WATER, SANITATION AND ITS IMPACT ON ENVIRONMENT AND HUMAN BEING – A CASE STUDY

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KEYWORDS: drinking water quality, microbial contamination, human health, India.

ABSTRACT

The present study was carried out to assess the drinking water quality, hygiene and human health existing in the city of Jodhpur. About 89.8% of houses use household drinking water from supply, and the remaining 10.2% houses depend on public taps or other water sources. Similar results for sanitation and hygiene observed as 97% of houses did not have any garbage disposal facility and in all 10.6% did not have easy access to a sanitary facility. The results of physical and chemical parameters of ground water were above the drinking water standards, whereas in the case of household drinking water were within standard limits. The presence of total coliform, faecal coliform and faecal streptococci were showing water contamination which may be the cause of significant prevalence 5.0% (p < 0.001) of gastrointestinal infections.

ZUSAMMENFASSUNG: Wasser, Gesundheitspflege und ihre Auswirkungen auf die Umwelt und die Menschen – eine Fallstudie.

Vorliegende Untersuchung wurde durchgeführt, um die Qualität des Trinkwassers sowie von Hygiene und Gesundheit der in Jodhpur, lebenden Menschen zu bewerten. Etwa 89.8% der Haushalte benutzen Trinkwasser aus der Wasserversorgung, während die verbleibenden 10.2% von öffentlichen Wasserhähnen oder anderen nicht etablierten Wasserquellen abhängig sind. Ähnliche, für die Gesundheitsversorgung und Hygiene festgestellte Ergebnisse belegen, dass 97% der Haushalte keine Einrichtungen für Abfallbeseitigung und insgesamt 10.6% der Haushalte keinen leichten Zugang zu Sanitäranlagen haben. Die Ergebnisse von physikalischen und chemischen Parametern des Grundwassers liegen höher als die Trinkwasserstandardwerte, während sie im Falle des Haushalt Trinkwassers innerhalb der Standardgrenzen liegen. Das Vorhandensein der Gesamtkolibakterien, der Fäkalkolibakterien und Fäkal Streptokokken zeigen die Wasserkontaminierung an, die gegebenenfalls die Ursache einer bemerkenswerten Prävalenz von 5.0% (p < 0.001) gastrointestinaler Infektionen sind.

REZUMAT: Apa, igiena și impactul lor asupra mediului și a populației – studiu de caz.

Acest studiu a evaluat calitatea apei potabile, a igienei și sănătății populației în orașul Jodhpur. Aproape 89.8% din gospodării folosesc apa potabilă de la rețeaua de alimentare cu apă, 10.2% de la robinete publice sau alte surse. Rezultate privind îngrijirea sănătății și igiena, arată că 97% dintre gospodării nu au facilități pentru deșeurile menajere și 10.6% nu au acces ușor la facilități sanitare. Valorile parametrilor fizici și chimici a apei freatice sunt mai mari decât standardele admise pentru apa potabilă, iar în cazul apei potabile a gospodăriilor aceste valori sunt între limitele standardului. Prezența colibacililor totali, a celor fecali și a streptococilor fecali, indică o contaminare a apei, care probabil este cauza prevalenței de 5.0% (p < 0.001) a infecțiilor gastro-intestinale.

INTRODUCTION

The needs of safe water supply, sanitation and hygiene are all unable to keep pace with urban growth followed by poor housing, poor drainage and garbage accumulation causes serious pollution problems. It finally has adverse effects on the health of people (Hutton et al., 2007; WHO, 2007; Kumar et al., 2011). The problem is aggravated due to the discharge of industrial effluents containing toxic pollutants, city sewage and overproduction of solid waste, which are the main cause of most waterborne diseases (CPCB, 2009). Toxic substances such as arsenic, lead, cadmium, nitrates, pesticides, etc., also enter the household drinking water supply at many points before reaching the tap, are also a matter of concern (Morris, 1995). Lack of hygiene further aggravates the problem. The magnitude of waterborne diseases such as cholera, diarrhoea, hepatitis, typhoid, amoebic, and bacillary dysentery are very high throughout the world (WHO, 2005). Nearly half the world's population does not have access to safe water through a household connection or a yard tap from a piped distribution system and live without sanitation (WHO/UNICE, 2000). In developing countries, over 90% of all diarrhoeal deaths occur in children under five years. Improving the drinking water quality, and providing enough water, for both personal and domestic hygiene are keys to prevention and control of diarrhoeal diseases (Fewtrell et al., 2005).

Water is one of the most priceless resource of Earth and under constant and variate anthropogenic impact (Vörösmarty et al., 2000; Flörke et al., 2013; Haddeland et al., 2013; Hutton and Chase, 2017). The needs of safe water supply, sanitation and hygiene are all unable to keep pace with urban growth followed by poor housing, poor drainage and garbage accumulation, and cause serious pollution problems (Mara, 2003; Hutton and Haller, 2004; Hutton et al., 2007; Gjyli and Mukli, 2009; Mara et al., 2010). It finally has adverse effects on the health of people (Ahern et al., 2005; Gerba, 2009; Kumar et al., 2011; Lim et al., 2012; Benova et al., 2014; Pepper et al., 2015).

