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RESEARCH ARTICLE

CHEMOMETRIC STUDIES OF WATER-QUALITY PARAMETERS OF DRINKING WATER- A CASE STUDY OF NARWANA CITY, HARYANA (INDIA)

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ABSTRACT

Water is an essential natural resource for sustaining life and environment but over the last few decades the water quality has been deteriorated due to its over exploitation. Water quality is essential parameter to be studied when the overall focus is sustainable development keeping mankind at focal point. The present study was conducted to analyze the various parameters of under-ground water in Narwana City, Haryana, India and to check its fitness for drinking. Fourteen Water samples were collected from different localities in cleaned polythene bottles and analyzed for the different parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium, magnesium, total alkalinity (TA), carbonate, bicarbonate, chloride, fluoride, iron, sodium, potassium, sulphate, nitrate and phosphate. The parameters were compared with the standard desirable limits prescribed by World Health Organization (WHO), Bureau of Indian Standard (BIS) and Indian Council of Medical Research (ICMR) standards of drinking water quality parameters. It is concluded that the water quality of water supply systems in different locations of Narwana is of medium quality and can be used for domestic use after suitable treatment. Suitable suggestions were made to improve the quality of water.

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INTRODUCTION

Water is life's matter and matrix, mother and medium**.** Water is a wander of the nature. "No life without water'' is a common saying depending upon the fact that water is the one of the naturally occurring essential requirement of all life supporting activities (Gorde and Jadhav, 2013). Not only the life processes of animals and plants depend upon water but it also has a significant role in industrial processes. Only a small fraction (about 2.5%) of earth's water is fresh and suitable for human consumption. Approximately 13% of this fraction is ground water; an important source of drinking water for many people worldwide (Bindhu and Selvamohan, 2009). The ground water has been used for drinking for a long time and its purity has made it a well known source of potable water all over the world. In Haryana, under-ground water is available in the form of drinking water and they are used by more than 50% of total population of the region to meet their daily requirements. In recent years, bore wells are also in use in many parts of the Haryana State as a source of potable water (Chauhan and Paliwal, 2009). Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic or industrial application (Ernst, 1991). Nitrate has been identified as one of the major anionic pollutants of ground water (Gandatra *et al*., 2008). High concentration of nitrates in ground water has been related with excessive use of nitrogen fertilizers in agriculture and high amount of organic waste generated by human population (Kataria, 2004).

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Review of Literature

Tatawati and Chandel (2008) have studied the ground water quality of Jaipur City, Rajasthan. An extensive study of the modeling of Buckingham Canal Water Quality is available in literature (Abbasi *et al*., 2002). The study by Jyashri *et al*. (2002) was also carried out on the water quality assessment of

the Purna River in Buldana District, Maharastra. Jha and Tignath (Jha and Tignath, 2009) have studied the assessment and impacts of surface water environment in and around Jabalpur city, Madhya Pradesh. Studies on Ground Water Quality were done in Hyderabad (Sriniwas *et al*., 2000). The physico–chemical properties of drinking water in town area of Godda District, Bihar were reported by (Jha and Verma, 2000). Patnaik *et al*. (2002) reported water pollution in industrial area. Ravisankar and Poongothai (2008) have studied the ground water quality of Tsunami affected areas Sirkazhi Taluk, Nagapattinam, Tamil Nadu. Some studies (Jha and Verma, 2000; Patnaik, 2002; Sharma *et al*., 1990) are available on the assessment of Fluoride level and trace metals in drinking water from various sources in and around Jaipur and in many villages. Recently, Sharma *et al*. (2004) have studied the industrial wastewater and ground water, and pollution problem in ground water. Singh and Chandel (2006) have analyzed the wastewater, which is used for agricultural purpose. Review on the literature showed that no studies have been undertaken in the study area in regard to physico-chemical characteristics of water yet. So the objective of this study is to investigate the quality of drinking water (underground water) in Narwana City, Haryana, India.

