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Research Article

ASSESSMENT OF HEAVY METALS, QUALITIES OF GROUND WATER, AND ITS CORRELATION WITH NATURAL ORGANIC MATTER

SUNITA BHASKAR, HARI MADHAV, PARAMJIT SINGH, GAUTAM JAISWAR*

Department of Chemistry, Dr. Bhim Rao Ambedkar University, Agra - 282 002, Uttar Pradesh, India. Email: gjaiswar@gmail.com

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ABSTRACT

Objective: This study was designed to predict the ground water qualities of different locations of central Agra city, Uttar Pradesh, India.

Methods: Physico-chemical parameters were investigated such as pH, total dissolved solids (TDS), total hardness (TH), levels of calcium (Ca^{++}) and magnesium (Mg^{++}), two carbonate, sodium carbonate (Na_2CO_3) and sodium bi carbonate ($NaHCO_3$), six heavy metals (Cu, Zn, Fe, Mn, Cd, and As), and they were analyzed by atomic absorption spectrophotometer (AAS), fluoride investigation by spectrophotometer, and analysis of natural organic matter (NOM) by Fenton's process.

Results: The results show that pH of water samples varies from 6.91 to 8.5, and the pH of TDS and TH varies from 800 to 3970 ppm and 74 to 1942 ppm, respectively. It was observed that experimental pH is under permissible limits, while TDS and TH are more than permissible limit. The carbonate concentration was observed between 0.0336 and 0.7056 g/L which was more than permissible limits at some locations. NOM and heavy metals were also evaluated.

Conclusion: This paper deals with the evaluation of pH, TDS, TH, levels of Ca^{++} and Mg^{++}, Na_2CO_3 and $NaHCO_3$, heavy metals, fluoride value, and NOM removal from ground water by Fenton's process. Correlation matrix shows a significant relation between heavy metals and NOM. The high values of these parameters might have health complications and so they need attention. The above studies are helpful to understand the ground water quality and their subsequent fitness or unfitness of ground water for drinking and domestic purpose at various sites undertaken. The obtained data were compared by standards.

Keywords: Ground water, Heavy metals, Atomic absorption spectrophotometer, Natural organic matter.

INTRODUCTION

"Water is the nectar of human life." Water is quite important for living beings. The main source of water is rain, so groundwater is an important source of water supply throughout the world [1]. It has been observed that water is polluted in all the surfaces of earth. Ground water makes up about 20% of the world's fresh water supply and it is about 0.61% of the entire world's water, so it is the most important source of potable water throughout the word [2]. Out of the total fresh water, ground water is maximum exploited in each and every sector such as agricultural, industrial, and domestic in developing countries such as India. Overburden by means of population pressure, unplanned urbanization, unrestricted exploration policies, and dumping of the polluted water at inappropriate place enhance the infiltration of harmful compounds to the ground water [3]. The quality of water is of vital concern for the humanity since it is directly linked with human welfare. There are several states in India where more than 90% populations are dependent on ground water for drinking and other purposes [4,5]. The uncontrolled disposal of industrial and urban wastes and the use of chemical substances in agriculture (fertilizers, herbicides, and pesticides) are the primary causes of ground water contamination [6]. Ground water contains large quantities of dissolved inorganic and organic compounds, which can be harmful for human health. The current water treatment is the conventional treatment based on chemical coagulation/flocculation process. The natural organic matter (NOM) present in ground water is a complex mixture of organic materials such as humic acids, hydrophilic acids, proteins, lipids, carbohydrates, and amino acids. It changes water characteristics such as taste, smell, and color [7]. Consequently, the number of cases of water-borne diseases has been seen that is a cause of health hazards.