The urban population has increased in India three and half times (UN, 2001), from 17.28% (1951) to 28% (2001). Clean drinking water facility through taps is available to only 35% of urban households and 18% of rural households in India as per the records of Registrar General and Census Commissioner of India 2001. Other residents use improper water sources like wells, ponds, and rivers. Lack of water, sanitation, and hygiene results in the loss of 0.4 million lives annually in India (WHO, 2007).

In the west sector of Rajasthan, which contain a sector of the Thar Desert, the situation evolves in a bad one due to a deficiency of secure water for drinking. Jodhpur area (Rajasthan, India) includes over one million residents with 2.1% annual human population increase as per census 2001. It has over 10,000 industrial sites, which induce pollution and influence the water quality. The studied locality has a complex system of pipelines for water supply and sewerage fluids, which does not support all the needs of the inhabitants and require numerous restorations. There is scarce available information in the present in India, concerning the drinking water pollution and its negative human's health effects. Thus, this study was developed to evaluate the significance of water pollution, sanitation problem, occurrence and predominance of diseases that may guide in planning and managing intervention activities.

Increasing urban population from about 869,403 to 972,259 and industries from 8,468 to 10,585 during the last five years, caused concern for increasing water pollution. The studied city has incomplete and inadequately maintained sewerage and water distribution system.

MATERIAL AND METHODS

Study area. Jodhpur the Sun City is placed in a dry region in the west of Rajasthan, where economic advancement was registered as very important since the last decade. Jodhpur has developed into the second biggest city of Rajasthan area and an outstanding centre both for industry and education. It is placed at latitude 26°18'N, longitude 73°04'E and at an elevation of 230 m above m.s.l. and cover a total area of 70 km^2. Placed at the margin of the Thar Desert the researched surface where there is acute dryness with very hot summers, with temperatures around 45°C, with numerous dust storms and moderate temperature in winter. The annual ordinary rainfall is 31.0 mm. Jodhpur continue to be one of the fastest developing cities in India.

Water sampling sites. The city has 60 wards with different landscapes (Fig. 1). Public Health Engineering Department (PHED) treats this water in waterworks and then supply the city for drinking purpose. Water samples were collected from following major categories of sites. Category one: the household drinking water samples were collected from twelve randomly selected sites in the city as shown in figure 1. Category two: similarly groundwater samples from open wells, step wells, tube wells and hand pumps were also collected from the twelve sites (Fig. 1). Category three: there are three main reservoirs of raw water in the city, Kailana, Takhat Sagar, and Balsamand. These reservoirs receive water continuously from the Rajiv Gandhi Canal. These water sources also receive runoff water from the adjoining watersheds during rains. Category four: waterworks water samples were also collected for comparative study. The main water works for drinking water supply to the city is set up at Kaylana Lake, Chopasani Road. The other one is at Balsamand Lake, which supplies water to a very small population of the city in its north. Samples were collected since 2004 to 2005, covering all seasons.

Collection of water sample. Water samples of various potable water sources as household drinking water and ground waters (open wells, tube wells, hand pumps, etc.) were collected in screw-capped, clean, sterile, 2.5-litre inert plastic containers (PVC bottles) from the selected sites. Immediately after collection of samples, bottles were put in an icebox and were transported to the laboratory. Samples are stored at 4°C to avoid any changes in their physical, chemical, and biochemical characteristics. For the microbial investigations samples were collected separately in sterile 500 mL bottles and analyzed within 30 hours.

