Int. J. Chem. Sci.: 7(4), 2009, 2519-2534

ANALYSIS OF WATER QUALITY PARAMETERS OF GROUND WATER NEAR BICHHWAL INDUSTRIAL AREA, BIKANER IN POST-MONSOON SEASON, NOVEMBER 2008

RAJDEEP KAUR and R. V. SINGH*

Centre for Advance Studies in Chemistry, University of Rajasthan, JAIPUR - 302055 (Raj.) INDIA

ABSTRACT

This paper presents quality of water samples from wells in order to find out the magnitude of health problems in industrial area of Bikaner city. The natural quality of ground water tends to be degraded by human activities. Five different locations were selected for the study. The parameters studied were pH, total alkalinity, total hardness, calcium hardness, magnesium hardness, carbonate and non-carbonate hardness, total acidity, free CO_2, chloride, sulphate, fluoride, total dissolved solids, iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and cadmium (Cd).The ion concentrations are expressed in mg/L.

Key words: Ground water, Bikaner, Domestic, Health, Analytical techniques.

INTRODUCTION

Ground water pollution occurs, when waste products or other substances change the chemical or biological characteristics of the water and degrade water quality so that animals, plants or human uses of the water are affected. The water quality undergoes rapid changes due to contamination. The quality of ground water is continuously changing as a result of natural and human activities. Water is polluted due to different phenomenon[1]. Groundwater quality comprises the physical, chemical, and biological qualities of groundwater. Temperature, turbidity, colour, taste and odour make up the list of physical water quality parameters. Since mostly ground water is colourless, odourless, and without specific taste, water pollution means contamination of water by foreign matters such as micro-organisms, chemicals, and industrial or other wastes, or sewage. Contamination of drinking water supplies from industrial waste is a result of various types of industrial processes and disposal practices. Industries that use large amounts of water for processing have the potential to

*Author for correspondence; Fax: +91 141 2704677; E-mail: rvsjpr@hotmail.com

pollute water ways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources[2,3].

Water is indispensable natural resources on earth. All living beings including human being depend on water. We have enormous resource on earth amounting to about 13, 481, 96000 km^3 of water[4]. Due to rapid growth of industrialization, much sewage is disposed off that generates fair chances of ground water pollution. Safe drinking water is the primary need of every human being. All ground water sources are not always safe. Physico-chemical characteristics of ground water of different parts of countries have been studied by many authors[6-11] . As regards the Bikaner city, it has two major industrial areas, viz. Bichhwal and Karni, housing a large number of small scales woolen and food industries including tile, manufacturing, milk product and packaging. The Bikaner city is located at 28˚1'E latitude and 73˚19' N latitude with both the industrial areas lying on the north of the city. Under ground water is the only source of water for the industrial areas of Bichhwal and Karni. We have selected the Bichhwal area for the present studies. The reason is that in this area, all the above mentioned industries are passing out their waste and wastewater in a Nalah namely CSWRI (Central Sheep and Wool Research Institute) and RAU (Rajasthan Agricultural University) Nalah. This Nalah is ultimately flowing nearby Rajasthan Agricultural University and Government Engineering College, where most of the students and faculty members have their residences. Because of this waste and waste water, the water quality of this Nalah is continuously degrading and the soils of the nearby fields are also being affected. Therefore, we have decided to analyze the water of this Nalah and find out some remedies for the improvement of the water quality of this area.

EXPERIMENTAL

In the present study, bore well water samples were collected from twelve different spots of Bikaner city and the quality test survey of the ground water was conducted in the post-rainy season 2008. Samples were collected in sterilized screw-capped polyethylene bottles having one-litre capacity, and analyzed in laboratory for their physico-chemical parameters. All the samples were properly labeled as B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, B_{10}, $B_{11}$and B_{12} and a record was prepared, which is given in Table 1.

Various inorganic contaminants were found in groundwater (Table 2). The various physico-chemical parameters, which were analyzed are given in Table 3. Health effects of chemical parameters are reported in Table 4. The parameters for their water quality characterization are listed in Table 5.