Agra city in Uttar Pradesh is situated at north-central part of India, and it is famous for the world heritage monument, Taj Mahal. Uttar Pradesh is situated between 27.11° Latitude North and 78.0 to 78.2° Longitude East. Its altitude is 169 m above the sea level. Agra is bounded by Mathura district in North, Dholpur district in South, Firozabad district in East, and Bharatpur district in West. Agra is situated on the bank of holy river, the Yamuna. It is the most populous district in Uttar Pradesh and had a population of 438,0793 as per 2011 census. In terms of urbanization level, Agra district ranks 8th place among the other district in Uttar Pradesh. The status of the ground water depends on a large number of individual physico-chemical parameters and heavy metals. Pollutants are added to the ground water system through anthropogenic activities and natural processes. Agra city is surrounded by many leather tanneries and small scale dying industries, and their effluents are discharged into the Yamuna river, causing impact on the quality of the underground water [8]. Underground water is one of the sources of water for activities of human beings (such as drinking, bathing, washing, farming, industrial purpose, etc.) in Agra district.

Hence, the focus of this study was to analyze and evaluate the quality of ground water in Agra city due to the contamination of drinking water. The ground water quality of Agra city is continuously degrading due to surface waste water, irrigation waste water, industrial waste water, hospital waste dumps in the river Yamuna, factories' waste, etc., and these affect the soil and ground water of nearby fields. Ground water level decreases day by day, therefore we have decided to analyze the ground water. Samples were randomly collected within Agra city. The different sampling locations pointed out by dark black circle covering the whole Agra city are shown in Fig. 1.

MATERIALS AND METHODS

Collection of samples

The collections of samples were done from six different locations of Agra city, namely, Bodla, Agra Cantt, Fatehabad, Dayalbagh, Trans

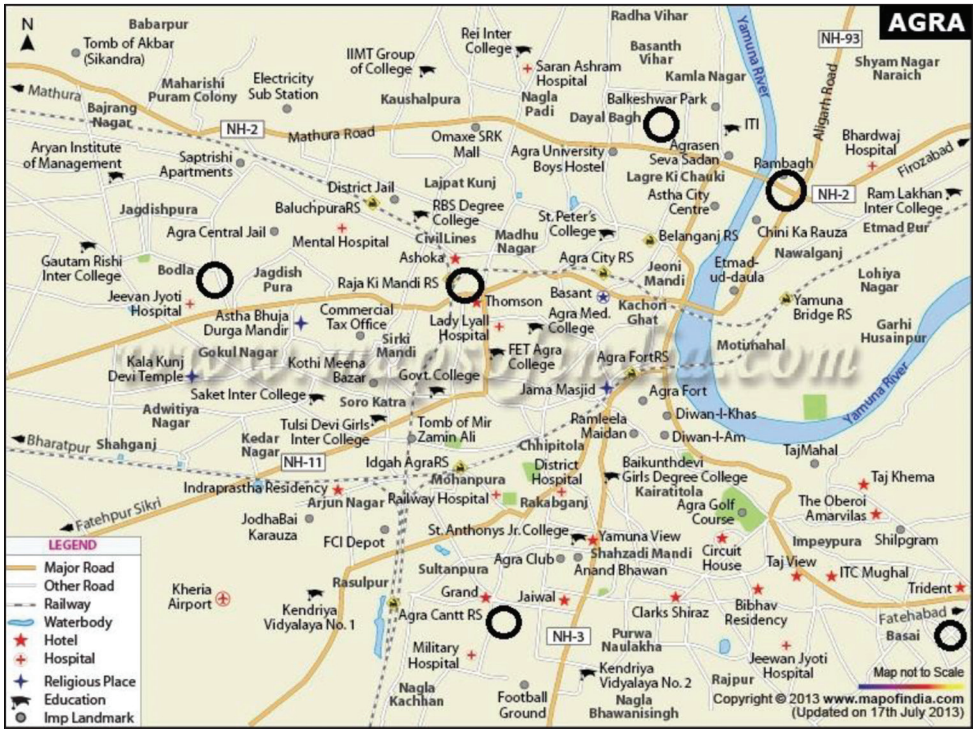

Fig. 1: Agra city map with different locations of sampling sites [9]

Yamuna, and Raja ki Mandi, and at each location, four different ground water samples were collected during the summer season (collection of samples' time: 10-15th June 2014). Ground water samples were collected by using clean and dried plastic bottles of capacity 2 L; before collecting the samples, the containers were washed with distilled water and 2-3 times rinsed with actual ground water. A total of 24 ground water samples were collected including water from hand pumps and borewells from different locations of Agra city. The different locations of sample collection were done by choosing approximately 200 m circumference distance from the main location of the sample collection. The depth of ground water samples was from 55 to 270 feet in Agra city. Location of the sampling sites and their respective depths are shown in Table 1.