Water analysis. Water quality was determined for physical, chemical, and bacteriological characteristics. Parameters measured for water pollution studies include pH, temperature, turbidity, conductivity and total dissolved solids (TDS), alkalinity, hardness, chlorides, fluorides, nitrates, phosphates, and sulphates for chemical, lead, cadmium, iron, dissolved oxygen, biological oxygen demand-BOD, total coliforms (TC), faecal coliform (FC) and faecal streptococci (FS). The levels of heavy metals were determined by acid digestion methods using Atomic Absorption Spectrophotometer (Perkin-Elmer Model 2380) and air-acetylene flame. The bacteriological investigation was carried out by the membrane filtration method. Direct plating and estimation of coliform densities were done. The coliform density was reported as membrane filtration count per 100 mL. The standard methodology was followed for water pollution assessment (APHA, 1992, 1998).
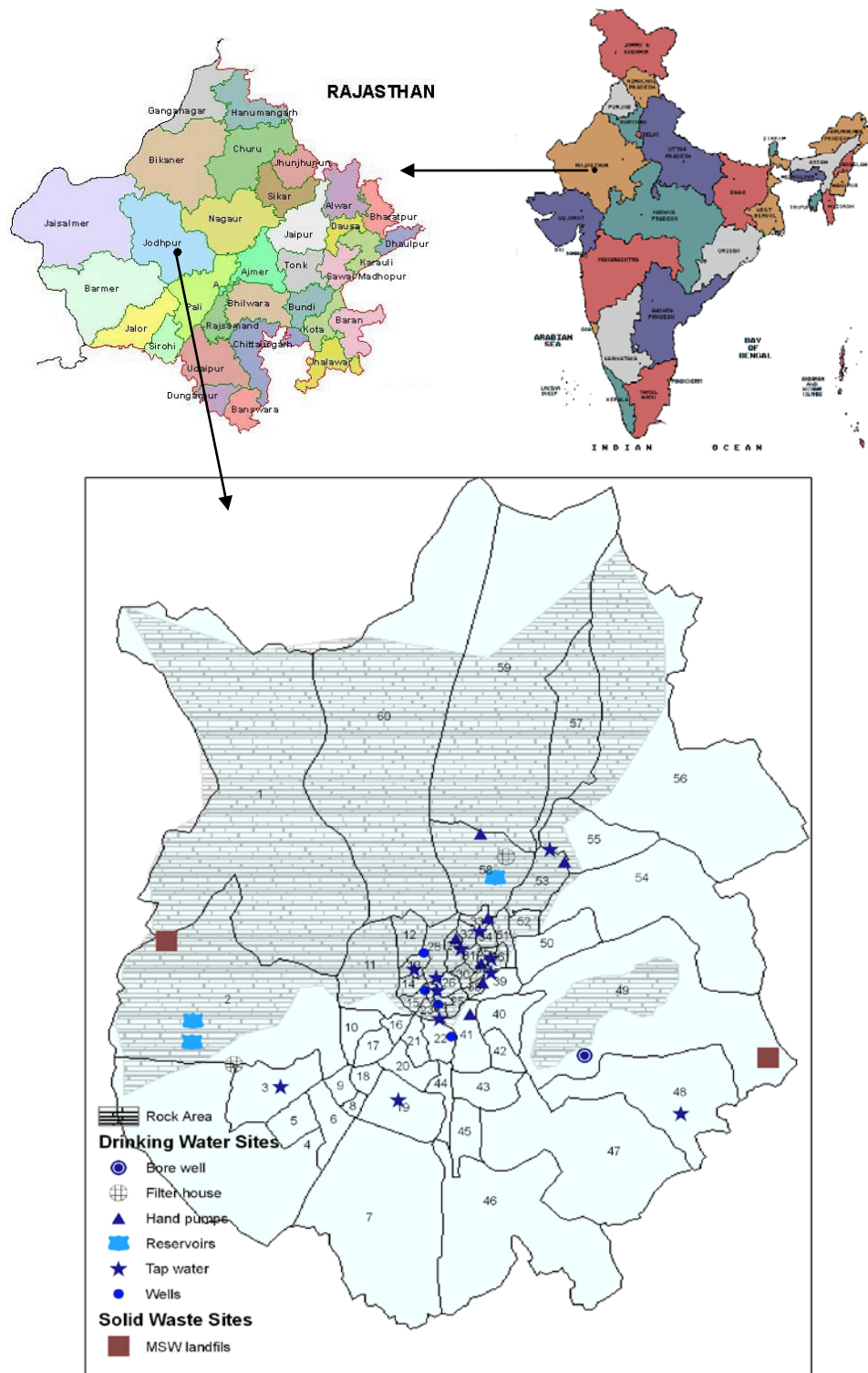
Figure 1: Ward map showing the drinking water pollution
and solid wastes study sites in Jodhpur, Rajasthan, India.

Sanitation issue. The most common method of disposal of municipal solid wastes in the city is by deposition in landfills. There are two dumping places in the city for municipal solid wastes. The main dumping ground for Municipal Solid Waste (MSW) is situated in the western part of the city near the Kaylana Reservoir. The municipal solid waste dumping area is spread over a large area of about 200 acres of lands in the western part of the city on a hilly and stony bed. The samples have been collected from the sites on a random basis to take an unbiased representative sample. Two main landfills or disposal sites have been selected for the present study (Fig. 1). For taking the solid and hazardous wastes samples from the selected sites, a one-two m diameter deep ditch was made with an area of about two m^2 from the surface of the landfills. The samples were analysed using standard methods as described in Laboratory Manual for Soil and Water Testing Methods (Ghosh et al., 1983).

Health survey. A human population cross-sectional health analysis was accomplished in the city. A sample size of 10,000 was taken to find out the prevalence of morbidity circumstances with a prevalence of 1% or over, with a 10% standard error. The samples were dispersed to 60 wards of Jodhpur. Data on local water-associated health problems as per the schedule at household level were collected. The information about the number of humans treated at OPD and wards of four teaching hospitals of Jodhpur regarding gastrointestinal illnesses and cancer were collected from office of Principal Dr. S. N. Medical College, Jodhpur. Exhaustive investigation of information about health and illnesses and their link with diverse water pollution has been achieved using Epi Info 2000 software.

RESULTS

Water quality. A total of 165 representative water samples were collected from different localities of the city. Out of 165 water samples, 123 were from household drinking water, six from the outlet of waterworks, nine from surface water sources and 36 from ground waters (open wells, step wells, hand pumps and tube wells) were collected. They were examined for physical, chemical, and bacteriological parameters and results of annual average water quality with the number of samples above the drinking water standards are described in tables 1-2. Drinking water samples collected from waterworks showed most of the parameters were within acceptable limits. Very few samples from household drinking water were reported outside the standards for their physical and chemical factors (Tab. 2). Only a few colonies of total coliform, faecal coliform and faecal streptococci bacteria were present. The results of water samples collected from surface waters (reservoirs/lakes) for most of physical and chemical parameters were found within the range of drinking water standards except turbidity (Tab. 1). The growth of all three types of colonies of bacteria as total colilfom, faecal coliform and faecal streptococci in these untreated water samples were observed (Tabs. 1-2).