Total alkalinities of the water samples were determined by titrating with N/50 H_2SO_4 using phenolphthalein and methyl orange as indicators[6]. The total hardness of the water samples was determined by complexometric titration with EDTA using eriochrome black-T as an indicator[6]. Sulphate and fluoride of the water samples were estimated by UV-Visible spectrophotometer[6]. TDS of water sample were measured using gravimetric method.

Table 1: Parameters, methods, standard values and unit employed in physico-chemical analysis of the samples

Parameters of water analysis	Methods	Standard values as guided by ICMR		Unit
		Desirable concentration	Maximum permissible concentration	
Colour	By sight	-	-	Hazen Units
Odour	Smelling	-	-	-
Temperature	Thermometric	-	-	ºC
pH	pH Meter	7.0-8.5	6.5-9.2	-
Dissolved oxygen (DO)	Axide Modification	7 mg/L at 35 ºC	-	mg/L
Total alkalinity	Titrimetric	200	600	mg/L
Total hardness	Titrimetric	300	600	mg/L
Cacium hardness	Titrimetric	75	200	mg/L
Magnesium hardness	Titrimetric	50	150	mg/L
Carbonate hardness	Titrimetric	300	600	mg/L
Non-carbonate hardness	Titrimetric	300	600	mg/L
Chloride	Argentometric	200	600	mg/L
Sulphate	Turbidity meter	200	400	mg/L
Nitrate	Ionometric	20	50	mg/L
Total dissolved solids	Conductivity meter	500	1500	mg/L

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Parameters of water analysis	Methods	Standard values as guided by ICMR		Unit
		Desirable concentration	Maximum permissible concentration	
Fluoride	Ion selective electrode	1.0	1.5	mg/L
Calcium	Titrimetric	-	-	mg/L
Magnesium	Titrimetric	-	-	mg/L
Free CO_2	Titrimetric			mg/L
Total acidity	Titrimetric			mg/L
Residual chlorine		0.2	-	mg/L
Iron		0.3	1.0	mg/L
Manganese		0.1	0.3	mg/L
Cadmium		0.01	-	mg/L
Zinc		5	15	mg/L
Copper		0.05	1.5	mg/L

Table 2: Health effects of chemical parameters

Parameters	BIS Guideline value (maximum allowable)	Potential health and other effects
TDS	200 mg/L	Undesirable taste; gastro- intestinal irritation; corrosion or incrustation
pH	6.5-8.5	Affects mucous membrane; bitter taste; corrosion; affects aquatic life
Alkalinity	600 mg/L	Boiled rice turns yellowish
Hardness	600 mg/L	Poor lathering with soap; deterioration of the quality of clothes; scale forming; skin irritation
Calcium	200 mg/L	Poor lathering and deterioration of the quality of clothes; incrustation in pipes
Magnesium	100 mg/L	Poor lathering and deterioration of clothes; with sulphate laxative
Iron	1.0	Imparts a bitter astringent taste to water and a brownish colour to laundered clothing and plumbing fixtures

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Parameters	BIS Guideline value (maximum allowable)	Potential health and other effects
Manganese	0.3	Causes aesthetic and economic damage; brownish stains to laundry; poor taste, colour and turbidity
Aluminium	0.2	Neurological disorders; Alzheimer's disease
Copper	1.5	Cause stomach and intestinal distress; liver and kidney damage; anemia in high doses and restricts growth of aquatic plants
Zinc	15	Astringent taste; opalescence in water; gastrointestinal irritation; vomiting; dehydration; abdominal pain; nausea and dizziness
Ammonia	-	Indicates pollution; growth of algae
Nitrite	-	Forms nitroso-amines, which are carcinogenic
Nitrate	100	Blue baby disease [methemoglobineamia], algal growth
Sulphate	400	Taste affected; laxative effect; gastro-intestinal irritation
Chloride	1000	Taste affected; corrosive
Fluoride	1.5	Dental and skeletal fluorosis; non-skeletal manifestations
Phosphate	-	Algal growth
Arsenic	0.05	Toxic; bio-accumulation; central nervous system affected; carcinogenic
Mercury	0.001	Highly toxic; causes 'minimata' disease neurological; mutagenic
Cadmium	0.01	Highly toxic; causes 'itai-itai' disease-painful rheumatic condition; gastrointestinal upsets and hypertension
Lead	0.05	Causes plumbism tiredness; lassitudes, abdominal discomfort, irritability, anaemia; bio-accumulation; impaired neurological and motor development and skin complaints
Chromium	0.05	Carcinogenic; ulcerations; respiratory problems and skin complaints
Pesticides	0.001	Affects central nervous system
Detergent	-	Undesirable foaming