Table 1: Location of sampling sites and their respective depth of hand pumps and borewells in Agra city

S. No.	Location of sampling sites	Depth (in Feet)
1	Bodla	
	BS 1	120
	BS 2	175
	BS 3	120
	BS 4	160
2	Agra Cantt	
	AS 1	140
	AS 2	220
	AS 3	150
	AS 4	90
3	Fatehabad	
	FS 1	220
	FS 2	200
	FS 3	270
	FS 4	150
4	Dayalbagh	
	DS 1	120
	DS 2	120
	DS 3	120
	DS 4	200
5	Trans Yamuna	
	TS 1	55
	TS 2	60
	TS 3	60
	TS 4	70
6	Raja ki Mandi	
	RS 1	100
	RS 2	120
	RS 3	95
	RS 4	95

Analytical procedure

Digital pH meter, electrical conductivity, atomic absorption spectrophotometer (AAS), and spectrophotometer were used for analysis of ground water.

Materials

Contaminated ground water samples were collected from six locations across Agra city. The observed locations were polluted, non-polluted, crowdy, and dirty, which were considered to be the most important sites in main city. Those hand pumps and borewells which are used in daily public use and for domestic utilization were selected for collection of samples. A total of 24 samples of ground water in 2 liter clean and dry bottles were collected from six selected regions.

Methods

Physico-chemical analysis

The collected ground water samples were analyzed for major physical and chemical water quality parameters such as hydrogen ion conductivity (pH), total dissolved solids (TDS), total hardness (TH), sodium bi carbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3), and calcium (Ca^{++}) and magnesium (Mg^{++}) levels. pH was determined electrometrically using precalibrated digital pH meter, model number LT-11. TDS was analyzed using digital conductivity meter model number CE1-14. The titration method was used to determine $NaHCO_3$ and Na_2CO_3, and complexometric titration using ethylenediaminetetraacetic acid or disodium salt was utilized to analyze the TH. Furthermore, AAS was applied to determine Ca^{++} and Mg^{++}.

Fluoride test

Fluoride was estimated using spectrophotometer model number DR-5000, HACH. The instrument was calibrated using 10 ml distilled water and 2 ml readymade SPADNS 2 (Arsenic-free) fluoride reagent solution, provided by the company (HACH) which was taken in cuboid and the timer being set for 1 minute. After calibration, the sample was analyzed for the estimation of fluoride contents in groundwater samples by using a mixture of 10 ml sample and 2 ml reagent in cuboid for spectrophotometer analysis.

Heavy metals by AAS

The heavy metals (Zn, Cu, Fe, Mn, Cd, and As) were analyzed by AAS model number GBC-932 plus. The calibration was done using standard stock solution (1000 ppm), and the required standards (Table 2) were prepared according to the hollow cathode lamps set. Air and acetylene gas cylinders were used as oxidant and fuel, respectively, for heavy metals (Zn, Cu, Fe, Mn, Cd, Ca^{++}, and Mg^{++}) except in the case of As element, where nitrous oxide with air and acetylene gas cylinders was used.

NOM in groundwater by Fenton's process

Fenton's reagent is a catalytic oxidative mixture that contains iron ions and hydrogen peroxide. In this process, hydroxyl radicals are produced during the decomposition of hydrogen peroxide in the presence of ferrous salts [10].

$H_2O_2 + Fe^{2+} \rightarrow HO^{\bullet} + OH^{-} + Fe^{3+}$

$^{\bullet}OH + RH \rightarrow$ Oxidation products

The generated OH radicals have a strong oxidizing potential and they are capable of oxidizing a wide range of compounds.

Analysis of NOM by Fenton's process in groundwater samples

About 500 ml of groundwater samples from each locations were taken, and 0.1 g of iron (II) sulfate was added to each sample, also few drops of concentrated HCl were added to set pH level between 3 and 3.5, and after that 15 ml of H_2O_2 (6%) was added to each sample and stirred for 30 minutes by a magnetic stirrer followed by the addition of activated charcoal 15 mg which was then stirred further for 5 minutes. The final solutions were filtered through Whatmann filter paper No. 1, and the obtained residues were completely dried in oven and weighed. The above procedure was repeated for all the samples. Caution was taken not to use citric, acetic, or phosphoric acids since they lower the effectiveness of the Fenton's process.

