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Investigations of Hygienic State of Drinking Water at Different Tourist Places of Alwar District of Rajasthan (India)

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Abstract: Tourist places in the Alwar District of the Rajasthan State are places of significant cultural and historical heritage and are also for pilgrimage. Evaluations of the chemical quality and hygienic status have been carried out to know the risk factor of drinking water in these different tourist places. The pH, chloride, fluoride, nitrate, total dissolved solids (TDS) and total hardness (TH) have been monitored and assessed. This study was performed to bring out a drinking water quality status report of the tourist places of Alwar district. Eight important tourist places of the district were taken into consideration to take the chemical investigation of drinking water: Jai Samand, Siliserh, Sariska, Kali Ghati, Pandupole, Bhathariji, Tal-Vriksha and Naldeshwar. Eleven samples have been analyzed, compared and assessed. It was concluded that there was a severe presence of particular constituents in all the tourist places. The results of this comparative study are compiled in the present article.

Key words: Alwar district, tourist places, pH, Cl^-, F^-, NO_3^-, TDS, TH, water quality.

Introduction

Water is not only essential for the lives of animals and plants but also occupies an unique position in industries. It is used for irrigation, sanitation, power and steam generation, air-conditioning, navigation, ecological and afforestation needs and recreation. It is also used as a coolant in power and chemical plants. In addition to it, water is widely used in other fields like production of paper, sugar, steel, atomic energy, textile, chemicals and ice production. The widely distributed substance 'water' has never been found naturally in a completely pure state. Even in the most unpolluted areas, rainwater has dissolved carbon dioxide, oxygen and nitrogen in variable concentrations. Water may also carry dust and other particulates in suspension form picked up from the atmosphere. Underground water may possess objectionable dissolved impurities like iron, manganese, calcium, nitrate, fluoride, sulphate, and chloride. These water pollutants are organic, inorganic chemicals, mineral substances or finely divided metals which affect the pH and chemical composition of water and thus make it saline and unhygienic for consumption.

Rajasthan is India's largest state with an area of 342, 269 km^2, which is 10.41% of the total area of our country, and with an estimated population of 54 million spread over its 41,583 villages, which is 5.5% of nation's population but having just 1% of the total water sources

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of the country. Due to the scarcity of the surface water in Rajasthan (Sharma et al., 2008), 70% of its population is dependent on groundwater resources for drinking, irrigation and other purposes. Besides a unique position in industries as stated earlier, it is also used for irrigation (Fereres and Soriano, 2007), sanitation, power and steam generation, air-conditioning, navigation, ecological and afforestation needs (Zhang et al., 2008) and recreation. It is essential as a coolant in power and chemical plants. In addition, water is widely used in other fields like production of paper, sugar, steel, atomic energy (Wilkinson et al., 2007), textile and chemicals (Hatti-Kaul et al., 2007).

The widely distributed substance 'water' has never been found naturally in a completely pure state. Even in the most unpolluted areas, rainwater has dissolved CO_2, O_2, N_2 and may also carry dust or other particulates in suspension form picked up from the atmosphere. Underground water may possess objectionable dissolved impurities (Dheri, 2007) like iron, manganese, calcium, nitrate, fluoride, sulphate and chloride. These pollutants are organic and inorganic chemicals, mineral substances and finely divided metals, which affect the pH of water and make it saline or toxic (Kim et al., 2008). Thus, much attention has been called in the recent years to water pollution caused by a number of inorganic and organic compounds. It is, therefore, equally necessary to take into account both the health-related constituents (Kjellstrom et al., 2007) and the consumer perception related to the aesthetic criteria when assessing the quality of drinking water (Lou et al., 2007).

This study was carried out to come up with a drinking water quality status report of the tourist places of the Alwar district in India. The places studied were Jai Samand, Siliserh, Sariska, Kali Ghati, Pandupole, Bhathariji, Tal-Vriksha and Naldeshwar. In the present study, six main problematic chemical constituents that best establish the hygienic state of water, and the risk of related health hazards, have been analyzed to secure a concise and clear profile of the chemical characterization and fresh assessment of safety, suitability and acceptability of drinking water quality. These parameters are: (i) pH, (ii) chloride, (iii) fluoride, (iv) nitrate, (v) total dissolved solids (TDS) and (vi) total hardness (TH). Then the critical water quality parameters have been compared with the drinking water standards to assess the severity of contamination potential and source delineation of various parameters. Although the major objective of the present study is to deduce whether safe and wholesome supply of drinking water is available to tourists or not, some efforts have also been made to identify the probable reasons and sources of contamination.

