method was followed with silver nitrate and potassium chromate as indicator to determine chloride concentration in water metrics.

Nitrate: Ultraviolet spectrophotometric screening method as per APHA [19] was adopted to determine the nitrate concentration in groundwater. Determination of nitrate absorbance at a single wavelength is not possible since both natural organic matter and nitrate absorb UV radiation hence will not give reliable results in spite of different time intervals of absorption. Hence, the absorbance has to be recorded at two different wavelengths, *i.e.* 220 nm and 275 nm, respectively and computing values effectively.

Fluoride: SPADNS colorimetric method as per APHA [19] was followed to determine the fluoride concentration in groundwater. In this method, zirconium dye reacts with fluoride that dissociates into colourless anionic complex, as the amount of fluoride increased with lighter complex. Absorbance was recorded by spectrophotometer with 1 cm light path at 570 nm.

Sulfate: It is measured by the turbidimetric method, where barium chloride forms barium sulfate crystals of uniform size in the presence of buffer solution as specified in APHA [19]. Turbidity produced by barium sulfate is measured by using spectrophotometer in the visible range of the spectrum. Calibration graph was plotted with certified reference material of sulfate to quantify the values of sulfate in the groundwater.

Sodium and potassium: Sodium and potassium were analyzed by flame photometer as per the APHA [19]. Trace amounts of sodium and potassium can be determined by flame emission photometer in which water sample is nebulized into a gas flame under controlled conditions. Certified reference materials for sodium and potassium were used to quantify the value of sodium and potassium in the groundwater.

Iron: Iron was tested by acid digestion followed by atomic absorption spectrophotometer as per APHA method [19]. Nitric acid was used for the digestion of groundwater and National Institute of Standards and Technology (NIST) traceable certified reference materials (CRMs) were used for quantification of the metal.

RESULTS AND DISCUSSION

Groundwater samples were collected from borewell and hand pump were analyzed, results of the samples are given in Table-1.

TABLE-1
HYDRO-CHEMICAL PARAMETERS FOR THE SURVEYED GROUNDWATER SAMPLES

Sample location	Type of sample	pH	EC (µS/cm)	TDS (mg/L)	Cations (mg/L)					Anions (mg/L)						TA (mg/L)	TH (mg/L)
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Iron	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-		
Arnota-1	B	7.46	1450	967	64.3	54.7	171.2	3.4	0.25	0	553.6	188.2	134.6	6.1	0.79	453.8	385.8
Arnota-2	H	7.85	1553	1050	84.4	48	185.4	7.8	0.42	0	689.3	167	145.4	8.6	0.68	565	408.6
Arnota-3	B	7.5	1564	1055	63.2	44.4	198.4	5.8	0.24	0	676.6	153.7	137.6	8.1	0.92	554.6	340.9
Basia Arela-1	H	7.35	2238	1492	115	76.4	382.4	10.9	0.58	0	615.8	345.1	210.1	16.5	1.58	504.8	601.9
Basai Arela-2	B	7.50	2231	1486	104	73.4	380.2	17.8	0.76	0	486.3	355.6	184.2	18.7	1.35	398.6	562
Basia Arela-3	H	7.52	1984	1422	99.5	64.4	338	10.3	0.65	0	556.3	316.2	202.8	16.3	1.63	456	513.8
NagalaBhari-1	H	7.76	1065	748	76.6	44.2	84.6	3.9	0.09	0	534.3	126.8	94.9	22.5	0.69	438	373.3
Nagala Bhari-2	B	7.72	841	584	71	42.5	56.9	1.6	0.08	0	350.6	88.2	56.9	16.9	0.87	287.4	352.3
Nagala Bhari-3	H	7.80	2356	1617	136.6	67.4	401.6	9.8	0.81	0	539	437.4	164.5	10.7	1.56	441.8	618.9
ManikPura-1	H	7.39	1782	1236	111.7	57	138.1	3.3	0.11	0	796.1	206.4	112	17.1	1.89	652.5	513.8
Manikpura-2	H	7.48	1696	1175	107.2	53.5	112.5	7.1	0.21	0	814.5	211.5	98.4	16.3	1.54	667.6	488
Manikpura-3	B	7.77	1152	798	84.4	52.3	69.8	4.2	0.36	0	515.3	130.4	78.8	14.7	1.23	422.4	426.2
Gurja Flu	B	7.84	1097	773	79.9	48.9	66.4	2.8	0.21	0	564.2	115	84.6	19.2	0.91	462.4	401.1
Bhadrauli-1	H	7.70	1387	978	87	44.1	203	6.8	0.48	0	561.2	213	89.3	16.5	0.98	460	398.9
Bhadrauli-2	B	7.80	1295	891	91.5	53.7	172	5.9	0.56	0	546.6	175	73.4	14.3	0.91	448	449.7
Bhadrauli-3	H	7.66	1179	814	82.6	43.3	123.4	6.4	0.43	0	587.7	172.5	98.3	9.9	0.83	481.7	384.5
Pharaira-1	B	7.80	1028	709	64.2	28.1	126.7	6.1	0.36	0	597.8	53.7	83	12.5	0.52	490	276.3
Pharaira-2	B	7.80	1108	767	60.5	32.7	118	8.4	0.41	0	587.7	88.4	74.2	11.1	0.65	481.7	286
Bah-1	B	7.90	1380	905	90.3	63.2	142	6.2	0.56	0	536.8	135	79.8	26.8	1.08	440	480