RESULTS AND DISCUSSION

Some physical tests were performed to find the physical parameters of water including determination of pH and TDS, while chemical test is executed to find TH, $NaHCO_3$, Na_2CO_3, and Ca^{++} and Mg^{++} levels. For obtaining more and more quality and purity of ground water, it was tested for its heavy metals (Zn, Fe, Cu, Mn, Cd, and As) and NOM. The experimental data were compared with the standard of groundwater by Jal Nigam, Agra, which is shown in Table 3, and standard by the WHO and ISI, which are shown in Table 4 [11,12].

pH

The lowest concentration of pH was observed in RS 2 at Raja ki Mandi location and the highest concentration of pH was observed in DS 4 at Dayalbagh location. The pH concentrations of groundwater at different sampling locations are shown in Table 5.

TDS

The lowest value of TDS (=800) was observed in FS 1 at Fatehabad location and the highest value of TDS (=5270) was observed in DS 3 at Dayalbagh location, and this location was highly dirty, where waste water gets directly mixed to groundwater and sewage facility is not up to the mark so that groundwater quality gets deteriorated and it is not good for human beings. The observed data for TDS results are shown in Table 5.

Table 2: Prepared standard solutions for the metal detection according to required metal standards used (in ppm)

Metal	Standards used (in ppm)
Zn	0.4, 0.8, 1.6, 2.0
Cu	0.2, 0.5, 1.0, 2.0, 3.0
Fe	2, 4, 6, 8,10
Mn	1, 2, 3, 4
Cd	0.2, 0.4, 0.8, 1.2, 1.6, 2.0
As	30, 60, 90, 120, 150
Mg^{++}	0.2, 0.4, 0.6, 0.8, 1.0
Ca^{++}	100, 200, 400, 800

Table 3: Standards of groundwater by Jal Nigam, Agra

Parameters	Unit of measurement	BIS acceptable limit	BIS permissible limit in the absence of alternate source
Turbidity	NTU	1.0	5
pH		6.5-8.5	6.5-8.5
TDS	ppm	500	2000
F	ppm	1	1.5
Fe	ppm	0.3	0.3
Cl	ppm	250	1000
TH	ppm	200	600
Alkalinity	ppm	200	600
As	ppm	0.01	0.05
Ca	ppm	75	200
Mg	ppm	30	100

TDS: Total dissolved solids, TH: Total hardness

Table 4: Standards of groundwater by the WHO and ISI

Parameters	WHO (2004)	ISI (1995)
EC	1400	-
pH	6.5-8.5	6.5-9.2
TDS	500-1000	1500
Ca	100	75-200
Mg	50	30-100
TH	100	300-600

TDS: Total dissolved solids, TH: Total hardness, EC: Electrical conductivity

Sodium bi carbonate ($NaHCO_3$) and sodium carbonate (Na_2CO_3)

The lowest value of $NaHCO_3$ was observed in BS 1 at Bodla location and the highest value was observed in RS 2 at Raja ki Mandi while the lowest value of Na_2CO_3 was observed in AS 1, AS 3, FS 4, DS 1, DS 2, and TS 2 and the highest value was observed in BS 3. The observed values of sodium bi carbonate and sodium carbonate data are shown in Table 5.

TH

In hard water which consists of a variety of dissolved polyvalent metallic ions, predominantly, calcium and magnesium cations, although other cations (e.g., aluminum, barium, iron, manganese, strontium, and zinc), also contribute. Although hardness is caused by cations, it may also be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. The lowest value of hardness was observed in DS 4 and the highest value of hardness was observed in DS 3 at Dayalbagh location. The observed data for TH are shown in Table 6.

Calcium (Ca^{++})

In DS 3 at Dayalbagh location, Ca**++** was observed at a high concentration (=321.55) that was out of permissible limit. In FS 1 at Fatehabad location,

Ca^{++} was observed at a lowest concentration (=68.21) and this was less than the permissible limit. The analysis results for concentration of Ca^{++} are shown in Table 6.