Groundwater is also used for drinking as well as other activities such as bathing, washing, cleaning, etc. The results of physical, chemical, and bacteriological characteristics of groundwater samples are given in table 1. The parameters such as conductivity, total dissolved solids, total hardness, nitrates, alkalinity, dissolved oxygen, total coliform, faecal coliform, and fecal streptococci in groundwater samples were found above the acceptable standard limits. The annual average level of these parameters was also found above the acceptable standards. The results of metal analysis show that lead, iron, and cadmium in all water samples were present in traces or below the detectable limit. The growth of colonies of total coliform, faecal coliform and fecal streptococci bacteria were found in all type of water samples.

Table 1: Annual average values of physical-chemical and bacteriological characteristics of different water sources (2004-2005); * values in mg/l; ** bacterial colonies as counts/100 ml; Turb. – turbidity (NTU), cond. (µS/cm), Hard. – hardness, Res. Cl* – Residual Cl*.

Parameters	Acceptable limit	Drinking water N = 123	Filter plant N = 6	Raw waters N = 9	Open/step wells N = 23	Hand pumps/bore wells N = 23
pH	6.5 - 8.5	7.6 + 0.34	7.4 + 0.3	7.6 + 0.26	7.6 + 0.23	7.5 + 0.3
Turb.	< 5.0	1.2 + 0.93	1.7 + 1.5	18.4 + 14.4	0.8 + 1.05	3.3 + 3.9
Cond.	< 600	256.6+118.58	450.7 + 302.0	425.3+267.17	1079.1+341.6	1820.2+988.9
TDS*	< 500	139.9 + 59.31	153.0 + 20.3	207.1 + 69.6	702.1+196.28	1256.8+670.9
Hard.*	< 300	95.2 + 22.12	132.5 + 32.7	143.9 + 52.6	270.8 + 43.35	393.2 + 230.6
Res. Cl*	< 0.20	0.1 + 0.04	0.2 + 0.1	0.1 + 0.04	0.1 + 0.03	0.1 + 0.0
T. (°C)	NA	25.1 + 7.62	24.7 + 5.0	24.6 + 6.89	25.1 + 2.21	25.1 + 2.0
Cl*	< 250	32.7 + 8.24	39.9 + 23.9	43.8 + 49.52	93.9 + 38.08	209.5 + 110.8
F*	< 1.0	0.1 + 0.10	0.7 + 0.6	0.7 + 0.58	0.2 + 0.12	0.7 + 0.4
NO$_3$*	< 45	9.3 + 11.89	5.1 + 2.8	6.4 + 4.09	124.6 + 57.72	296.1 + 167.9
SO$_4$*	< 200	39.8 + 29.01	49.0 + 22.3	73.2 + 35.37	146.3 + 69.67	202.3 + 127.4
Alk.*	< 200	97.3 + 44.70	87.9 + 44.0	132.1 + 39.80	272.2+102.67	302.6 + 124.5
DO*	> 7.5	6.0 + 1.01	5.5 + 0.8	5.3 + 0.77	4.4 + 2.02	4.5 + 1.8
BOD*	< 2.0	1.0 + 0.51	0.9 + 0.6	1.0 + 0.97	1.1 + 0.75	1.1 + 0.6
Pb*	< 0.05	0.0 + 0.00	0.0 + 0.00	0.0 + 0.00	0.0 + 0.00	0.0 + 0.0
Fe*	< 0.30	0.1 + 0.08	0.2 + 0.10	0.2 + 0.09	0.2 + 0.21	0.2 + 0.2
Cd*	< 0.01	0.0 + 0.05	0.0 + 0.00	0.0 + 0.00	0.0 + 0.00	0.0 + 0.0

Table 2: Number of water samples outside the acceptable standard (2004-2005); *Values are in mg/l; **Bacterial colonies as counts/100 mL.

Parameters	Acceptable limit	Filter house N = 6	Drinking tap water				Raw water sources N = 9	Open/step well (N = 9)	Hand pumps/ bore wells (N = 23)
			Winter N = 47	Summer N = 40	Monsoon N = 36	Annual N = 123			
pH	6.5 - 8.5	0	0	8	2	10	1	0.0	1.0
Turb.	< 5.0	0	0	0	1	1	7	0.0	3.0
Cond.	< 600	0	2	2	0	4	2	9.0	22.0
TDS*	< 500	0	1	0	0	1	0	8.0	22.0
Hard.*	< 300	0	0	0	0	0	0	3.0	15.0
Res. Cl*	< 0.20	0	0	0	0	0	0	0.0	0.0
T. (°C)	NA	0	0	0	0	0	0	0.0	0.0
Cl*	< 250	0	0	0	0	0	0	0.0	8.0
F*	< 1.0	0	0	0	0	0	3	0.0	5.0
NO$_3$*	< 45	0	2	0	0	2	0	9.0	22.0
SO$_4$*	< 200	0	0	0	0	0	0	1.0	12.0
Alk.*	< 200	0	1	0	0	1	0	7.0	19.0
DO*	> 7.5	0	47	40	36	123	8	9.0	21.0
BOD*	< 2.0	0	1	0	1	2	1	2.0	1.0
TC**	0.0	6	34	38	35	107	8	7.0	22.0
FC**	0.0	0	18	25	26	69	7	6.0	15.0
FS**	0.0	0	14	16	21	51	7	6.0	9.0