Bah-2	B	8.10	1585	1116	85.5	65.4	256	8.2	0.67	0	544.1	263	112.5	17.9	1.23	446	483
Bah-3	H	7.80	1265	823	79.2	62.5	169	5.4	0.27	0	510	156	67.5	19.8	0.91	418	455
Jarar	B	7.90	1195	786	82	57.1	86.6	4.1	0.36	0	567.3	88	57.4	16.2	0.99	465	440
Pinahat-1	B	7.90	1536	1084	103	60.2	283	8.9	0.36	0	514.8	265	84.3	26.5	0.93	422	505
Pinahat-2	H	7.80	1455	963	95	54.3	224	7.3	0.27	0	531.9	192	76.6	23.6	1.07	436	461
Syahipura-1	H	7.80	1595	1124	107	67.4	245	12.5	0.67	0	652.7	265	102	21	1.03	535	545
Syahipura-2	B	7.90	1523	1066	92	62.5	223	9.3	0.59	0	636.8	242	109	13.6	2.14	522	487
Chandrapur	H	7.60	890	594	67	29.8	69.8	3.5	0.26	0	322.1	49.9	48.9	12.5	0.95	264	290
Roop Pura	B	7.70	962	637	62	37.7	56.2	32.6	0.13	0	420.9	42	56.9	10.9	0.43	345	310
Pahadpura	H	7.60	890	594	67	29.8	69.8	3.5	0.29	0	322.1	49.9	48.9	12.5	0.27	264	290
Natauli	B	7.70	962	637	62	37.7	56.2	3.2	0.37	0	420.9	42	56.9	10.9	0.64	345	310
Holipura	H	7.70	850	552.5	68.4	47.1	62.8	4.5	0.21	0	392.8	54.5	42.4	20.5	0.65	322	365
Bateshwar	H	7.50	967	592	76.2	49.5	53.7	6.4	0.42	0	436.8	70.5	52.5	16.4	0.78	358	394
Vipraoli	B	7.70	1056	704	76.5	59	87.3	5.2	0.31	0	481.9	125.2	43.4	19.2	0.85	395	434
Narhauli	H	7.60	1254	805	88.5	68.5	105	7.1	0.55	0	558.8	134	56.6	9.7	0.61	458	503.2
Gungawali	H	7.20	1507	972	94	41	140	7.8	0.15	0	492.9	220	66.2	10.4	0.95	404	403.7
Harlalpura	B	7.30	1660	1074	95	38	145	8.2	0.24	0	499	264	82.4	12.7	1.25	409	393.9
Rani ka bagh	H	7.50	1377	885	98	40	114	5.4	0.22	0	478.2	190	72.4	8.5	1.2	392	409.6
Chousingi	H	7.70	1854	1187	118	58	247	12.4	0.41	0	517.3	298	104.6	23.4	1.3	424	533.7
Chousingi-1	B	7.50	1605	1045	106	42	225	11.9	0.12	0	514.8	202	86.5	13.5	1.1	422	437.8
Changauli	H	7.70	1524	976	101	53	185	10.5	0.35	0	500.2	224	78.1	11.7	1.3	410	470.6
Sunsar	H	7.50	1277	832	84	44	134	9.4	0.43	0	395.3	196	56.7	9.3	1.55	324	391.1
Bichoula	H	7.60	1111	722	88	43	95	8.2	0.12	0	372.1	170	46.7	8.9	1.05	305	396.9
Gonsili	H	7.20	1165	740	87	46	145	11.8	0.38	0	353.8	200	48.6	9.4	1.53	290	406.8
Chamraua	H	7.50	1433	914	95	43	154	12.8	0.23	0	457.5	228	53.5	10.5	1.1	375	414.4
Hajarpura	H	7.20	1607	1048	99	45	235	18.4	0.33	0	516.1	267	56.8	15.4	1.25	423	432.7
Vijoli	H	7.70	1427	930	102	47	204	12.1	0.25	0	420.9	225	63.4	13.5	1.6	345	448.4
Vijoli-1	B	7.50	1556	1012	104	45	242	14.2	0.2	0	474.6	258	54.5	16.2	1.45	389	445.2
Kenjra	H	7.60	1375	895	99	41	191	10.6	0.18	0	495.3	180	45.9	12.5	1	406	416.2
Bhagwanpura	H	7.60	1479	946	102	39	190	11.4	0.19	0	505.1	257	58.9	14.8	0.9	414	415.5
Basoni	B	7.60	1436	936	96	38	216	9.2	0.17	0	424.6	264	54.7	13.1	1.1	348	396.4
Kukthari	B	7.50	1904	1244	115	54	252	15.9	0.32	0	639.3	305	66.8	24.5	1.52	524	509.7