Study area & sampling

Fourteen water samples were collected in post-monsoon (October-December-2014). These samples were collected in pretreated and labeled plastic bottles (1.5 L) and were immediate preserved and analyzed following standard protocols given in APHA (APHA 1992). Each bottle was washed with 2% Nitric acid and then rinsed three times with distilled water. The sampling places are referred as stations (N_1-N_{14}). The different sampling locations are given in Table 1.

MATERIALS AND METHODS

Portable water analyzer Kit (WTW Multy 340/ SET) was used to measure four water quality parameters on site and these were pH, water temperature (WT), dissolved oxygen (DO) and electrical conductivity (EC). Other parameters were determined by using standard methods recommended in manual of APHA/AWWA/WEF (APHA 1992). All The reagents used for the analysis were AR grade and double distilled water used for preparation of solutions. In the present study Minimum, Maximum, Average and Standard Deviation have been calculated for each pair of water quality parameters by using Excel spreadsheet for the experimental data. The standard formulae were used in the calculation for statistical parameters are as follows (BIS 2012). Details of the methods are summarized in Table 2.

RESULTS AND DISCUSSION

The respective values of all water quality parameters in the water samples are illustrated in Table 3. All the results are compared with standard permissible limit recommended by the Bureau of Indian Standards (BIS), Indian Council of Medical Research (ICMR) and World Health Organization (WHO), depicted in Table 2. Statistical Parameters of groundwater samples of study area are summarized in Table 4.

pH

The pH is used to determine the acidity or alkalinity of water and the concentration of hydrogen ions in the water. The pH value of all groundwater samples is found to be in the range of 7.00 to 8.39. The highest value of 8.39 is observed at station N_7 whereas the lowest value of 7.00 is observed at station N_2. In terms of pH value, the groundwater samples are well within the acceptable limit of WHO (BIS, 2012). There is no anomalous change in the groundwater samples. Long term exposure to pH beyond the permissible limit affects the mucous membrane of cells.

Electrical conductance

Electrical conductivity is the measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic form and capable of conducting current and conductivity is a good indicator to assess groundwater quality. EC is useful parameter of water quality for indicating salinity hazards. In the study area, EC values varied between 0.51µmohs/cm to 3.07µmhos/cm. Conductivity is the ability of water to conduct an electrical current, and the dissolved ions are the conductors. The major positively charged ions are sodium, (Na^+) calcium (Ca^{+2}), potassium (K^+) and magnesium (Mg^{+2}). The major negatively charged ions are chloride (Cl^-), sulphate (SO_4^{-2}), carbonate (CO_3^{-2}), and bicarbonate (HCO_3^-). Nitrates (NO_3^-) and phosphates (PO_4^{-3}) are minor contributors to conductivity, although they are very important biologically. Salinity is a measure of the amount of salts in the water. Because dissolved ions increase salinity as well as conductivity, the two measures are related. Salinity is an ecological factor, which influences organisms that live in a water bodies and the growth of plant that will grow either in the water bodies or on the land fed by the ground water (BIS, 2012; Rani *et al*., 2003).

Total dissolved solids (TDS)

In present study, the groundwater samples showed variation between 130 and 1785 mg/L, in terms of TDS. For domestic uses, the maximum permissible limit of total dissolve solids is 1000 mg/L (prescribed by WHO). The maximum value of 1785 mg/L is recorded at station N_8 and minimum value of 130 mg/L is recorded at station N_{12}. Hence all the groundwater samples are not saline except water of station N_8. An elevated level of TDS, by itself, does not indicate that the water present a health risk. The concentration of dissolved ions may cause the water to be corrosive, salty or brackish taste, result in scale formation (BIS, 2012).

Total hardness (TH)

Total hardness is the sum of concentration of alkaline earth metal cations such as Ca^{+2} and Mg^{+2}. The total hardness is the total soluble magnesium and calcium salts present in water expressed as its $CaCO_3$ equivalent. Total hardness also includes the sulphates, chlorides of calcium and magnesium. In most natural water the predominant ions are those of bicarbonates associated mainly with calcium to lesser degree with magnesium and still less with sodium and potassium.