Table 3: Parameters for water quality characterization and standards (Domestic water supplies)

S. No.	Parameters	USPH Standard	ISI Standard (IS: 2296-1963)
	1	2	3
1.	Colour, odour, taste	Colourless, odourless, tasteless	-
2.	pH		6.0-8.5 6.0-9.0
3.	Specific conductance	300 mmho cm^{-1}	-
4.	Dissolved oxygen (DO)	4.0-6.0 (ppm)	3.0
5.	Total dissolved solids	500	-
6.	Suspended solid	5.0	-
7.	Chloride	250 mg/L	600
8.	Sulphate	250	1000
9.	Cyanide	0.05	0.01
10.	Nitrate + Nitrite	<10	-
11.	Fluoride	1.5	3.0
12.	Phosphate	0.1	-
13.	Sulphide	0.1 mgL^{-1} (ppb)	-
14.	Ammonia	0.5	-
15.	Boron	1.0	-
16.	Calcium	100	-
17.	Magnesium	30	-
18.	Arsenic	0.05	0.2
19.	Barium	1.0	-
20.	Cadmium	0.01	-
21.	Chromium (VI)	0.05	0.05
22.	Copper	1.0	-

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S. No.	Parameters	USPH Standard	ISI Standard (IS: 2296-1963)
	1	2	3
23.	Iron (filterable)	<0.3	-
24.	Lead	<0.05	0.01
25.	Manganese (filterable)	<0.05	-
26.	Mercury	0.001	-
27.	Selenium	0.01	0.05
28.	Silver	0.05	-
29.	Uranium	5.0	-
30.	Zinc	5.5	-
31.	Organics COD	4.0	-
32.	Carbon $CHCl_3$ extract (CCE)	0.15	-
33.	Methylene blue active substances	0.5	-
34.	Phenols	0.001	0.005
35.	Pesticides (total)	0.005	-
36.	Polycyclic aromatic hydrocarbons (PAH)	0.2 ppb (0.002ppm)	-
37.	Surfactants	200	-
38.	Radioactivity gross beta	1000 pc/L	-
39.	Radium-226	3 pc/L	-
40.	Strontium-90	10 pc/L	<5000
41.	Bacteriological Parameters Coliform Cells/1000 mL	100	-
42.	Total bacteria count/100 mL	1×10^6	

Table 4(a): Analyzed data of well water samples from different locations

Samples Parameters	B_1	B_2	B_3	B_4	B_5	B_6
Temperature	26ºC	27.5ºC	28ºC	24.1ºC	24.3ºC	26.2ºC
pH	7.1	7.5	7.9	7.7	8.0	8.0
Total alkalinity as ($CaCO_3$)	280	300	300	310	80	310
Total hardness ($CaCO_3$)	330	380	310	290	120	320
Calcium hardness ($CaCO_3$)	56	64	48	20	24	56
Magnesium hardness ($CaCO_3$)	274	316	262	270	96	264
Carbonate hardness ($CaCO_3$)	280	300	300	290	80	310
Non-carbonate hardness ($CaCO_3$)	50	80	10	nil	40	10
Total acidity as ($CaCO_3$)	290	280	210	260	200	210
Free CO_2	44	44	22	44	66	44
Chloride	510	620	630	640	40	550
Sulphate	150	180	200	220	40	180
Fluoride	1.3	1.3	1.5	1.3	0.3	1.2
Total dissolved solids	1260	1540	1540	1610	238	1470
Iron (Fe)	0.175	0.008	0.018	ND	0.041	ND
Manganese (Mn)	0.024	ND	0.003	0.000	0.002	0.001
Zinc (Zn)	0.048	0.028	0.357	ND	0.360	ND
Copper (Cu)	0.032	ND	ND	0.010	0.008	0.005
Cadmium (Cd)	0.024	0.010	0.011	0.009	0.008	0.011