Sidhawali	H	7.70	1826	1161	114	51	257	14.2	0.34	0	600.2	296	67.5	21.4	1.25	492	494.9
Pratap pura	H	7.40	1721	1124	112	50	243	16.1	0.34	0	574.6	266	68.4	18.5	1.2	471	485.8
Rudmuli	B	7.60	1564	996	106	44	183	11.3	0.3	0	463.6	236	58.5	16.6	1.54	380	446.1
Abhaypura	H	7.50	1412	905	105	42	172	11.2	0.46	0	444.1	225	56.4	14.3	1.2	364	435.3
Lakhanpura	H	7.80	1525	971	99	44	187	13.4	0.38	0	470.9	257	61.2	21.1	0.97	386	428.6
Bamroli	H	7.60	1878	1227	107	57	267	20.1	0.44	0	555.1	304	87.5	21.5	1.6	455	502.1
Vijkoli	H	7.50	1936	1238	115	55	274	20.5	0.51	0	564.9	346	88.9	26.8	1.62	463	513.8
Mai	H	7.60	1725	1105	105	46	231	18.3	0.3	0	491.7	273	78.5	18.4	1.2	403	451.8
Kwari	B	7.20	1424	943	101	40	224	17.4	0.36	0	420.9	255	62.4	12.3	1.05	345	417.1
Derak	H	7.80	1987	1269	116	52	268	21.3	0.54	0	649	326	112.4	18.5	1.57	532	504
Karkoli	B	7.50	1956	1255	113	44	277	22.8	0.23	0	569.7	358	87.6	20.4	1.24	467	463.6
Kherdanda	H	7.50	1854	1202	110	52	245	16.9	0.33	0	556.3	285	70.6	21.5	1.57	456	489
Utsana	H	7.50	1956	1240	117	58	246	19.3	0.42	0	606.3	297	102.5	26.8	1.6	497	531.2
Utsana-1	B	7.60	1832	1182	115	46	259	18.8	0.36	0	557.5	293	94.6	23.2	1.45	457	476.8
Gajoura	H	7.80	2013	1312	118	51	282	20.6	0.55	0	556.3	404	101.2	24.2	1.65	456	504.9
Paprinagar	B	7.60	2153	1402	112	46	287	28.2	0.32	0	544.1	414	116.7	26.5	1.54	446	469.3
Paprinagar-1	H	7.30	2015	1307	103	55	268	22.1	0.39	0	483.1	406	96.5	23.1	1.38	396	483.8
Pai	H	7.40	2205	1404	102	52	254	26.6	0.38	0	560	416	106.5	19.5	1.15	459	469
Pai-1	B	7.30	2003	1312	121	56	245	25.4	0.45	0	534.4	402	97.8	17.4	1.1	438	532.9
Badagaon	H	7.80	2027	1296	113	49	236	22.4	0.41	0	555.1	396	90.8	22.4	1.25	455	484.1
Chitrahat	H	7.50	1987	1265	125	43	232	23.1	0.22	0	569.7	407	87.5	23.8	1.7	467	489.4
Richhapura	H	7.60	2095	1368	96	48	243	24.6	0.21	0	564.9	425	95.2	25.2	1.56	463	437.5
Kamtari	B	7.60	1787	1137	114	53	189	16.9	0.22	0	544.1	261	67.8	19.4	1.7	446	503.1
Korath	H	7.60	1636	1068	103	46	196	12.4	0.37	0	468.5	281	56.8	16.3	1.2	384	446.8
Khilawali	H	7.60	1780	1162	117	55	224	10.6	0.34	0	566.1	316	65.9	17.3	0.95	464	518.8
Amahi	H	7.60	1576	1030	114	48	186	8.9	0.25	0	516.1	266	49.6	12.3	1.3	423	482.5
KheraRathor	H	7.30	1568	1002	107	58	210	8.6	0.26	0	473.4	275	44.7	11.4	1.54	388	506.2
Nawali	H	7.60	1605	1048	111	46	234	9.5	0.39	0	507.5	278	54.5	13.1	1.26	416	466.8
Tasond	H	7.20	1561	994	85	38	228	10.8	0.19	0	416	310	49.6	10.5	1.1	341	368.9
Balai	H	7.30	1556	978	113	48	210	10.3	0.53	0	484.3	264	47.6	10.2	1.63	397	480
Kyori	B	7.20	1633	1078	107	58	245	14.3	0.43	0	517.3	302	50.6	9.5	1.54	424	506.2
Sabora	B	7.20	1667	1058	111	52	219	13.1	0.52	0	556.3	269	54.7	11.7	1.59	456	491.5
Pidhora	B	7.00	1922	1224	115	55	257	16.3	0.24	0	545.3	307	66.7	16.9	1.2	447	513.8