Sanitation issue. Removal of waste is a main problem of worry. Municipal Corporation gathers wastes and transports to the disposal sites, which are commonly a low-lying surface on the periphery of the city. The data about it was obtained from Jodhpur Municipal Corporation. Jodhpur Municipal Corporation gathers city solid wastes in open trucks, which cannot compress the wastes. About 30-35 trucks, of 10 tons each, of solid wastes are gathered and transported to the dumping areas. The principal dumping area is located near Badli in the western part of the city. This is located in the basin area of Kaylana, the main water reservoir of Jodhpur. The city solid waste dumping field is spread over a broad area of about 200 acres in the western side of the city on hilly and stony substrata. The main dumping area is under the expanding state of motorized machinery for compacting and levelling the wastes, and covering the top level with soil before finally compacting it. Solid waste fragments were sampled from these landfills, and separated into its contents. The principal elements were minerals, coal, vegetables, paper, glass, rags, wood, plastics, iron, rubber, dust, etc., which may be rich in toxic chemicals and also pathogens. The organic matter was isolated. The percentage fractions of each element of municipal solid wastes samples are presented in table 3.

Table 3: Percentage and average weight of municipal solid waste fractions.

Components	Average (n = 12)	
	Weight in grams	%
Minerals and building materials (mixed)	1,661.4	33.2
Polythene bags and plastics (mixed)	136.2	2.7
Glasses and porcelains (mixed)	130.3	2.6
Fibers (textile and a part of waste wood)	112.3	2.3
Metal: iron (mixed)	73.5	1.5
Total compostable material	1,280	25.6
Fine soil	1,606.3	32.1
Total weight	5,000	100.0

Health Assessment

Health survey was conducted in 1,600 houses in the city, which included 9,287 individuals (46.2% females and 53.8% males). Out of 9,287 individuals, 81.1% were Hindus, 18.2% were Muslims, 0.5% were Sikhs and 0.2% were Christians. Based on their housing details, 2.9% of individuals were slum dwellers (lowest income group), 46.7% lived in low-income settlement, 47.3% in middle-income settlement and 3% lived in posh colonies (high-income settlement). Educational status of the population shows that 24.0% population (17.4% males and 31.7% females) was illiterate and 76% literate. Most houses (97%) did not have any garbage disposal facility, and garbage from these houses was dumped on roadsides or open plots. It was found that toilets were not available in 5.9% houses and these residents practiced open field defecation, whereas 0.1% individuals depended on common toilets meant for a group of families, 1.3% on dry pits and 3.3% on public toilets. In all 10.6% of houses in the city did not have easy access to sanitary facilities. Tap water supply was available to 85.6% population (89.8% houses), and the remaining 14.4% population (10.2% house) depended on public taps/tankers, hand pumps, reservoirs, bore wells and open wells.

The percent prevalence of different environmental related diseases such as gastrointestinal diseases, diabetes mellitus and skin diseases are described in tables 4-6. The prevalence of gastrointestinal infections was 5.0% (Tab. 4). It was 4.9% in males and 4.7% of females. Of all 1.2% had abdominal pain, 0.4% loss of appetite, 0.8% hyperacidity, 0.3% diarrhoea, 0.3% dysentery, 0.7% gastritis, 0.3% hepatitis, 0.6% jaundice and 0.4% has typhoid. In the survey, 2.1% males and 2.2% of females have shown a history of diabetes (Tab. 5). Percent prevalence of skin diseases was 4.1% (Tab. 6). Prevalence of various skin diseases such as allergic manifestation, fungal infections, dermatitis, leucoderma and patch of discolouration were 3.0, 0.3, 0.8, 0.2, and 0.3% respectively.

Table 4: Percent prevalence of gastrointestinal diseases in Jodhpur.

Age-group	Sex	Number examined (n)	Percent prevalence of									
			Abd. pain	Loss of appetite	Hyper-acidity	Diarrhoea	Dysentery	Gastritis	Hepatitis	Jaundice	Typhoid	Total
0-1	M	42	2.4	0.0	0.0	2.4	0.0	0.0	0.0	2.4	0.0	7.2
	F	31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	M + F	73	1.4	0.0	0.0	1.4	0.0	0.0	0.0	1.4	0.0	4.2
1-5	M	305	0.3	0.7	0.0	2.3	1.0	2.3	0.0	1.3	0.0	7.9
	F	258	0.4	0.0	0.4	1.2	0.8	1.6	0.0	0.8	0.4	5.6
	M + F	563	0.4	0.4	0.2	1.8	0.9	2.0	0.0	1.1	0.2	7.0
5-14	M	967	1.4	0.3	0.2	0.4	0.7	0.6	0.1	1.0	0.4	5.1
	F	802	2.1	0.4	0.0	0.4	0.5	0.6	0.2	0.5	0.6	5.3
	M + F	1,769	2.0	0.3	0.1	0.4	0.6	0.6	0.2	0.8	0.5	5.5
15-44	M	2,581	0.9	0.2	0.6	0.1	0.3	0.7	0.3	0.8	0.4	4.3
	F	2,226	1.1	0.6	0.9	0.2	0.1	0.4	0.3	0.2	0.4	4.2
	M + F	4,807	1.0	0.4	0.7	0.1	0.2	0.6	0.3	0.5	0.4	4.2
45-59	M	695	0.7	0.3	1.7	0.0	0.4	0.8	0.6	0.3	0.4	5.2
	F	561	2.0	0.4	3.2	0.2	0.0	0.4	0.2	0.4	0.4	7.2
	M + F	1,256	1.3	0.3	2.4	0.1	0.2	0.7	0.4	0.3	0.4	6.1
60 +	M	403	0.0	1.2	0.2	0.0	0.2	0.7	1.0	0.2	0.0	3.5
	F	416	1.0	0.0	1.7	1.0	0.5	0.0	0.2	0.2	0.0	4.6
	M + F	819	0.6	0.6	1.0	0.5	0.4	0.4	0.6	0.2	0.0	4.3
All ages	M	4,993	0.9	0.4	0.6	0.3	0.4	0.8	0.3	0.8	0.4	4.9
	F	4,294	1.4	0.4	1.0	0.3	0.2	0.5	0.2	0.3	0.4	4.7
	M + F	9,287	1.2	0.4	0.8	0.3	0.3	0.7	0.3	0.6	0.4	5.0