Table 4(b): Analysis data of well water samples from different locations

Samples parameters	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}
Temperature	25.2ºC	26.8ºC	24.4ºC	24.7ºC	25.2ºC	28ºC
pH	8.4	7.6	7.9	7.7	7.4	7.7
Total alkalinity as ($CaCO_3$)	300	300	90	290	280	290
Total hardness ($CaCO_3$)	350	420	190	380	410	350
Calcium hardness ($CaCO_3$)	40	76	36	68	80	60
Magnesium hardness ($CaCO_3$)	310	344	154	212	330	290
Carbonate hardness ($CaCO_3$)	300	300	90	290	280	290
Non-carbonate hardness ($CaCO_3$)	50	120	100	90	130	60
Total acidity as ($CaCO_3$)	230	250	120	190	220	280
Free CO_2	66	66	22	44	66	66
Chloride	500	580	40	460	480	480
Sulphate	180	200	60	160	170	170
Fluoride	1.1	1.2	0.3	0.9	1.0	1.2
Total dissolved solids	1330	1470	273	1260	1260	1260
Iron (Fe)	ND	0.175	ND	0.509	ND	0.021
Manganese (Mn)	ND	0.001	0.001	ND	ND	0.005
Zinc (Zn)	ND	ND	ND	ND	ND	ND
Copper (Cu)	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	0.011	0.011	0.010	0.012	0.014	0.014

RESULTS AND DISCUSSION

The samples collected from Bichhwal industrial area and Kolayat area were analyzed. The discharge from various industries may increase the pH of water, where as in monsoon, addition of rain water diluted the effect and resulted in increase pH value.

The physico-chemical parameters, which were analyzed in post-monsoon season, November 2008, have been shown in Table 2.

Colour

The colour of a water sample is caused by both dissolved and particulate material in water, and is measured in Hazen Units (HU). The presence of colour in water does not necessarily indicate that the water is not potable. Colour-causing substances such as tannins may be harmless. Colour is not removed by typical water filters; however, slow sand filters can remove colour, and the use of coagulants may also succeed in trapping precipitate. In the present study, water is almost colourless.

Odour

Many substances, with which water comes into contact in nature of human use, may impart perceptible taste and odour. These include minerals, metals and salts from soil however, inorganic substances are more likely to produce taste unaccompanied by odour. In domestic waste water, gases produced by the decomposition of organic matter cause odour. It cause psychological stress rather than a harm to the human body. Offensive odour can cause poor appetite for food, lowered water consumption, impaired respiration, nausea, vomiting and mental perturbation. Analyzed water samples were found odourless.

Temperature

Water temperature affects the ability of water to hold oxygen, the rate of photosynthesis by aquatic plants and the metabolic rates of aquatic organisms. Temperature of water samples is varied from 24.1^{o}C to 28^{o}C and the variation of the water temperature is having more effect directly or indirectly on all life processes.

pH

pH is an indicator of the acid or alkaline condition of water. The pH scale ranges from 0-14; 7 indicates the theoretical neutral point. pH of most natural water falls within the range of 4 to 9. The majority of waters are slightly basic (i.e. generally over 7.0) because of the presence of carbonate and bicarbonates. Generally the pH increases (acidic) during

daytime due to photosynthetic activity because of consumption of carbon-dioxide, whereas it increases (alkaline) at night due to respiratory activity[13]. Low pH causes corrosion. It also causes taste and soapy feel; pH < 8.0 is preferable for effective disinfection with chlorine. In the present study area, the pH value ranged from 7 to 8.4. A pH range from 7.0 to 8.5 is desirable as per guided by ICMR.

