Original Research Article

INVESTIGATION INTO THE PREVALENCE OF ENTEROCOCCI AND COLIFORM BACTERIA IN DRINKING WATER RESOURCES AND ASSOCIATED GASTROENTERIC ISSUES IN ISLAMABAD REGION PAKISTAN

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ABSTRACT

A systematic study was conducted to investigate the causes of gastroenteritis in Pakistan Institute of Medical Sciences, Islamabad during June, 2010. Of 220 individuals, 180 cases of gastroenteritis (81.8%) were recorded, compared to an average 18 monthly cases. Case study revealed that, illness was associated with drinking tap and poor filtered water. Enterococci were recovered from both gastroenteritis patients and water samples. Bacteriological analysis of 50 water samples showed that more than 80% of samples deviate from the WHO standards. This is an issue of public health significance and appropriate steps are required on behalf of authorities to address it.

Key words: Gastroenteritis, drinkable water sources, coliforms, and enterococci

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INTRODUCTION

Coliform bacteria, including Escherichia spp., Klebsiellaspp., Serratia spp., Citrobacter spp. and Enterobacter spp.,are considered to be an indicator of fecal contamination in feed and water, found in faces of the warm-blooded animals. *E.coli*is enteropathogenic bacteria associated with gastroenteritis particularly in developing countries. Exposure to fecal contaminated water does not always translate into infection. However, the higher the fecal bacterial levels in water, the higher the chances of pathogens to be present in significant numbers too. Dehydrating diarrhea is of critical importance related with poor microbial water quality, as it could lead to death within 48 hours after the initial symptoms. The diseases associated with fecal contaminated water are gastroenteritis, typhoid and paratyphoid fevers, salmonellosis, cholera, meningitis, hepatitis, encephalitis, amoebic meningoencephalitis, cryptosporidiosis, giardiasis, dysentery, and amoebic dysentery (Jorge *et al*., 2010). Similarly, inadequate treatment of gastroenteritis kills 5 to 8 thousand people per year (Kasper *et al*., 2005) and is a leading cause of death among infants and children under 5 worldwide (King *et al*., 2003). In the USA, over 200, 000 children of this age have been reported to suffer from acute gastroenteritis (Malek MA *et al*., 2006).These extreme

cases are more predominant in developing countries where overcrowding and poor sanitary conditions are the norm (WHO, 2004).

Over large parts of the world, humans have inadequate access to potable water, and use sources contaminated with disease vectors, pathogens or unacceptable levels of dissolved chemicals. The distribution of drinking water is done through municipal water systems, and it has been observed that cross connection between drinking and sewage water pipes has led to contamination of the ground water system. Many of the 3.5 billion people (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2010) having access to piped water receive a poor or very poor quality of service, especially in developing countries where about 80% of the world population lives (WHO/UNICEF, 2010). The WHO/UNICEFF estimates that 500 million diarrhea cases reportedly take place each year in children less than five years in Asia, Africa and Latin America (WHO/UNICEF, 2010). Several community wide outbreaks resulting from contamination of public water systems with coliform and enterococci have been reported (Engberg*et al*., 1998). In subcontinent, especially in Pakistan it has been estimated that each year, more than three million Pakistanis become infected with waterborne diseases as the quality of water supplies in many cities of Pakistan is deteriorating fast (Karachi, supply and sanitation services, 2004).

The Rawalpindi/Islamabad Metropolitan area is the third largest in Pakistan with a population of over 4.5 million inhabitants (Frantzeskakis 1995) where 81,996 cases of water related diseases included gastroenteritis were registered during 1994 (Tahir,1994; Din, 1997).

Pakistan Institute of Medical Sciences, Islamabad recorded 220 cases of gastroenteritis from June 3rd, 2010 to June 25th, 2010 as compared to 60% normal cases that are unusual increase during this period. Therefore, we conducted epidemiological, environmental, and microbiological investigations to determine the scope, the likely cause, and the contributing factors of gastroenteritis associated with the poor quality of drinking water resources in Rawalpindi and Islamabad. The objective of this study is to determine the relationship between the water resource patterns and the prevalence of coliforms and enterococci.