B = Bore well; H = Hand pump; TA = total alkalinity; TH = total hardness

pH: The pH measures the concentration of hydrogen ions and in natural water is an important index of acidity or alkalinity. The pH value is determined mainly by the correlation between the concentration of free carbon dioxide, bicarbonates and carbonates. This correlation, in turn, depends substantially on the intensity of the process of photosynthesis and biochemical oxidation of organic substances, as well as on the chemical conversion of some mineral substances. Most of the natural waters are generally of alkaline nature due to presence of a sufficient quantity of carbonates. Under natural conditions, the pH value in the surface water ranges usually from 5.0 to 8.6. The pH is affected by the increase in the content of coloured humus substances. pH of water gets drastically changed with time due to exposure to air, biological activities and temperature changes. Significant changes in pH of water also occurs due to increased contents of acids or alkalis discharged into the water bodies. Higher pH tends to precipitate the ionic species of heavy metals to the sediment [25].

pH of the study area ranges from 7.0 to 8.1. The maximum pH (8.1) was recorded from Bah tehsil whereas minimum (7.0) was recorded from Pidhora village of Bah tehsil of Agra district. The normal pH range for drinking water is from 6.5 to 8.5 as per the Indian standard. The mean value of pH is 7.58 which is within the acceptable range. From Table-1, it is clear that pH values of Bah tehsil are within the maximum desirable limits (8.5), which is also a maximum permissible limit as per IS 10500:2012 [26].

Distribution of pH values are expressed in Figs. 2 and 3, the values of samples are distributed between pH 7 to 8.1, minimum pH value (pH 7) was reported in one sample, while the maximum pH value (pH 8.1) was reported in one sample. All the reported samples are within the acceptable limits as prescribed by bureau of Indian standard IS 10500:2012.

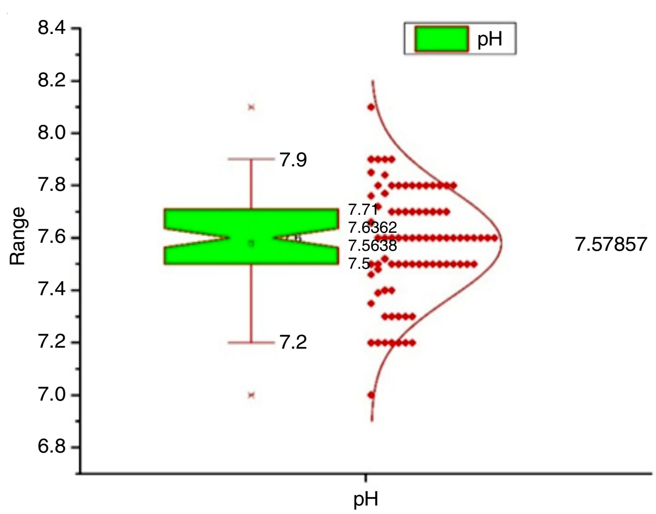

Fig. 2. Distribution of pH

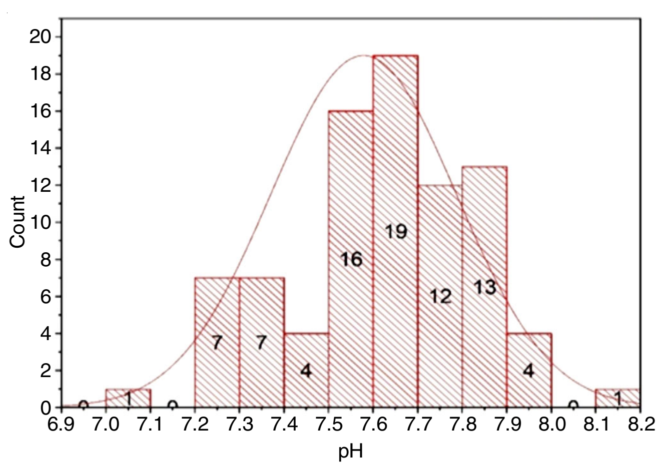

Fig. 3. Distribution of pH

Electrical conductivity: According to Langenegger [27], the importance of EC is its measure of salinity. Irrigation using river water can add salt concentration to the soils and a problem occurs if the added salt accumulates to a concentration that is harmful to the crop or landscape. Salinity of river water that is used for irrigation is determined by electrical conductivity (EC), which is used as a surrogate measure of total dissolved solids (TDS) concentration in water.

Electrical conductivity of the study area ranges from 841 to 2356 µS/cm. The maximum value of conductivity (2356 µS/cm) was recorded from Nagla Bhari village, average value of conductivity was recorded 1560 µS/cm which indicates higher values of total dissolved solids (TDS) and minimum value (841 µS/cm) was also recorded from Nagla Bhari village of Bah Tehsil, Agra District. There is no prescribed limits under drinking water for electrical conductivity as per IS 10500:2012 [26].

Electrical conductivity values are ranged of the reported values found between 841 µS/cm (minimum value) to 2356 µS/cm (maximum value). The frequency histogram is plotted from 800-2400 to cover entire range of the reported values of electrical conductivity. The maximum number of electrical conductivity values (23 Nos.) are reported between 1400 µS/cm to 1600 µS/cm (Fig. 4).