Optimal pH for industrial water supplies

Process	Minimum	pH Range
Food canning and freezing	7.5	--
Washing clothes	--	6.0-6.8
Rayon manufacturing	--	7.8-8.3
Steel making	--	6.8-7.0
Tanning leather	--	6.0-8.0

Total acidity

The acidity of a water sample is its capacity to neutralize hydroxide ions. Acidity may be caused by mineral acids such as sulphuric acid or hydrochloric acid or by dissolved carbon dioxide. Most commonly in drinking water, carbon dioxide is the principal cause of acidity. Drinking water with a high acidity is likely to be corrosive to copper water pipes. Acidity is generally measured by titration with sodium hydroxide to an accepted pH value. Phenolphthalein is an acid-base indicator, which changes from colorless to pink (magenta) at a pH of about 8.3. The value of study area ranged from 120 to 290 mg/L.

Total alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. A solution having a pH below 4.5 contains no alkalinity, because there are no CO_3^{2-} or HCO_3^- ions left. The alkalinity of surface water is primarily due to the presence of hydroxide (OH^-), carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions. These ions react with H^+ ions by means of the following chemical reactions:

$$OH^- + H^+ \rightarrow H_2O$$

$$CO_3^{2-} + H^+ \rightarrow HCO_3^-$$

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$

Alkalinity is significant in the treatment of waste water and drinking water, because it will influence treatment processes such as anaerobic digestion. Alkalinity is reported in units of mg/L $CaCO_3$, because the carbonate ion (CO_3^{2-}) is its primary constituent. Total alkalinity is the sum of the phenolphthalein alkalinity and the methyl orange alkalinity. The desirable limit of total alkalinity is 200 mg/L (ICMR). The value of study area ranged from 90 to 310 mg/L.

Total hardness

Total hardness is defined as the sum of the total calcium and magnesium concentration, both expressed as $CaCO_3$, in mg/L. Hardness in water is defined as the presence of multivalent cations. In fresh water, the principal hardness- causing ions are calcium and magnesium, which precipitate soap.

Degree of hardness of drinking water

- Soft 0-60 mg/L
- Medium 60-120 mg/L
- Hard 120-180 mg/L
- Very hard > 180 mg/L

The maximum limit of hardness in drinking water is 600 mg/L (ICMR). If water contains less than 3.5 gpg, it is considered soft water. If it contains more than 7 gpg, it is considered hard water. The total hardness of water sample is larger than desirable limit (300 mg/L) [14]. The total hardness value ranged in the studied area from 120 to 420 mg/L. So the water of almost all sampling areas is hard. The total hardness of water sample was determined by complexometric titration with EDTA using eriochrome black-T as an indicator[6].

Calcium hardness

Calcium is the common constituents of natural water and important contributor to the hardness of water. The source of Ca is the rocks from which it is leached. Being an important contributor of hardness, it reduces the utility of water for domestic use. The amount of calcium in water is measured in ppm. High levels can cause scale buildup. Low levels can cause etching and equipment corrosion. The maximum permissible limit of calcium hardness is 200 mg/L (ICMR). The value of cadium hardness of sampling stations ranged from 20 to 80 mg/L.

Magnesium hardness

Magnesium has been considered as non-toxic to humans at the concentration expected in water. Magnesium salts have a laxative and diuretic effect particularly for individuals not accustomed to high dosage. The maximum permissible limit of magnesium hardness is 150 mg/L (ICMR). Magnesium hardness value in studied area ranged from 96 to 344 mg/L.