Table 1. Sampling site, sources, code & depth of water samples

S.No.	Sampling Site	Sources	Code	Depth (Ft)
01	Shiv Mandir	Hand-Pump	N_1	50
02	Near gabi Sahib Mandir	Hand-Pump	N_2	55
03	Nehru Park	Hand-Pump	N_3	55
04	Govt. Hospital	Bore-Well	N_4	150
05	Nehru-park(Near water tank)	Hand Pump	N_5	50
06	Patram Nagar	Hand-Pump	N_6	50
07	Railway Station	Hand-Pump	N_7	60
08	Ghandi Nagar	Hand-Pump	N_8	65
09	Near Water Canal	Hand-Pump	N_9	45
10	Dharmsala	Hand-Pump	N_{10}	50
11	Bansanti Mata mandir	Hand-Pump	N_{11}	70
12	Jind Road	Hand-Pump	N_{12}	60
13	Subash Chowk	Hand-Pump	N_{13}	70
14	Birbal Nagar	Hand-Pump	N_{14}	65

Table 2. Analytic methods, BIS, ICMR & WHO parameters for drinking water

S. No.	Parameter	Method employed	Prescribed by				
			BIS (IS 10500-91)		ICMR		WHO
			Desirable Limit	Max. permissible Limits	Desirable Limit	Max. permissible limits	
1	pH	Digital pH Meter	6.5 -8.5	No relaxation	7.0 – 8.5	6.5 – 9.2	6.5-8.5
2	TDS (mg/L)	Digital TDS Meter	500	2000	500	1500-3000	1000
3	TH (mg/L)	Titrimetric (EDTA)	300	600	300	600	500
4	Ca^{+2} (mg/L)	Titrimetric (EDTA)	75	200	75	200	200
5	Mg^{+2} (mg/L)	Titrimetric (EDTA)	30	100	50	-	50
6	Cl^- (mg/L)	Titrimetric (AgNO3)	250	1000	200	1000	200
7	Turbidity (NTU)	Nephelometry	1	5	1	5	5
8	SO_4^{-2} (mg/L	Spectrometric method	200	400	200	400	400
9	NO_3^- (mg/L)	Spectrometric method	45	100	20	100	10
10	PO_4^{-3} (mg/L)	Spectrometric method	-	-	-	-	-
11	Na/K (mg/L)	Flame photometer	-	-	-	-	200/15
12	Fe^{+3} (mg/L)	Spectrometric method	0.3	1.0	0.1	1.0	1.0
13	F^- (mg/L)	APHA-Method	1.0	1.5	1	1.5	1.5
14	As mg/L	APHA-Method	0.0	0.05	0.0	0.05	0.05

Table 3. Chemometric parameters of groundwater from fourteen different locations in Narwana, Haryana (India)

SITE → PAR (↓)	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}
pH	7.69	7.00	7.65	8.35	7.61	7.43	8.39	7.41	7.8	7.33	7.4	7.92	7.37	7.55
Temp (^{0}C)	27.2	27.6	25.3	25.9	26.0	27.8	27.5	27.4	27.4	27.3	27.9	27.9	27.0	27.0
EC	0.73	2.36	1.16	0.56	0.51	1.09	0.77	3.07	0.3	2.67	2.01	1.87	1.31	1.92
TDS	471	152	740	387	323	740	520	1785	187	1360	1150	130	828	1060
TH	408	1300	500	310	280	730	180	1140	210	1050	760	130	610	720
Ca^{2+}	81.6	280	102	66	56	156	38	232	42	225	156	25	124	144
Mg^{2+}	49.8	145.8	59.5	40.9	34.0	94.7	23.08	136.1	25.5	137.3	89.9	15.8	75.3	87.5
TB	1.0	15.0	4.0	1.0	0.0	2.0	0.0	12.0	1.0	0.0	2.0	0.0	0.0	3.0
TA	290	520	280	200	160	390	350	270	190	350	720	120	330	610
HCO_3	290	520	280	178	160	390	305	270	190	350	720	120	330	610
CO_3^{2}	0.0	0.0	0.0	18.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cl	75	450	340	90	65	220	85	515	25	580	405	25	260	280
F	0.5	1.5	0.5	4.5	0.0	2.5	5.5	3.0	0.0	2.5	2.5	0.0	3.5	3.0
Fe^{+3}	0.0	0.12	0.23	0.0	0.0	0.2	0.3	0.4	0.3	0.5	0.0	0.3	0.2	0.3
Na^+	54.2	63.0	68.6	108.3	25.1	146.4	195.8	395.7	23.2	273	290.0	18.1	184.7	210
K^+	17.8	9.6	42.1	9.4	6.0	13.4	7.5	2.5	6.9	39.1	1.9	5.4	39.2	39.8
SO_4^{2}	256	480	202	64.0	127	198	304	405	182	236	212	96	105	213
NO_3	23.8	44.3	56.3	42.3	13.5	24.2	6.5	16.6	3.5	28.7	15.7	3.4	6.3	15.8
PO_4^{3}	0.3	0.3	0.0	0.0	0.75	0.91	0.98	1.23	0.8	1.0	0.6	0.73	0.7	0.6