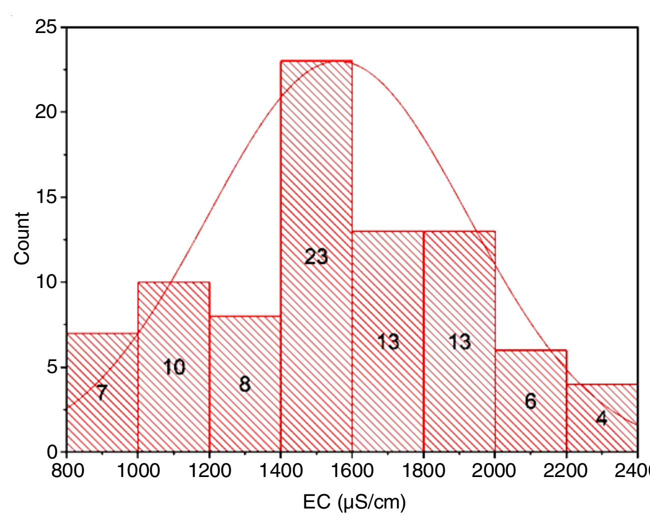

Fig. 4. Distribution of electrical conductivity

Total dissolved solids: Total dissolved solids (TDS) refer to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than pure water (H_2O) molecules and suspended solids. TDS of the study area ranges from 553 mg/L to 1617 mg/L, the maximum TDS (1617 mg/L) was recorded from Nagla Bhari-3 village whereas minimum TDS (553) was recorded from Holipura village of Bah tehsil. The acceptable limit for drinking water is 500 mg/L as per the Indian standard [26]. Mean value of total dissolved solids is 1026 which is acceding the acceptable limit. All the samples are having the value more than 500 mg/L therefore water quality of the area is not meeting the requirement of acceptable limit prescribed in IS 10500: 2012.

Frequency histogram is plotted to express the number of reported values with the concentration of the total dissolved solids (mg/L), the minimum reported value is found (553 mg/L), which exceeds the acceptable limit prescribed by the Bureau of Indian standard in IS 10500:2012 (Fig. 5). Maximum number of reported values are found from 800 mg/L to 1000 mg/L. All the reported samples exceeds the acceptable limit (500 mg/L) prescribed in IS 10500:2012.

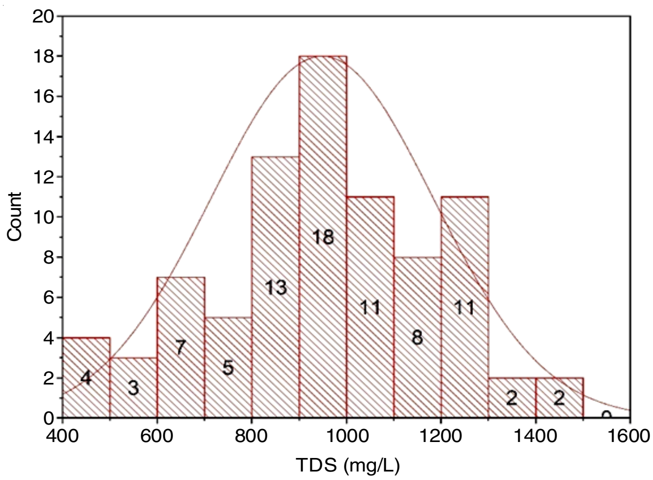

Fig. 5. Distribution of total dissolved solids

Hardness: Sawyer & McCarty [28] classified groundwater, based on total hardness (TH), as groundwater with TH < 75, 75-150, 150-300 and > 300 mg/L, designated as soft, moderately hard, hard and very hard, respectively. Range of total hardness of the study area from 276.3 to 618.9 mg/L, maximum value of hardness (618.3 mg/L) was recorded from Nagla bhari-03 village, while the minimum value of total hardness (276.3) was recorded from Pharaira village of tehsil Bah, Agra district. The acceptable limit for total hardness is 200 mg/L and permissible limit in absence of alternate source is 600 mg/L as per IS 10500:2012. Mean value of total hardness (448.2 mg/L) is above the acceptable limit (200 mg/L) and comes under the category of hardwater. All the analyzed samples show the values exceeding to the acceptable limit.

Distribution of the reported values of total hardness are expressed in Figs. 6 & 7, the minimum reported value is 276.3 mg/L, maximum reported value is 618.9 mg/L and the value which is close to maximum number of values is 448.2 mg/L.