Table 5: Percent prevalence of known diabetics in Jodhpur.

Age-group	Sex	Number examined (n)	Percent prevalence of known diabetics
5-14	M	967	0.1
	F	802	0.1
	M + F	1,769	0.1
15-44	M	2,581	0.6
	F	2,226	0.7
	M + F	4,807	0.6
45-59	M	695	5.6
	F	561	5.7
	M + F	1,256	5.7
60 +	M	403	12.4
	F	416	11.3
	M + F	819	11.8
All ages	M	4,993	2.1
	F	4,294	2.2
	M + F	9,287	2.2

Table 6: Percent prevalence of skin diseases in Jodhpur.

Age group (years)	Number examined (n)	Allergy	Fungal infections	Dermatitis	Leuco-derma	Patch decolouration	Total
0-1	73	0.0	0.0	1.4	0.0	0.0	1.4
1-5	563	2.7	0.4	0.2	0.0	0.0	3.3
5-14	1,769	3.5	0.2	0.3	0.1	0.1	4.2
15-44	4,807	2.4	0.3	0.4	0.1	0.4	3.6
45-59	1,256	3.5	0.5	0.1	0.1	0.7	4.9
60 +	819	3.4	0.1	0.4	0.6	0.1	4.6
All ages	4,993	2.8	0.3	0.3	0.0	0.4	3.8	–
	4,294	3.1	0.3	0.3	0.3	0.3	4.3	–
	9,287	3.0	0.3	0.3	0.2	0.3	4.1	–

Table 7: Number of Gastroenteritis diseases and cancer patients.

Teaching hospitals Jodhpur	Year		
	2002	2003	2004
Infections of GIT	43,813	39,740	47,700
Malignancies of GIT	302	300	300

Secondary data for gastrointestinal infections, gastrointestinal malignancies and leukaemia were also collected from all teaching hospitals of the city and is shown in table 7. The numbers of cases of gastrointestinal diseases were showing an increasing trend. However, there was not any trend observed for the number of cases of gastrointestinal cancer (oesophagus, stomach, and intestine) no change was observed for gastrointestinal malignancies (Fig. 2). Leukaemia also did not show an increasing trend.
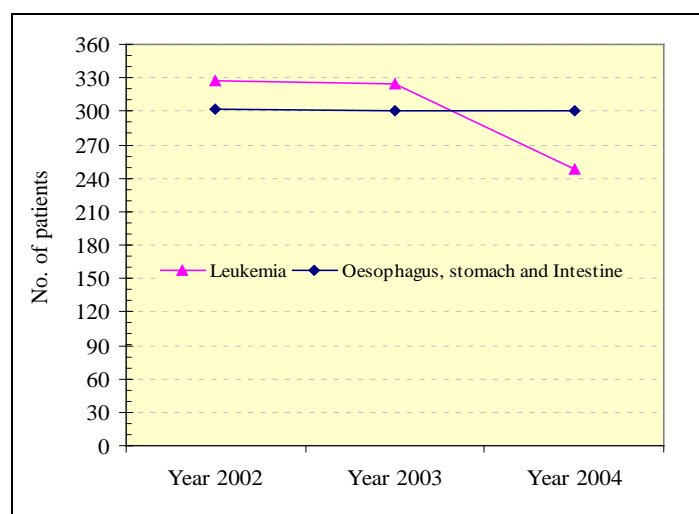
Figure 2: Number of gastrointestinal malignancies at teaching hospitals.