MATERIALS AND METHODS

Case population and Epidemiological investigation

The staff of Pakistan Institute of Medical Sciences, Islamabad recorded the data of 220 individuals who visited the hospital because of gastrointestinal symptoms including diarrhea, nausea, vomiting, and abdominal cramps who had illness onset from June 3rd, 2010 to June 25th, 2010.The line list included demographic data, and information about illness onset and symptoms. Of 220 case patients that contacted the PIMS, 180 cases were found positive during investigation (see Table 1). We conducted a case-control study to determine the risk factors to gastroenteritis. A case was defined as an illness with acute gastroenteritis defined as diarrhea with at least three loose stools per 24 hours and/or vomiting and/or abdominal pain in a resident of Rawalpindi/Islamabad since June 2010. Participants were interviewed about symptoms, treatments, consumption of water from various sources (tap water, well water, bottled water), and consumption of poultry, eggs, and unpasteurized milk products. Hospital administration and Microbiology department of said institute approved the gastroenteritis investigation which was conducted by the Laboratory staff and supervised by the head of microbiology department.

Verbal consent was obtained from all study subjects. All patients from whom fecal coliform/enterococciwere isolated from their stool cultures were also included in this control study. All controls were matched to cases according to sex, year of birth, and residency in the metropolitan area. A case-control was conducted, wherein 145 controls took part. A questionnaire study was performed 3 days soon after the medical report. All subjects completed the same questionnaire during a personal interview. Specifically, there was an effort to interview as many people as possible and to record the same number of cases and controls. Unfortunately, this was not feasible because of the special characteristics of the incident. From personal interviews and the questionnaires collected, those who had not developed any relevant symptom became 'controls', while all others became 'cases'.

Data recorded included dates of onset, frequency and types of symptoms, duration of illness and consumption of food items.

Microbiological samples from patients

The paramedical staff of the hospital obtained stool samples from 105 (58%) of 180 patients who had gastrointestinal symptoms. The samples were analyzed for the presence of fecal Coliform, Enterococci, Salmonella and Shigellaspecies by routine bacteriological methods by using the selective media and identified these species by Gram staining and biochemical tests.

Analysis of water samples

To study the risk factors and pattern of gastroenteritis, it was decided to investigate the municipal water supply system. For this investigation, water samples were analyzed for certain physico-chemical and microbiological parameters by using standard methods. To investigate the source of gastroenteritis and study the pattern of infection in the metropolitan area, it was decided to collect water samples from various sites of both cities. For this purpose, a total of 50 samples, 17 sites of residential area were selected where filtration units have been installed by the municipal authorities, 16 household tap water samples were analyzed along with mineral water (250ml) of various brands were also included in this study (Table 5).

Site selection and samples collection

Of 50 water samples, 17 samples were collected from municipality installed filtration units from various sites of Rawalpindi/Islamabad, 16 were taken from the wells and hand pumps (tap water) while remaining 17 were of bottled samples of various brands. All these samples were analyzed to investigate the offending microbes for gastroenteritis. Sites were selected randomly from areas of different use patterns. Water was collected in 1) sterile test tubes 2) autoclaved polystyrene 200ml bottles 3) disposable 50ml falcon tubes in day time. All samples were collected in duplicate. Water temperature was measured at each site using a stream thermometer. All samples were packed, shipped and stored in a safe and sanitary manner, and accurately labeled according to Good Laboratory and Microbiology Practices. Sample label bear all the necessary information including the date and time of the sampling, quantity and source of the sample, area and signature of the collector. Samples were sealed, transported and kept in refrigeration. Rectal samples were collected from the individuals who showed consent to participate.

Physico-Chemical Analysis

The physico-chemical tests included the determination of temperature, turbidity, odor, color, pH, acidity, total hardness and chloride content using the methods of FAO (American Public Health Association, 1992; Food and Agriculture Organization, 1997).