Magnesium (Mg^{++})

The lowest concentration of Mg^{++} was observed in FS 1 (=2.219) at Fatehabad location and the highest concentration of Mg^{++} was observed in AS 1 (=3.022) at Agra Cantt location. The observed data for Mg^{++} contents are shown in Table 6.

Table 5: Analysis of physico-chemical parameters of groundwater samples in Agra City

Location	pH ($log_{10}H^+$)	TDSs (ppm)	Sodium bi carbonate (g/L)	Sodium carbonate (g/L)
Bodla	7.65	1080	0.0336	0.4664
	7.4	1380	0.5376	0.2332
	7.2	1590	0.0672	0.6148
	7.6	2620	0.3696	0.212
Agra Cantt	7.15	3970	0.6384	0.0848
	7.2	3530	0.5712	0.1272
	7.25	3530	0.4368	0.0848
	7.7	2100	0.42	0.106
Fatehabad	8.1	800	0.4704	0.1484
	7.1	1820	0.6048	0.1272
	7.5	1600	0.588	0.106
	7.2	2570	0.7056	0.0848
Dayalbagh	7.7	1030	0.504	0.0848
	7.55	1090	0.4536	0.0848
	7.01	5270	0.4368	0.1272
	8.5	1280	0.2016	0.212
Trans Yamuna	7.24	1710	0.504	0.1272
	7.06	2360	0.6888	0.0848
	7.54	1280	0.3864	0.1272
	7.3	2880	0.5376	0.1272
Raja Ki Mandi	7.35	2050	0.3864	0.1272
	6.92	2200	0.7392	0.1908
	7.4	1290	0.3528	0.2544
	7.25	2020	0.588	0.106

TDS: Total dissolved solids

Fluoride (F^-) test

The lowest concentration of fluoride concentration was found in AS 4 at Agra Cantt location and the highest concentration was found in BS 2 at Bodla location. The observed data of fluoride content are shown in Table 7.

Heavy metal determination

Metallic elements (Cu, Cd, Zn, and Fe)

The lowest concentration of Zn was observed in BS 1 at Bodla location and the highest concentration was observed in AS 2 at Agra Cantt location. The standard permissible limits for heavy metals by the WHO and ISI [13,14] are shown in Table 8, and the investigated data are shown in Table 9. The impact of heavy metals on human body is shown in Table 10 [15].

The lowest concentration of Fe was observed in DS 2 at Dayalbagh and the highest in BS 1 at Bodla location. The lowest value of Cu was observed in RS 1 at Raja ki Mandi and the highest value in TS 3, Trans Yamuna location while the lowest value of Cd was observed in DS 2 at Dayalbagh and the highest concentration was observed in BS 4, AS 2, and FS 3 sites. The examination data for Cu analysis are shown in Table 9. The experimental data for these heavy metals are shown in Table 9.

Transition metals (Mn)

In AS 4 and FS 2 sites, lowest concentration of Mn was found and highest concentration was found in AS 2 site. The experimentally obtained data are shown in Table 9.

Toxic element (As)

Arsenic was not found in most of the samples, but one place, i.e., AS 1 at Agra Cantt location, it was found to be 0.08 ppm. The concentration limit of As is 0.01-0.05 ppm according to the WHO and ISI standards. The results of the concentration of As are shown in Table 9.

NOM in groundwater by Fenton's processes

From our study of ground water in different locations of Agra city, it was observed that the maximum value for NOM was found in the BS 2 (0.075) at Bodla location and minimum value was found in