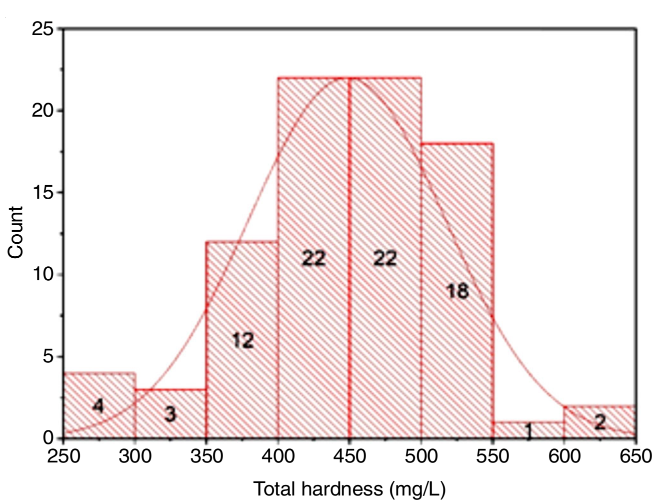

Fig. 6. Distribution of total hardness

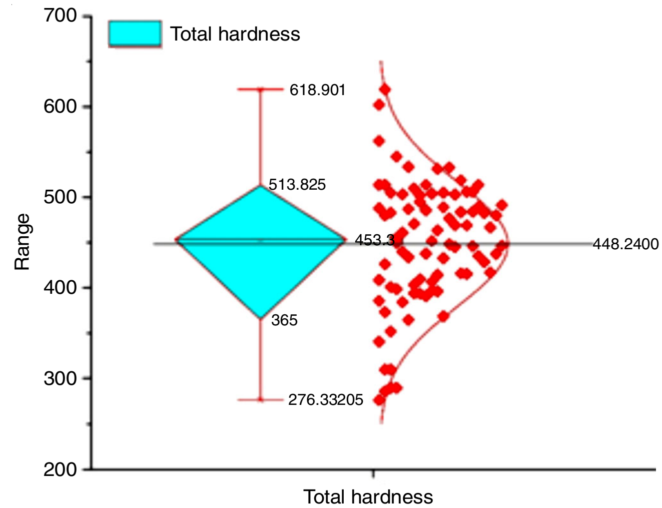

Fig. 7. Distribution of total hardness (TH)

Calcium and magnesium: The presence of calcium in water supplies may deposit as calcium carbonate and produced corrosion in metal pipes. Calcium and magnesium concentration in water contributes major amount in total hardness. Range of calcium and magnesium were recorded 60.5 to 136.6 mg/L & 28.1 to 49.7mg/L, respectively. Maximum values for calcium were recorded 136.6 mg/L as calcium in Nagla Bhari-03 and maximum value of magnesium was recorded in Basai Arela-01 villages of Tehsil Bah. Average value of calcium and magnesium were 97.5 mg/L and 49.7 mg/L, respectively which are above the acceptable limit of drinking water and it indicates that groundwater of the area is hard and prone to produce corrosion in the metal pipes. The acceptable limits for calcium and magnesium were 75 mg/L and 30 mg/L, respectively.

Distribution of calcium and magnesium values are shown in Fig. 8 for the calcium (mg/L) and Fig. 9 for magnesium (mg/L). Range of calcium is recorded from 60.5 mg/L to 136.6 mg/L and the range of magnesium is reported from 28.1 mg/L to 49.7 mg/L. The maximum number of the samples were found with the concentration values from 100 mg/L to 120 mg/L for calcium and between 40 mg/L to 50 mg/L for magnesium concentration.