Abbreviations: EC-Electrical Conductance; TDS-Total Dissolved Solids; TH-Total Hardness; TK-Total Alkalinity; TB-Turbidity; ppm-Parts Per Million.

Table 4. Statistical analysis of the data for mean and standard deviation

Param (↓)	Stat (→)	Minimum	Maximum	Mean	(Sd)	Variance (Sd)	Population (Sd)
pH		7.00	8.39	7.63	0.38	0.15	0.37
EC (µmhos/cm)		0.51	3.07	1.44	0.875	0.76	0.84
TDS (mg/L)		130.0	1785.0	702.3	494.4	244441.8	476.4
TH (mg/L)		130.0	1300.0	594.8	374.5	140268.7	360.9
Ca^{2+} (mg/L)		25.0	280.0	123.4	79.8	371.9	76.92
Mg^{2+} (mg/L)		15.8	145.8	72.5	44.4	1974.9	42.8
TB		0.0	12.0	2.92	4.7	21.9	4.51
TA (ppm)		120.0	720.0	341.4	172.4	29720.8	166.1
HCO_3 (ppm)		120.0	720.0	336.6	174.1	30308.5	167.8
CO_3^{2} (ppm)		0.0	30.0	3.42	9.03	81.5	8.69
Cl (ppm)		25.0	580.0	243.9	190.4	36273.7	183.6
F (ppm)		0.0	5.5	2.11	1.8	3.08	1.69
Fe^{+3} (ppm)		0.0	0.5	0.20	0.16	0.026	0.16
Na^+ (ppm)		18.1	395.7	146.8	116.4	135432.2	112.1
K^+ (ppm)		2.5	42.1	17.2	15.5	241.7	14.9
SO_4^{2} (ppm)		64.0	405.0	220.0	115.8	13414.2	111.6
NO_3 (ppm)		3.4	56.3	21.5	16.4	268.4	15.8
PO_4^{3} (ppm)		0.0	1.2	0.64	0.37	0.14	0.4

SD= $s = (\Sigma (x - M)^2 / (n - 1))$; population SD = $(\Sigma (x - M)^2 / (n))$

Consumption of salty water in excess is reported to have caused hypertension and increases the risk for stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma. The present study showed that the total hardness analyzed in the water samples were found in the range of 130 to 1300 mg/L. However, the WHO guideline value (total hardness range: 300-600 mg/L) indicates that all samples N_6, N_8 N_{10} N_{13}, N_{14} exceeded the maximum limit for drinking water. Calcium content of water in the present study was found in the range of 25 to 280 mg/L. Similarly, Mg content varied from 15.8 to 145.8 mg/L. Ca and Mg are both essential minerals for living organisms. Recommendations have been made for the maximum and minimum levels of calcium (75–200 ppm) and magnesium (~50 ppm) in drinking water (Rani *et al*., 2003).

Total alkalinity (TA)

Total alkalinity of the water samples was varied from 120 to 720 mg/L. Water of sampling sites N_5, N_9 and N_{12} recorded normal values and within the guideline as recommended by WHO (18 &19) for total alkalinity (200 mg/l). Total alkalinity in natural water is attributed to bicarbonate (Sriniwas *et al*., 2000). Very high value of alkalinity for water of sampling site N_{11} is due to high bicarbonate (720 ppm) and sulphate contents in the reported sample.