Table 6: Analysis of hardness of groundwater samples in Agra city

Location	TH (ppm)	Permanent hardness (ppm)	Temporary hardness (ppm)	Calcium (ppm)	Magnesium (ppm)
Bodla	86	62	24	102.44	2.499
	98	66	32	97.62	2.477
	154	112	42	123.58	2.617
	502	380	122	182.57	2.531
Agra Cantt	412	396	16	265.93	3.022
	500	404	96	232.03	2.854
	876	352	20	250.08	2.981
	1016	552	78	112.41	2.698
Fatehabad	136	90	46	68.21	2.219
	330	272	58	161.41	2.85
	876	750	126	128.04	2.552
	1016	692	324	174.89	2.759
Dayalbagh	440	350	90	100.31	2.599
	474	364	110	109.45	2.586
	1942	1730	212	321.55	2.94
	74	52	22	86.04	2.344
Trans Yamuna	570	400	170	127.17	2.592
	1048	684	364	177.59	2.751
	690	308	382	108.66	2.583
	770	602	168	186.11	2.629
Raja Ki Mandi	732	566	166	118.96	2.583
	1134	664	470	101.23	2.777
	376	268	108	101.2	2.507
	580	340	240	147.56	2.592

TH: Total hardness

FS 1 (0.001) at Fatehabad location. The observed NOM data are shown in Table 11.

Table 7: Analysis of fluoride in groundwater samples in Agra city

Location	Fluoride (ppm)
Bodla	1.59
	2.68
	1.38
	1.76
Agra Cantt	0.53
	0.22
	0.61
	0.11
Fatehabad	1.01
	0.78
	0.22
	0.58
Dayalbagh	1.13
	0.24
	0.6
	2.64
Trans Yamuna	1.98
	0.22
	1.02
	1.08
Raja Ki Mandi	0.17
	0.4
	0.79
	0.38

Table 8: Permissible heavy metal limits according to the WHO and ISI

Metal	WHO (1994)	ISI (1991)
As	0.01	0.05
Mn	0.05-0.5	0.1-0.5
Cu	0.05-1.5	0.05-1.5
Cd	0.01	0.01
Fe	0.1-1	0.3-1
Zn	5-15	-

Statistical analysis

Level of Cd in groundwater was positively associated with the level of Cu (0.244), Mn (0.353), and negatively with Fe (−0.274). In addition, Mn was related considerably with Zn (0.513). Similarly, NOM was optimistically correlated with Mn (0.289) and Cd (0.240). Correlation between heavy metals and NOM in ground water samples is shown in Table 12.

CONCLUSION

In the present research work, related to groundwater quality of Agra city, the obtained results of groundwater samples conclude that the pH of ground water samples is under permissible limit as per the WHO guidelines (1994), but in FS 1, Fatehabad region and DS 4, Dayalbagh region, groundwater sample is basic (alkalinity), and in RS 2, Raja ki Mandi region, groundwater sample is acidic. TDS of ground water samples was found to be highest in DS 3, Dayalbagh region, because that area was highly polluted. For TH in the ground water samples, the highest hardness was obtained in DS 3, Dayalbagh and FS 4, which were contaminated and not beneficial for drinking, bathing, etc., because that water may cause many diseases such as hair fall and osteoporosis. Analysis of magnesium and calcium in all locations of ground water samples shows that in DS 3, Dayalbagh region, ground water is highly infected with calcium, and in FS 1, Fatehabad region, calcium is less than the limit. High and low ranges of calcium have an effect on human body. From the analysis, it was observed that BS 2 and DS 3, Dayalbagh regions are highly polluted by fluoride that were out of permissible limit which indicates that Agra city is contaminated by fluoride. The heavy metal detection shows that the element of arsenic was not found in most of the samples, this may be due to the detection limit of arsenic which is very low, so it could not be detected in our samples, but in one place at Agra Cantt region, the As was found to be 0.08 ppm. Copper element was found to be at 0.002-0.018 ppm, and cadmium concentration ranged from 0.008 to 0.034 ppm. From the analysis, Zn metal concentration ranges from 0.022 to 0.872 ppm, which shows that in Agra city, zinc metal concentration was less than the limit. At some location, observed iron concentration was under permissible limit which ranges from 0.012 to 0.101 ppm and manganese (Mn) concentration varies from 0.003 to 0.081 ppm. The NOM in groundwater of Agra city was also observed, its value ranges from 0.001 to 0.075. Correlation is significant in between heavy metals and NOM as per r and p values ($p<0.05$). NOM presents in the groundwater in every location of Agra city.