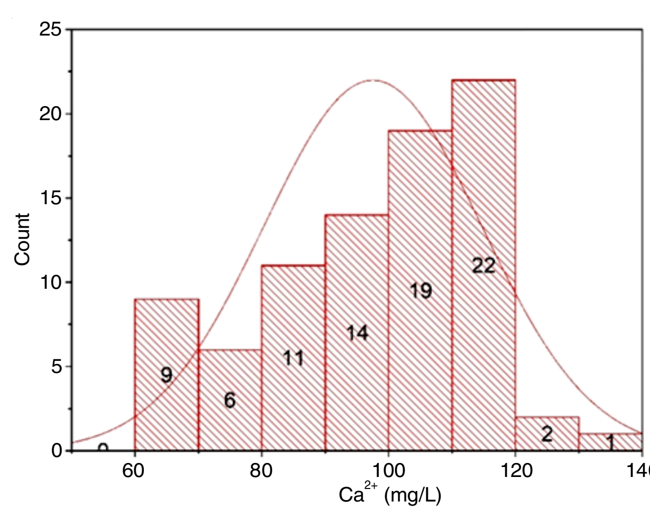

Fig. 8. Distribution of calcium

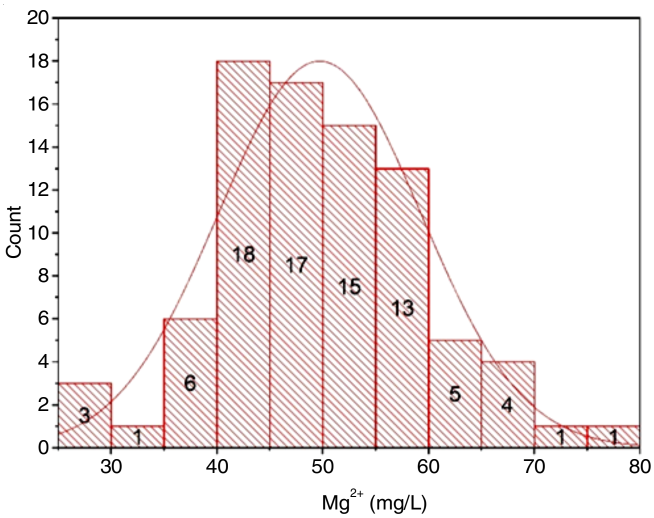

Fig. 9. Distribution of magnesium

Total alkalinity: Alkalinity is the capacity to neutralize the acid, alkalinity depends on carbonate, bicarbonate and hydroxyl ion present in the water. A positive correlation was found between the pH and fluoride, which indicates that high alkaline nature of the water promotes leaching of fluoride and thus, affects the concentration of fluoride in groundwater [29]. Alkalinity may be present in water samples as hydroxyl alkalinity, carbonate alkalinity, phenolphthalein alkalinity and bicarbonate alkalinity in the form of calcium carbonate, when pH is less than 8.3 means phenolphthalein alkalinity/carbonate alkalinity and hydroxyl alkalinity are absent.

All the samples were found pH values less than 8.3 which indicated absence of phenolphthalein alkalinity, when phenolphthalein alkalinity is zero then hydroxyl alkalinity, carbonate alkalinity will be zero therefore all the samples were having only bicarbonate alkalinity.

The range of total alkalinity was found to be 264-667.6 mg/L. Maximum value of total alkalinity was reported (667.6 mg/L), which was found in the village of Manikpura-02 and minimum value (264 mg/L) was recorded from the village of Chandrapur in Tehsil Bah. The average value of total alkalinity was 429 mg/L. The acceptable limit of total hardness is 200 mg/L in accordance to IS 10500:2012 [26]. All the sample values were found above the acceptable limit *i.e.* 200 mg/L. Frequency histogram is plotted to express concentration of the total alkalinity (mg/L) *versus* number of the reported samples, minimum reported value is found (264 mg/L) and the maximum value is reported 667.7 mg/L. Maximum number of reported values of total alkalinity are recorded between 400 mg/L to 500 mg/L.

Fluoride: Earth Crust of Agra District is rich with fluorine content which is common element and widely distributed as fluoride. The water level is going down day by day and deeper zones, which are having traces of fluoride are coming with more contact with groundwater as a results fluoride from deeper zones coming in groundwater *via* leaching process. Acceptable limit of fluoride is 1.5 mg/L as per IS 10500: 2012 and WHO [7]. Concentrations above this value may increase risk of dental fluorosis and skeletal.

Fluoride concentration of the area was observed between 0.27 to 2.14 mg/L, maximum value (2.14 mg/L) was recorded in the sample collected from Syahipura-2 village of Tehsil Bah. The average value of fluoride was found 1.2 mg/L, which is slightly higher value. Recommended value of fluoride is usually 0.5 to 1.0 mg/L as per WHO guidelines. Fluoride is also beneficial elements for prevention of dental caries by adding fluoride content in balanced amount. Fluoride values are distributed in Fig. 10, range of the reported values are found between 0.27 mg/L (minimum value) to 2.14 mg/L (maximum value), The frequency histogram is plotted to express the distribution of the concentration of fluoride with the number of reported samples.

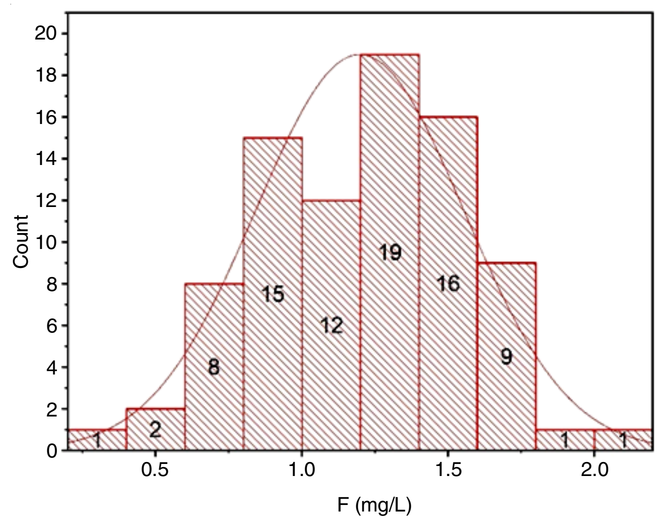

Fig. 10. Distribution of fluoride

Sulfate: The presence of sulfate in groundwater may cause noticeable taste and contribute to the corrosion in water supply system. Very high concentration in drinking water might cause laxative effect. Sulfate values of the area were observed between 42.4 mg/L to 210.1 mg/L as SO_4^{2-}. Highest value of sulfate (210.1 mg/L) was recorded from Basai Arela-1 village and lowest value of sulfate (42.4 mg/L) was recorded from Holipura village of tehsil Bah. Acceptable limit for sulfate is 200 mg/L, two samples Basai Arela-1 and Basai Arela-3 are not meeting the requirements of acceptable limit as per IS 10500:2012 [25]. Average value of sulfate observed was 81.1 mg/L sulfate as SO_4^{2-}. The frequency histogram expresses the distribution of the concentration of sulfate values distribution from 42.4 mg/L (minimum value) to 210.1 mg/L (maximum value) (Fig. 11).