Bacteriological Analysis

Bacteriological characteristics were determined as described by Bezuidenhout (2002) and Jolt (1994). The media used for the bacteriological analysis of water include nutrient agar (NA), lactose broth (LB), and Eosin Methylene blue agar (EMB). All the media used were weighed out and prepared according to the manufacture's specification, with respect to the given instructions and directions. A serial dilution method was used for total viable count and the presumptive test for coliforms. The Most Probable Number technique was used for coliform enumeration. All plates were incubated at 37^{o}C for 24-48hrs. Presumptive colonies were confirmed by gram staining and biochemical reactions as described by Jolt (1994) and each plate was given a positive or negative score. The sterility of each batch of test medium was confirmed by incubating one or two un-inoculated tubes or plates along with the inoculated tests. The un-inoculated tubes or plates were always examined to show no evidence of bacterial growth.

RESULTS

Case population and Epidemiological investigation

In our study results, out of 220 individuals, 180 case patients of gastroenteritis (81.8%) were diagnosed during the month of June 2010 who visited the Pakistan Institute of Medical Sciences Islamabad compared with the baseline of an average 18 monthly cases of gastroenteritis. Attack ratio (AR) among male and female cases has been calculated (See Table 2). Most cases of infection were found in 40-60 years of age groups followed by the cases below 80, and 52% were women (Table 3). The symptoms were typical for gastroenteritis, predominantly diarrhea (38.8%) followed by the abdominal pain, nausea (16%) and fever (Figure 1). The case-control study questionnaire was sent to 220 cases and 250 controls. One hundred and eighty cases (response rate, 81.8%) and 145 controls (response rate, 58%) completed the questionnaire. Treatment was prescribed to 100 (55.5%) cases, and 80 (44.4%) received antibiotics. Of 180 case patients, 125 (69%) reported having drunk un-boiled tap water at home or outside the home during the two weeks before onset of illness compared with control subjects followed by the case patients found after using the municipality filtered water (30.5%). Drinking bottled brands and boiled water was all associated with decreased likelihood of illness (see table 4).

Microbiological samples from patients

Coliform and Enterococciwere cultured from 45 (42.8%) of 105 stool samples submitted for examination from patients with gastroenteritis. No other pathogens were isolated. These cultures were identified by standard morphological Gram staining and biochemical methods.

Analysis of water samples

During survey, it was observed that the water filtration units installed in Rawalpindi/Islamabad area are equipped with UV disinfection system, but it was found that at many filtration plants, this system was not working properly and bacterial contaminations were passing through the filtered water. Similarly, a compost heap for household wastes was also located near filtration

units of both cities. A questioner filled by the citizens indicated that about 55% of the residents received tap water, 41% have access of filtered water while just 4% belongs to elite class used mineral water. The Rawal Lake and Simli dam are used as sources to supply water to cities, which were not fenced, allowing people and animal's access to the area.

Physico-Chemical Analysis

As Table 6 indicated that physico-chemically mineral water samples were within set limits defined by the World Health Organization (WHO) and US Environmental Protection Agency (EPA). The 100% pH deviation and 35% slight discoloration observed in water samples taken from filtration units diverging the WHO standards while rest of the parameters were under control limits. Similarly, tap water samples showed deviation against WHO standards in following parameters pH (100%); discoloration (56%); chloride ions (12.5%) and turbidity measured by nephelometer (12.5%).

Table 1: Distribution of Laboratory-confirmed cases of Gastroenteritis by sex and clinical manifestation

Symptoms	Female		Male		Total cases	p-value
	Cases	%	Cases	%		
Bloody Diarrhea	15	60	10	40	25	$2.866x10^{-7}$
Diarrhea	37	53	33	47	70	$2.965x10^{-17}$
Nausea	18	60	12	40	30	$2.160x10^{-8}$
Abdominal pain	10	33	20	67	30	$2.160x10^{-8}$
Fever/Vomiting	13	52	12	48	25	$2.866x10^{-7}$

Table 2: Attack Ratio (AR) among exposed infected male and female cases

Symptoms	Infected Female		Infected Male		Total infected cases	Attack Ratio (AR)*
	Cases	Attack Ratio (AR)	Cases	Attack Ratio (AR)		
Bloody Diarrhea	15	0.068	10	0.045	25	0.114
Diarrhea	37	0.168	33	0.15	70	0.318
Nausea	18	0.081	12	0.055	30	0.136
Abdominal pain	10	0.045	20	0.090	30	0.136
Fever/Vomiting	13	0.059	12	0.055	25	0.114
Gender specific cases	93	0.423	87	0.395	180	0.818