Chloride/Fluoride

The chloride content in the present study was found in the range of 25 to 580 mg/L. Chloride concentration higher than 200 mg/L is considered too risky for human consumption and causes unpleasant taste of water (Sharma *et al*., 2004). In some water samples fluoride concentrations were found higher than the permissible range 0.6 – 1.5 mg/L. The observed range of the fluoride level in the study area was found 0.0 mg/L to 5.5 mg/L. Very high level of fluoride in the study area (N_4, N_6, N_7, N_8, N_{10}, N_{11}, N_{13}, and N_{14}) might be due to the presence of fluoride bearing minerals in the region. Some cases of dental or skeletal Fluorosis were observed in the study area of Govt. Hospital and Near Railway station.

Nitrate

The nitrate ion in the present study was found in the range of 3.4 to 56.3 mg/L. Nitrate values are commonly reported as either nitrate or as nitrate-nitrogen (NO_3-N). The maximum contaminant level (MCL) in drinking water as nitrate is 45 mg/l, whereas the MCL as NO_3-N is 10 mg/l. The MCL is the highest level of NO_3 or NO_3-N that is allowable in public drinking water supplies by the U.S. Environmental Protection Agency (EPA). High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. The stomach acid of an infant is not as strong as in older children and adults. This causes an increase in bacteria that can readily convert nitrate to nitrite. Very high value of nitrate in the water sample of Nehru Park is due to high value of potassium nitrate.

Iron (Fe^{+3})

Iron content in the present study was found within the guideline value as recommended by NDWQS and WHO. The study revealed that all sampling sites contained the metal content in the normal range of 0.0 to 0.5 mg/L. Iron is one of the most abundant elements in nature ranking fourth by weight. All kinds of water including groundwater have appreciable quantities of iron. Although the metal has got little concern as a health hazard but is still considered as a nuisance in exceeding quantities for domestic as well as industrial uses.

Sodium/potassium ions

The value of sodium in the drinking water samples was found in the range from 18.1 to 395.7 mg/L. All samples except N_8, N_{10} & N_{11} are within the range given by WHO/BIS (200 mg/L). Potassium values ranged between 2.5 to 42.1 mg/L. The permissible limit of WHO is 15 mg/L. In healthy individuals, high levels of potassium (up to 3700 mg/day) possess no harmful effects because potassium is rapidly excreted. A very high dose of potassium results in chest tightness, nausea, vomiting, diarrhea, hyperkalaemia, shortness of breath and heart failure (BIS 2012).

Sulphate

Natural water contains sulphate ions and most of these ions are also soluble in water. Many sulphate ions are produce by oxidation process of their ores, they also present in industrial wastes. The method to measure quantity of sulphate is by UV Spectrophotometer. As per IS: 10500-2012 Desirable limit for Sulphate is 200 and 400 mg/l in Permissible limit.

Phosphate

Phosphorus is an essential plant nutrient and most often controls plant growth in fresh water. Normally ground water contains only a minimum phosphorus level because of the low solubility of native phosphate minerals and the ability of soils to retain phosphate.

Turbidity

Suspension of particles in water interfering with passage of light is called turbidity. Turbidity is caused by wide variety of Suspended particles. Turbidity can be measured either by its effect on the transmission of light which is termed as turbidity-metry or by its effect on the scattering of light which is termed as nephelometry. As per IS: 10500-2012 the acceptable and permissible limits are 1 and 5 NTU respectively.

Conclusion

The present work is an attempt to assess the drinking water quality. Most of the samples analyzed were found contaminated either due to one or more parameters. Only pH and iron values of all the samples were in the permissible range. Certain parameters in all samples crossed the WHO. Arsenic is carcinogenic and is reported in one sample1 as high as 694 ppm (N_4) and therefore its presence is a serious threat. In nutshell from the results, it is suggested that drinking water must be treated before supply.

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