Carbonate and non- carbonate hardness

Carbonate hardness refers to the amount of carbonate and bicarbonates in solutions that can be removed or precipitated by boiling. This type of hardness is responsible for the deposition of scale in hot water pipes and kettles. Carbonate hardness was formerly called temporary hardness, because it can be removed by boiling and it is caused by dissolved Ca and Mg bicarbonates. It is usually expressed either as parts per million (ppm or mg/L). The carbonate hardness value ranged from 80 to 310 mg/L. The maximum permissible limit for carbonate hardness is 200 mg/L (ICMR).

Non-carbonate hardness is caused by the association of the hardness-causing cation with sulphate, chloride or nitrate and is referred to as "permanent hardness ".

Non-carbonates hardness is called permanent hardness because this type of hardness cannot be removed by boiling. It is much more expensive to remove non-carbonate hardness than carbonate hardness. The non- carbonate hardness value ranged from nil to 130 mg/L.

Chloride

The presence of chloride in natural waters can be attributed to dissolution of salt deposits, discharges of effluents from chemical industries and oil well operations. Each of these sources may result in local contamination of both; surface water and ground water. The salty taste produced by chloride depends on the chemical composition of the water. High chloride content may harm metallic pipes and structures as well as agricultural plants.

The maximum permissible concentration of chloride is 1000 mg/L (ICMR). The value of chloride varies from 40 to 640 mg/L.

Sulphate

The maximum permissible limit of sulphate is 400 mg/L (ICMR). In the sampling areas, the sulphate concentration ranged from 40 to 220 mg/L. All the water samples have

the sulphate content in the permissible limit except point-4.

Fluoride

Ground water sources such as dug wells, shallow and deep hand pumps and especially tube wells may contain excess fluoride, where minerals like cryolite, biotite and fluorapatite are present. This is mainly due to the dissolution of fluoride from fluoride bearing minerals. About 96% of the fluoride in the body is found in bones and teeth. Fluoride is also essential for the normal mineralization of the bones and formation of dental enamel. A permissible limit of fluoride concentration in drinking water as per WHO guidelines is up to 1.5 mg/L. The probable relationship between fluoride concentration in drinking water and its effects are given here[5].

Effects of fluoride concentrations

Fluoride concentration (mg/L)	Effect
Less than 1.5	No effect
1.5 to 3.0	Dental fluorosis
3.1 to 6.0	Mild skeletal fluorosis
More than 6.0	Crippling skeletal fluorosis

High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/L is a major health problem. The fluoride value ranged in investigated area is 0.3 to 1.5 mg/L.

Total dissolved solids (TDS)

Total dissolved solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L), also referred to as parts per million (ppm). While TDS is not considered a primary pollutant, high TDS levels typically indicate hard water and may lead to scale buildup in pipes, reduced efficiency of water filters, hot water heaters, etc. and aesthetic problems such as bitter or salty taste.

Desirable limit of TDS is 500 mg/L (ICMR). All the values obtained are much higher than the limit except points 5 and 9.

Free carbon dioxide (CO_2)

Free carbon dioxide accumulates in the water due to microbial activity and respiration of organisms. Surface waters normally contain less than 10 mg free CO_2 per litre while some ground water may easily exceed that concentration up to 30 to 50 mg/L. This imparts the acidity to the water because of the formation of carbonic acid ($CO_2 + H_2O = H_2CO_3$). Free CO_2 is determined by titrating the sample using a strong alkali to pH 8.3. Free CO_2 value in studied area ranged from 22 to 66 mg/L.

CONCLUSION

The present results of water investigation show that the waters of study area are highly contaminated with total dissolved solids. Because of high concentration of TDS water loses its potability and high concentration of TDS also reduces the solubility of oxygen in water. Water of almost all study points are hard and because of this, people of Bikaner area are facing many problems like stomach diseases, gastric troubles etc.

It is recommended that water should be used after boiling by the people of Bikaner because after boiling the water, temporary hardness (carbonate hardness) can be removed and concentration of total dissolved solids can also be decreased. Alum treatment is also a good option to make the water potable.

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Accepted : 10.08.2009