*Total exposed persons: 220

Table 3: Age wise sub-classification of Gender cases

Gender	Age Sub-groups (Years)					Total Gender cases
	1-20	20-40	40-60	60-80	80-100	
Female cases	10	22	28	20	13	93
Male cases	10	15	25	22	15	87
Total cases	20	37	53	42	28	180

Table 4: Frequency of exposure among infected and control cases

Risk factors	Infected cases			Control cases			Odds Ratio
	Exposed	Not exposed	% exposed	Exposed	Not exposed	% exposed	
Tap water	102	20	57%	35	25	24%	3.64
Municipal filtered water	78	20	43%	65	38	36%	2.18
Bottled water	0	0	0	45	42	40%	0
Total cases (n)	180	40	100%	145	105	100%	

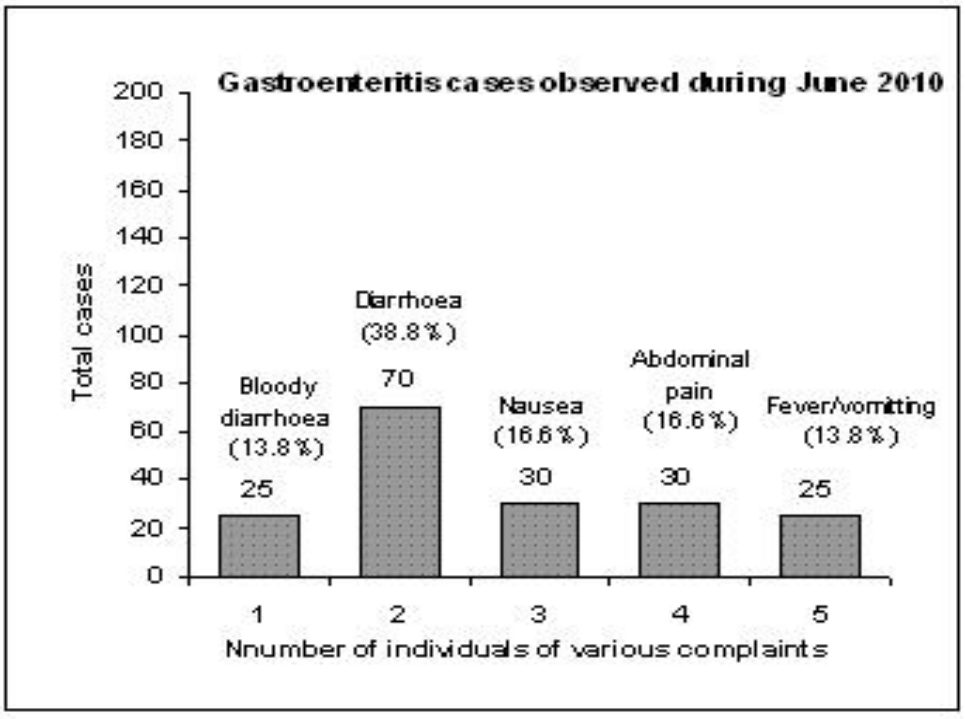

Figure 1: Frequency of symptoms among case patients of gastroenteritis recorded during the month of June 2010.

Table 5: Collection of random water samples from various sites of Rawalpindi/Islamabad metropolitan area recorded during the month of June 2010