Table 9: Experimental data for heavy metals of groundwater samples in Agra city

Location	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Cadmium (ppm)	Arsenic (ppm)
Bodla	0.022	0.101	0	0.041	0.026	0
	0.125	0	0	0	0.021	0
	0.141	0.07	0.002	0	0.016	0
	0.047	0	0.007	0	0.034	0
Agra Cantt	0.056	0.057	0	0	0.017	0.08
	0.872	0	0.018	0.081	0.034	0
	0.194	0.034	0.006	0.02	0.023	0
	0.061	0	0.015	0.003	0.031	0
Fatehabad	0.044	0.095	0	0	0.018	0
	0.119	0	0	0.003	0.017	0
	0.037	0	0.012	0	0.034	0
	0.042	0.062	0.006	0.028	0.026	0
Dayalbagh	0.19	0	0	0.022	0.023	0
	0.083	0.012	0	0	0.008	0
	0.797	0.067	0	0	0.009	0
	0.061	0.028	0.012	0.02	0.031	0
Trans Yamuna	0.058	0	0	0	0.017	0
	0.152	0	0.002	0	0.031	0
	0.117	0	0.038	0.02	0.015	0
	0.087	0.024	0.027	0	0.025	0
Raja Ki Mandi	0.064	0.022	0.001	0	0.027	0
	0.101	0	0.004	0.012	0.03	0
	0.324	0	0.005	0.019	0.023	0
	0.101	0	0	0	0.017	0

Table 10: The impact of heavy metals on human body

Heavy metals	Effect on human body
Copper (Cu)	Astringent taste but essential elements for metabolism, deficiency results is anemia in infants, excess may results in liver damage
Iron (Fe)	Promote iron bacteria in water, bad taste, in trace is nutritional
Manganese (Mn)	Produce bad taste, essential as cofactor in enzyme system and metabolism process. Excess causes reduced metabolism of iron to form hemoglobin
Zinc (Zn)	Causes astringent taste and opalescence in water, essential elements in human metabolism
Arsenic (As)	Beyond this limit, water become toxic, causes skin damage circulatory problem increase risk of skin cancer

Table 11: NOM from groundwater of Agra city

Location	Weight of filter paper (A) (g)	Weight of charcoal (B) (g)	Total weight (A+B) (g)	After treatment with Fenton's process drying of filter paper (C) (g)	Weight of NOM [C-(A+B)] (g)
Bodla	0.627	0.015	0.642	0.686	0.044
	0.705	0.015	0.72	0.795	0.075
	0.798	0.015	0.813	0.815	0.002
	0.797	0.015	0.812	0.815	0.003
Agra Cantt	0.81	0.015	0.825	0.825	0.015
	0.8	0.015	0.815	0.815	0.04
	0.805	0.015	0.82	0.82	0.008
	0.652	0.015	0.667	0.667	0.002
Fatehabad	0.818	0.015	0.833	0.834	0.001
	0.784	0.015	0.799	0.808	0.009
	0.663	0.015	0.678	0.705	0.027
	0.78	0.015	0.795	0.825	0.03
Dayalbagh	0.812	0.015	0.827	0.899	0.072
	0.804	0.015	0.819	0.828	0.009
	0.668	0.015	0.683	0.691	0.008
	0.805	0.015	0.82	0.825	0.005
Trans Yamuna	0.82	0.015	0.835	0.838	0.003
	0.777	0.015	0.792	0.852	0.06
	0.654	0.015	0.669	0.678	0.009
	0.804	0.015	0.819	0.846	0.027
Raja Ki Mandi	0.838	0.015	0.853	0.861	0.008
	0.835	0.015	0.85	0.858	0.008
	0.813	0.015	0.828	0.839	0.011
	0.789	0.015	0.804	0.813	0.009

NOM: Natural organic matter

Table 12: Correlation between heavy metals and NOM in groundwater samples

	Zn	Fe	Cu	Mn	Cd	As	NOM
Zn	1						
Fe	−0.02756	1					
Cu	0.07892	−0.26598	1				
Mn	0.513417	0.049029	0.282737	1			
Cd	−0.07631	−0.27429	0.244071	0.353442	1		
As	−0.10403	0.213342	−0.1413	−0.1263	−0.16803	1	
NOM	0.111061	−0.1343	−0.09181	0.2893	0.24034	−0.04966	1

NOM: Natural organic matter

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