The Study Area

The study area is in the district of Alwar which was founded by Rao Pratap Singh in 1775. According to Cunningham, Alwar derived its name from the Salwar tribe and was originally Salwapur, later on known as Salwar, and eventually Alwar. It is situated in North-East of Rajasthan between 27°04′ and 28°04′ North latitude and 76°07′ and 77°13′ East longitudes covering a geographical area of about 44.76 km^2. It is bounded on North and North-East by Gurgaon district of Haryana state and Bharatpur district, on the South-West by Jaipur district and South by Dausa district. However, the Alwar city is located between North latitude 27°30′20″ and 27°36′30″ and East longitude 76°35′ and 76°40′ and is covered in the Survey of India G.T. Sheet no. 54A 10. The district is in the National Capital Region. It is a part of Jaipur division and divided into six subdivisions, 12 Tehsils and 14 Panchayat Samitis.

The total population of district is 2,296,580 persons among which 1,976,293 persons are in rural and 320,287 persons are in urban areas. There are three important dams namely Siliserh, Jaisamand and Mangalansar and two seasonal rivers namely Ruparel and Sabi in the district. The district is mainly drained by a number of rivers and rivulets mainly Sabi, Ruparel and tributaries of Banganga river. The area of Alwar city is drained by the Gazukli River and local nallahs.

Hydrogeology of Alwar District

The study area comprises *Alluvium*, *Quartzite* and *Slate* as hydrogeological units.

Alluvium: It occupies the major part of the area. South-Western area and small pockets in different parts are exception which are occupied by crystalline rocks. Alluvium encompasses nearly 84% potential area.

Quartzite: The litho unit covers the most extensive area in Rajgarh block. Parts of the Umrain and Kishangarh blocks have also been demarked with quartzite aquifer. The rock unit encompasses nearly 8% of the potential area.

Slate: The litho unit covers an extensive area in the Tanagaji block. A small area occupied by the rock unit has also been delineated in Reni block. Slate occupies nearly 8% of the potential area. Groundwater in Alwar city area occurs under unconfined to semi-confined conditions in the Older Alluvium. Alluvium comprises sand, gravel, clay and 'kankar' bed and its thickness extends from 45 to 76 m.b.g.l. (metres below ground level). Fractured and weathered rocks form minor aquifiers where boulders are encountered in foot hills. The boulder area of the city gives a moderate yield of water.

Experimental

The present work is based on the sampling and analysis of drinking water from different sources conducted during 2001-2003. The study proposed and designed for the experimental observations included the following two steps: sampling and water sample analysis.

Sampling

(a) *Sample containers:* Inert material containers were used for the determination of pH, chloride, fluoride, nitrate, total dissolved solids (TDS) and total hardness (TH). Glass containers were not preferred because trace metals are adsorbed onto the walls (Meena et al., 2005) of the container and silica and sodium are leached out (Chen et al., 2006).

(b) *Sampling location:* The exact sites for sampling were chosen carefully to provide samples that were representative of the whole location. The whole state was distributed into four zones (North-East, South-East, North-West and South-West) for uniformity in the study area. In practice, the sampling locations were best chosen using local knowledge concerning water sources, distribution systems and the specific problems.

(c) *Sampling point:* In areas with more than one water source, the location of the sampling was selected on the basis of the number of inhabitants served by that source.

(d) *Collection of sample:* It was ensured that the procured sample was representative of that source. To collect the samples from tubewells, they were pumped sufficiently to ensure that the samples represented the groundwater source. The samples from surface sources were procured from 30 cm below the surface of water in order to avoid floating impurities and unwanted material. Before filling, the sample bottles were rinsed two or three times with the water being collected.

(e) *Volume of the sample:* Enough sample in a volume of 500 mL was collected to allow for sufficient measurement to be made properly.

(f) *Labelling of the sample:* Each sample was adequately labelled to furnish the information regarding name of the source, location and the date of collection to avoid errors.

(g) *Time interval in between sampling and analysis:* It was ensured that the concentration of the substance to be determined has not changed between sampling and analysis. In general, analysis was done soon after collection of the samples (Sliwka-Kaszynska et al., 2003). The following maximum limits have been suggested by the standard methods:

Clean water	72 hours
Slightly polluted water	48 hours
Polluted water	12 hours

The concentration of the chemical species in a sample may change as a result of: (i) external contamination during collection of the sample (Rodriguez et al., 2006), (ii) contamination from the container, and (iii) the chemical, physical or biological processes going on in the sample (Sawaittayothin and Polprasert, 2007).