Nitrate: Nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring anions in the environment and both are important nutrients for plant growth. Nitrite is unstable form and oxidized to more stable form *i.e.* nitrate. Nitrogen present in the environment comes to soil by the nitrification process and use by plant in the form of nitrate, this is also the potential way to reach nitrate and nitrite in groundwater. Excess amount nitrate and nitrite present in the agriculture land are being reached to the groundwater aquifers by soil and rock leaching process.

Range of nitrate content in the area was recorded from 6.1 mg/L to 26.8 mg/L and nitrite content was not reported in

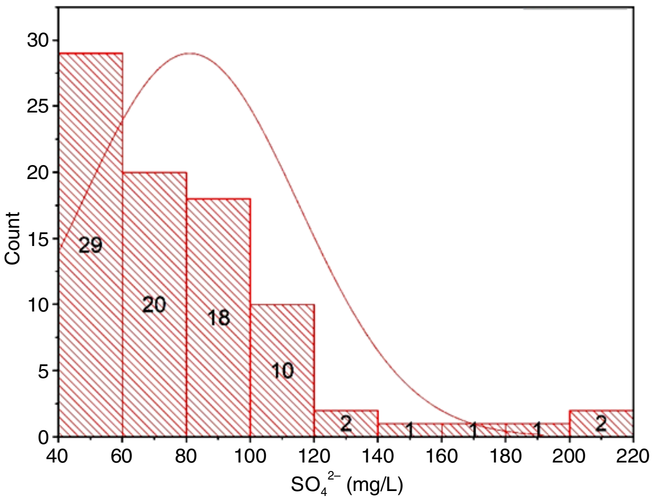

Fig. 11. Distribution of sulfate

any samples of groundwater. Maximum value of nitrate (26.8 mg/L) was recorded from Bah-1 which is within the acceptable limit (200 mg/L) given by BIS in IS 10500:2012 [26].

Chloride: Salty taste of water indicates the presence of chloride in higher amounts. Range of chloride (Cl^-) was observed between 42 to 437.4 mg/L. Average value of chloride was 239.1 mg/L. Maximum value of chloride was recorded as 437.4 from Nagla Bhari-03 village, which is higher than the acceptable limit of chloride (250 mg/L). Average value (239.1 mg/L) is also very close to the acceptable limit prescribed in IS 10500: 2012 [26]. Chloride content coming to the groundwater which indicates leaching from the deeper rocks, which are rich with minerals. There are no health-based guidelines for chloride content in groundwater.

Sodium and potassium: Sodium and potassium are essential element in humans and found in all types of food and water. Excess concentration of sodium (200 mg/L) may give rise to unacceptable taste. Sodium and potassium are also the chief contributor in total dissolved solids (TDS).

Range of sodium and potassium concentration were recorded 53.7 mg/L to 401.6 mg/L and 1.6 mg/L to 32.6 mg/L, respectively. Maximum value of sodium (401.6 mg/L) and potassium (32.6 mg/L) were observed from Nagla Bhari-03 and Roop Pura village of Tehsil Bah, Agra district. Average values of sodium were195.4 mg/L, which may give unacceptable taste of water. Mean value of potassium is 12 mg/L, which may not cause any adverse impact on water quality.

Iron: Iron in groundwater may be present in the form of ferrous as anaerobic conditions are persist in groundwater aquifers, once groundwater comes contact with atmosphere then ferrous oxidized to ferric which is stable form of iron. Iron is an essential element in human nutrition and also play a vital role in transportation of oxygen in respiratory system with hemoglobin.

Iron value were observed in the area between 0.08 mg/L to 0.81 mg/L, average value of iron was 0.35 mg/L which is higher than the limit prescribed by WHO (0.1 mg/L) and IS 10500:2012 (0.3 mg/L). Minimum value of iron was recorded in Nagla Bhari-02.

Conclusion

The main objective of this paper is to analyse ground water samples for some physico-chemical parameters for drinking purpose. This analysis will help the general public and the researchers understand the water quality of groundwater in Tehsil bah, Agra district high levels of TDS, alkalinity, hardness, calcium, magnesium and F^- are major water quality issues in drinking purpose. It is further recommended that community based quality control equipment should be explored in order to reduce waterborne health issues. The quality of groundwater of tehsil Bah is not meeting the requirement of acceptable limit given under Indian standard for drinking water due to the over exploitation of groundwater. It is found that the rate of the pumping of underground water for domestic, irrigation and other purposes is more over the recharge or replenish of groundwater. The difference between pumping of groundwater and recharge or replenish of groundwater is one of the reasons for exploitation of groundwater quality. It is required to recharge the groundwater resources and to maintain the sustainable approach for groundwater to maintain the difference of recharge or replenish of groundwater and the pumping of groundwater. It is also suggested to check the groundwater quality on regular intervals to know about the current status of groundwater quality. Conducting public awareness programs to update the knowledge to save the water contamination. It is further recommended for piped water supply wherever quality of water is not meeting the requirement of IS 10500:2012.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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