DISCUSSION

The absence of faecal coliform and faecal streptococci in chlorinated water at filter house outlet samples and presence of FC in 69 samples (56%) and FS in 51 (42%) samples of household drinking water (Tabs. 1-2) indicates contamination of water during its flow in the supply network. The residual chlorine level was found between 0.2-0.4 ppm in outlet waters of waterworks, ideally, which should be about 0.7 ppm. It was concluded from the work of Tavakoli et al. (2005) that total chlorine levels of less than 0.71 mg/l in water supply systems could not provide the recommended safety levels. They have reported that *Aeromonas hydrophila* was get inactivated in < 100 minutes time at chlorine levels of 0.11 mg/l to 0.90 mg/l; whereas. *Escherichia coli* were able to tolerate 0.30 mg/l chlorine for > 1,000 minutes while *Enterococcus faecalis* and *Salmonella typhi* survived at total chlorine concentration of 0.50 mg/l for 100 minutes. The higher number of counts of total coliform also indicates chances of other bacterial contamination. Diarrhoeal diseases, jaundice and hepatitis, were observed at low levels in all age groups indicating that most of the water quality is improving except a few sites (on site-specific contamination). During the present study 5.0% prevalence of gastrointestinal diseases might be due to water pollution (Tabs. 1-2). Of all 1.2% had abdominal pain, 0.3% diarrhoea, 0.3% dysentery, 0.7% gastritis, 0.6% jaundice, 0.4% typhoid, 0.3% hepatitis, and 0.4% had typhoid. Almost similar results was observed at Bikaner City in North-West Rajathan where 15.5% of the population and 44.5% of families suffered from one or more common water-borne diseases including amoebiasis, diarrhoea (5.4%), dysentery, jaundice and typhoid (Saxena and Chhabra, 2004). The presence of total coliform, faecal coliform and faecal streptococci in household drinking water may be due to leakage of pipes, mixing of sewer wastewater with supply lines particularly in narrow and tight roads, or storage endpoints as tanks or earthen/brass vessels (mutkas) in households. Another factor responsible for it is intermittent water supply on alternate days, which also encourage bacterial growth in pipelines. Similar observations for drinking water were also reported by George et al. (2006) in Lebanon where intermittent water supply systems exist. The causes of pollution can also be predicted on the basis of the ratio of FC/FS (Tab. 8). It was inferred from the FC/FS ratio that household drinking water contamination is due to human pollution (Gerba, 2000; Gerba and Pepper, 2006; Gerba, 2009; Hass et al., 2014).

Table 8: FC/FS ratio in all water samples and type of pollution (2004-2005) (*Gerba, 2000; 2009; 2015).

Water source	FC/FS	FC/FS*	Pollution source*	Water source	FC/FS
Drinking water N = 123	4.3	> 4.0	Human pollution	Drinking water N = 123	4.3
Filter plant N = 6	1.4	2.0-4.0	Human waste in mixed pollution	Filter plant N = 6	1.4
Raw water N = 9	0.7	< 0.7	Animal pollution	Raw water N = 9	0.7
Open/ step wells N = 9	0.9	0.7-2.0	Animal waste in mixed pollution	Open/ step wells N = 9	0.9
Hand pumps/ bore wells N = 23	7.3	> 4.0	Human pollution	Hand pumps/ bore wells N = 23	7.3

The results of household drinking water quality showed that all physical and chemical parameters were within the range of ICMR/WHO drinking water standards (Tabs. 1-2). Same is true for water samples of surface water sources and waterworks (Tab. 1).

Household drinking water supply was available to 85.6% population (89.8% houses), and the remaining 14.4% population (10.2% houses) depended on public taps or other improper water sources such as tankers, hand pumps, reservoirs, tube wells and open wells. The presence of total coliform, faecal coliform and faecal streptococci in all groundwater samples except the samples collected from the tube well indicates pollution in the groundwater aquifer in Jodhpur City. It indicates that groundwater contamination is also has link with seepage and leachate from sewerage, industrial effluents, industrial hazardous wastes, landfills and agricultural runoff. The same is not be the cause of higher concentration of nitrates, sulphates, chlorides, total hardness (calcium and magnesium), conductivity, and total dissolved solids as it is occurring naturally in a large area of western Rajasthan. Higher concentration of chloride content of water may also indicate possible pollution from human sewerage, animal manure or industrial wastes (APHA, 1998; CPCB, 2009). The higher concentrations of total dissolved solids (TDS) may cause adverse taste effects as highly mineralized water may also deteriorate domestic plumbing and appliances (APHA, 1998; CPCB, 2009). The presence of higher concentration of above-mentioned parameters also favours the bacterial contamination. Some studies carried out by Kumar et al. (2006) on drinking water drawn from hand pumps and tube wells at different locations in district Bathinda, Punjab had revealed a higher concentration of sodium, potassium, calcium, magnesium, chlorine and total hardness along with the pH value and conductivity of the water. Similar, observations of contaminations of drinking water drawn either from surface waters or groundwater by leaching from the soil were made by Holt (2000), and Reimann and Banks (2004).

Groundwater samples from open wells/hand pumps and tube wells showed high levels of nitrates (124.6 mg/l, 296.1 mg/l; Tab. 1). It was three-six times higher than the acceptable standard given by the World Health Organization (2005, 2007, 2008). Groundwater NO_3^- contamination in shallow unconfined aquifers in Jodhpur is occurring naturally through the use of industrial effluents and city sewerage for irrigation and land application of animal manures and inorganic, commercial fertilizers also increase its level through the leaching process. Many studies have documented the relationship between agricultural activities and NO_3^- leaching in shallow aquifers (Power and Schepers, 1989; Spalding and Exner, 1993; Stuart et al., 1994; Puckett et al., 1999; Nolan and Stoner, 2000; Gupta et al., 2000; Nolan, 2001; Sandor et al., 2001; Kumar et al., 2002; Robert et al., 2003). The present results of the high level of nitrates in groundwater of Jodhpur City are also in line with the findings of major parts of Churu, Alwar, Bharatpur, Jalore, Jaipur, Sikar, Tonk, and Jhunjhunu districts of Rajasthan which are also inherited by nitrate-rich ground waters (Kumar et al., 2002). They have classified nitrate toxicity into five water quality zones, namely, safe, mild, moderately problematic, highly problematic and dangerous with a view of health effects. The groundwater nitrate has much increased in the last years, and the demonstration of endogenous nitration among highly exposed subjects raises the concern of elevated cancer risk. The high-level groundwater nitrates may be one of the causes of gastrointestinal cancers in the city, which have been observed (Tab. 7). Similar results regarding gastric cancers and its association of nitrate content were observed by Sandor et al. (2001) in a small area of inequalities. In the present study, history of diabetes was given by 2.1% of males and 2.2% of females but was not found among groundwater water users in Jodhpur (Tab. 5). Kostraba et al. (1992) have suggested that even low-level nitrate exposure through drinking water may play a role in the etiology of Insulin Dependent Diabetes Mellitus (IDDM).