Some determination of water parameters are more likely to be affected by sample storage. pH may change significantly in a matter of minutes (Pyrzynska, 2007). Changes in pH-alkalinity-carbon dioxide balance may cause calcium carbonate to precipitate, decreasing the value of total hardness (Benaduce et al., 2008). Microbiological activity is responsible for changes in the nitrate content (Mertoglu et al., 2006), and residual chlorine is reduced to chloride resulting in changes in the chloride concentration. In this study, due consideration was given to the latter facts. When the interval between sample collection and analysis was long enough to produce changes either in the concentration or the physical state of the constituents to be measured, preservation methods were followed. The precautionary requirements adopted for this study are summarized in Table 1.

Analysis of Water Samples

Different methods have been recommended for the quantitative determination of chemical characteristics or substances in the literature. The following standard methods for analysis* of water samples have been used in this study:

* Methods for the examination of waters and associated materials: General principles of sampling and accuracy of results, Her Majesty's Stationary Office, London, England 1980 and Manual of water and waste water analysis, Public Health Engineering Department, Rajasthan (February 2000); Manual on water supply and treatment, Ministry of Urban Development, Govt. of Delhi, 1991; Standard methods for the examination of water and waste water, 17th ed., Washington, DC. American Public Health Association, 1989; Vogel, A.I.; Qualitative Chemical; Indian Standards (IS): 10500, BIS, India 1991 9 (IS No.3025; Methods of sampling and test (physical and chemical) for water and waste water; Part 11 (1983), pH value; Part 16 (1984), Total Dissolved Solids; Part 21 (1983), Total Hardness; Part 32 (1988), Chloride; Part 34 (1988), Nitrate; Part 23 (1964), Fluoride); Analysis. Langmans, Green and Company; Willard, H.H.; Merritt, L.L.; Dean, J.A.; Instrumental methods of analysis.

Table 1: Summary of sampling and handling requirements

Determination	*Container†*	*Sample Size (mL)*	*Preservation*	*Maximum storage recommended/regulated*
pH	P, G	50	Analyze immediately	2 H/stat
Chloride	P, G	50	Not required	28 d
Nitrate	P, G	100	Analyze as soon as possible or refrigerate*	48 h/48 h(28 d for chlorinated samples)
Fluoride	P	300	Not required	28 d/28 d
Total dissolved solids (TDS)	P, G	500	Refrigerate*	28 d/28 d
Total hardness	P, G	100	Add HNO_3 to pH<2	6 months/6 months

†P = Plastic (Polyethylene or equivalent) ; G = glass, * = Refrigerate= storage at 4°C in the dark, stat = No storage allowed, analyzed immediately

(a) *pH determination:* The determination has been carried out by the electronic method with the help of a pH-meter which is most widely used for finding out the hydrogen ion concentration in water samples (Durve et al., 1991).

(b) *Chloride-determination:* The determination has been carried out by the titrimetric (argentometry) method. Mohr developed the method in 1986. This method involves silver nitrate titration with chromate indicator.

(c) *Nitrate determination:* Nitrate ions were estimated usually by the phenoldisulphonic acid colorimetric method. 'Standard Series Method' has been carried out for quantitative comparison of colours.

(d) *Fluoride determination:* Fluoride ions have been estimated by colorimetric methods.

(e) *Determination of Total Dissolved Solids (TDS):* The determination has been carried out by the electronic method.

(f) *Determination of Total Hardness (TH):* The determination has been carried out by micrometric (complexometric) method.

The desirable and permissible limits as recommended by Indian Standards (IS: 10500. Drinking Water Specifications. (First revision) BIS, India, 1991) are summarized in Table 2.

Table 2: Desirable and permissible limits of some problematic chemical parameters (ppm)

	pH	*Cl^-*	*NO_3^-*	*F^-*	*TDS*	*TH*
Desirable limit	6.5-8.5	250	45	1.0	500	300
Permissible limit	No Relaxation	1000	100	1.5	2000	500

Depending upon the above mentioned drinking water standards, the quality of water (with respect to pH, Cl^-, F^-, NO_3^-, TDS and TH) can be categorized as follows:

***Good** (G)* **–** When a chemical constituent is below desirable limit.

***Permissible** (P)* **–** When a chemical constituent is above desirable but below permissible limit.

***Unsatisfactory** (U)* **–** When a chemical constituent is above permissible limit.

Considering all the investigated problematic chemical constituents collectively, the suitability of water for drinking purpose has been determined as detailed below:

***Excellent to Good* –** All chemical constituents below desirable limit.

***Good to Permissible* –** All chemical constituents between desirable and permissible limit. 1 to 5 constituents may be below desirable limit.

***Doubtful to Unsuitable* –** If all constituents except any one of pH, Cl^-, TDS and TH are below permissible limit.

***Unsuitable* –** If any one of direct health affecting constituent (nitrate and fluoride) or 2 to 6 constituents are above permissible limit.

Results and Discussion

The results of the water quality monitoring and pollutant speciation are presented in Table 3.

Key Observations

All samples had a pH within the desirable range, chloride and nitrate contents below desirable limits. Only 9.1% samples had a fluoride concentration above the desirable limit of 1.0 ppm. 36.4% samples had a TDS above desirable limit of 500 ppm but below the permissible limit of 2000 ppm. 36.4% samples had a total hardness above the desirable limit while only 9.1% samples had it above the permissible limit of 500 ppm. In direct inference of these results, the drinking water samples tested at the tourist places selected for the monitoring had their pH, chloride and nitrate concentrations below the respective desirable limits. The water samples of the tubewell in Sariska had the fluoride concentration above

Table 3: Chemical status and drinking water quality in tourist places

Location	*Parameter (ppm)*						*Drinking water quality*
	pH	Cl^-	NO_3^-	F^-	*TDS*	*TH*	
Jai Samand							
H.P., Guest House	7.9(G)	40(G)	5(G)	0.4(G)	448(G)	310(P)	Good to Permissible
D.W., South side of Dam	8.1(G)	40(G)	5(G)	0.2(G)	728(P)	540(U)	Doubtful to Unsuitable
Siliserh							
T.W., near Guest House	7.7(G)	30(G)	5(G)	0.8(G)	224(G)	160(G)	Excellent to Good
Sariska							
T.W., near Guest House	7.8(G)	50(G)	10(G)	1.2(P)	672(P)	320(P)	Good to Permissible
Kali Ghati							
T.W., near Road	7.0(G)	40(G)	5(G)	0.2(G)	336(G)	190(G)	Excellent to Good
Pandupole							
D.W., Hanuman Temple	7.6(G)	50(G)	10(G)	0.2(G)	392(G)	350(P)	Good to Permissible
Bharathariji							
D.W., Hanuman Temple	7.8(G)	90(G)	5(G)	0.6(G)	672(P)	200(G)	Good to Permissible
Surface Water, near Samadhi	7.9(G)	50(G)	5(G)	0.2(G)	392(G)	180(G)	Excellent to Good
Tal-Vriksha							
D.W., Hot Water	7.6(G)	60(G)	10(G)	0.2(G)	448(G)	250(G)	Excellent to Good
D.W., Cold Water	8.1(G)	60(G)	10(G)	0.4(G)	448(G)	260(G)	Excellent to Good
Naldeshwar							
D.W., Basement of Temple	8.1(G)	60(G)	5(G)	0.4(G)	616(P)	260(G)	Good to Permissible

Table 4: Extreme values of investigated chemical constituents in drinking water samples of tourist places

Chemical parameter	*Minimum values (ppm)*	*Maximum values (ppm)*	*Mean (ppm)*
pH	7.0 (T.W., Kali Ghati)	8.1 (D.W., Jai Samand; D.W., Tal-Vriksha; D.W., Naldeshwar)	7.55
Chloride	30 (T.W., Siliserh)	90 (D.W., Bharathariji)	60
Nitrate	5 (in 7 samples of diff. places)	10 (T.W., Sariska; D.W., Pandupol; D.W., Tal-Vriksha)	7.5
Fluoride	0.2 (in 5 samples of diff. places)	1.2 (T.W., Sariska)	0.7
Total Dissolved Solids	224 (T.W., Siliserh)	728 (D.W., Jai Samand)	476
Total Hardness	160 (T.W., Siliserh)	540 (D.W., Jai Samand)	350

the desirable limit of 1.0 ppm and average 1.2 ppm. Also, the water samples collected and tested for Jaisamand, Sariska, Bharthariji and Naldeshwar had the TDS above the desirable limit and at some locations exceeding the permissible limit of 500 ppm. The total hardness has been found to be above the desirable limit in water samples of Jaisamand, Sariska and Pandupole.

The present chemical testing and the subsequent comparison of the results with the quality standards (IS 1991) has revealed that the quality and suitability of drinking water are safe and acceptable. Out of the 11 samples, only one has been identified as 'doubtful to unsuitable' for drinking. Five samples had one, two or more problematic chemical constituents above their respective desirable limit but satisfactorily below the permissible limit, and could be regarded as being of 'good to permissible' quality. Five samples had all constituents below the respective desirable limits and could be regarded as being of 'excellent to good' quality. The latter inferences are summarized in Table 4.

Final Note

This study has provided reliable water quality data testing and assessment. The approach presented here can be reproduced to further and continually assess the current water quality at other locations in Alwar district and gauge the potential for health risks. The sets of results would be an indication for the framing up of effective management and the necessary water treatment requirements of drinking water sources.

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