Metals like lead, cadmium, and iron in household drinking water samples from supply during the study period were detected within the limit (Tab. 1). This can be inferred from the absence of heavy metal pollution in surface waters and water works outlets that it is potable and good for consumption. The presence of metals in household drinking water indicates pollution at endpoints that may be due to leakage of supply pipelines or storage tanks at household levels. Similar reports of Alam and Sadiq (1989) on metal contamination of drinking water in Dhahran found that copper, iron, and zinc in the drinking water increased during its transportation which was related to the length and material of distribution pipes and the concentration of copper and zinc were increased during overnight storage of water in the appliances. The absence of metals indicates ground waters that they may be absent in leachate or seepage from landfills, city sewer lines, hazardous waste effluent. Almost similar results were reported from Delhi region by Dixit et al. (2003) for drinking waters drawn from tube wells and surface waters where marginally high levels of manganese, copper, selenium, and cadmium than Indian Standards (IS) specification regulated for drinking water. The levels of iron, nickel, lead, and zinc were within limits (final water supply of four treatment plants; Dixit et al., 2003).

The main dumping ground for MSW is situated in the western part of the city. The percent fractions of the main components of municipal solid waste samples such as minerals and building material (29.25%), glasses and porcelains (3.3%), polythene bags, rubbers and plastics (3.8%), fibers (textile and a part of waste wood, papers, vegetable matter, etc.) (3%), metals with iron (2.2%), compostable material (26.0%), and fine soil with ash (32.5%) were found during the present study (Tab. 3). Similarly percent fractions of municipal solid wastes reported in 40 cities by Bhinde and Sundaresan (1983) and 23 mega cities by EPTRI (1995) and were compared with the present status of MS in Jodhpur City. The difference lies in the

presence of stones and building material (29.2%), which seems to be absent in other cities in India. This may be due to the presence of sandstone quarries and mineral extractions industries in the city. The other important fraction was the presence of a lower amount of compostable matter and fine ash/soils as compared to other cities (Bhinde and Sundaresan, 1983; EPTRI, 1995). Present findings for plastics, fibbers (rags), glasses, and metals are almost the same as reported by EPTRI (1995) in mega cities. Bhinde and Subdersan (1983) has reported that the urban population generate 374 g/capita/day of solid wastes whereas later on EPTRI (1995) has estimated about 456 g/capita/day of solid waste. According to their findings, it can be estimated that in Jodhpur the total amount of MSW generated per day will be between 374 to 456 tons per day. Each of urban residents generates 350-1,000 g solid wastes every day (Upadhyay et al., 2005). The high amount of non-degradable (9.3%) and slow degradable fractions is a matter of public health concern. About 0.3% of the population was facing pollution problem due to solid wastes in their surroundings in Jodhpur City. Most houses (97%) did not have any garbage disposal facility, and garbage from these houses was dumped on roadsides or open plots. It was found that toilets were not available in 5.9% houses and these residents practiced open field defecation, whereas 0.1% individuals depended on common toilets meant for a group of families, 1.3% on dry pits and 3.3% on public toilets. In all 10.6% of houses in the city did not have easy access to sanitary facilities. All these might be the main cause of the significant prevalence (4.1%, $p < 0.001$) of skin disease. The poor sanitary facility, personal hygiene and lack of safe drinking water may cause health problems in the near future at a much larger scale due to the presence of contaminants, toxic metals and other pathogens.

CONCLUSIONS

The human health is adversely affected by the pollution of water and bad sanitation, which is more marked in developing countries like India. Presence of faecal coliform in 56% and faecal streptococci in 42% water samples, indicating the microbial contamination (human pollution). The study indicates that low levels of diarrhoeal diseases (diarrhoea 0.3%, dysentery 0.3%, and gastritis 0.7%), jaundice (0.6%), hepatitis (0.3%), and typhoid (0.4%) the improving health condition in all age groups. Except for a few sites all water samples from surface water, waterworks outlets and household drinking water as stored in tanks or earthenware vessels were found potable as their physical and chemical quality are concerned. Nitrates were three-six times higher in all groundwater samples (124.6 mg/l and 296.1 mg/l respectively) than the drinking water standards given by WHO (2008). They can be the cause of elevated gastrointestinal cancer and diabetes mellitus. Electric conductivity, nitrate, pH, chloride, calcium, sulphate, magnesium, cadmium, iron and lead were measured, all of these not exceed the drinking water standards but reveal pollution at endpoints that may be due to leakage of pipelines or storage tanks. Thus, increasing demand for safe drinking water may cause health problems in the near future at a much larger scale.

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