	Location/city			
Sources of samples	**No. of samples/Codes**	**Islamabad**	**No. of samples/Codes**	**Rawalpindi**
Water filtration system installed by Capital Development Authority Islamabad and City Government Rawalpindi, Punjab Quantity of water collected = 200ml	S-1	G-6/1-4 sector	S-12	Askari 7
	S-2	G-6/1-2 sector	S-13	Baber colony
	S-3	G-9/4 sector	S-14	Dhamial camp
	S-4	G-8/1 sector	S-15	Dhokli Akbar
	S-5	G-11/3 sector	S-16	Aviation base
	S-6	RIU, I-14 sector	S-17	MH Peshawar road
	S-7	F-10/2 sector		
	S-8	F-10/1 sector		
	S-9	G-10/2 sector		
	S-10	G-11/1 sector		
	S-11	G-10/1 sector		
Tap water (Hand pump, well, stream and Electric pump) Quantity of water collected = 200ml	S-18	RIU, Haji camp I-14	S-25	Askari 11
	S-19	ICB G-6/3 sector	S-26	Askari 7
	S-20	F-10/1 sector	S-27	Westridge III
	S-21	G-8/1 sector	S-28	Sadiqabad
	S-22	G-11/3 sector	S-29	Dhamial camp
	S-23	G-10/2 sector	S-30	Dhokli Akbar
	S-24	G-10/1 sector	S-31	Satellite town, D-block
			S-32	Baber colony
			S-33	T.W. Hostel Pakistan town
Mineral Water 250ml bottled Brand of various companies	S-34	G-6/1-3 café Irum market	S-47	Dhamial camp
	S-35	G-6/1-3 cooperative market	S-48	Dhamial camp
	S-36	D.Watson Blue area	S-49	Saddar cant
	S-37	G-7/4 IIMC Café	S-50	Saddar cant
	S-38	G-7/4 IIMC Café		
	S-39	G-7/4 IIMC Café (1)		
	S-40	G-7/4 IIMC Café (2)		
	S-41	G-7 khada market (1)		
	S-42	G-7 khada market (2)		
	S-43	G-6/2 café Irum market		
	S-44	G-6/2 café Irum market (		
	S-45	G-6/2 café Irum market (2)		
	S-46	D.Watson Blue area		

Table 6: Physicochemical Analysis of water samples of positive fifty case patients of gastroenteritis recorded during the month of June 2010.

Sources of Samples	No. of samples / Codes	Test Parameters						
		pH	Color (HU)	Odor	Turbidity	Acidity	Hardness	Chloride
Water samples collected from water filtration units	S-1	7.77	7	U	3.5	0.2	85	150
	S-2	7.84	5	U	3.5	0.2	85	130
	S-3	7.88	6	U	3.5	0.1	90	150
	S-4	7.85	5	U	3.5	0.1	85	150
	S-5	7.56	6	U	3.4	0.1	70	110
	S-6	7.70	7	U	3.5	0.2	75	115
	S-7	7.95	5	U	3.7	0.1	90	155
	S-8	7.82	7	U	3.6	0.2	85	145
	S-9	7.56	5	U	3.4	0.1	50	105
	S-10	7.90	7	U	4.0	0.2	90	155
	S-11	7.56	5	U	3.4	0.1	70	110
	S-12	7.37	5	U	3.3	0.1	40	70
	S-13	7.30	5	U	3.3	0.2	45	70
	S-14	7.66	5	U	3.4	0.1	65	75
	S-15	7.85	7	U	4.2	0.1	90	80
	S-16	7.78	7	U	4.0	0.1	90	100
	S-17	7.32	5	U	3.2	0.1	45	60
Tap water (Hand pump, well, stream and Electric pump)	S-18	7.75	6	U	3.9	0.2	80	155
	S-19	8.07	9	U	7.1	0.1	140	220
	S-20	7.82	7	U	4.5	0.2	110	170
	S-21	7.80	7	U	4.5	0.1	120	180
	S-22	8.05	8	U	7.0	0.2	150	230
	S-23	7.60	7	U	4.0	0.1	115	190
	S-24	7.67	7	U	4.0	0.1	90	180
	S-25	7.45	6	U	4.0	0.1	90	110
	S-26	7.76	7	U	4.1	0.2	100	150
	S-27	7.54	6	U	4.2	0.2	90	100
	S-28	7.64	6	U	4.5	0.1	85	115
	S-29	7.59	6	U	4.0	0.1	100	100
	S-30	7.53	6	U	4.0	0.2	95	100
	S-31	7.58	6	U	4.5	0.2	105	100
	S-32	7.78	7	U	5.0	0.2	120	120
	S-33	7.88	7	U	5.0	0.1	110	170
Mineral Water 250ml bottled Brand	S-34	7.08	4	U	2.5	0.05	40	57
	S-35	7.08	4	U	2.8	0.05	45	60
	S-36	7.15	4	U	2.9	0.1	40	55
	S-37	7.30	5	U	3.2	0.1	40	50
	S-38	7.25	5	U	2.8	0.1	40	60
	S-39	7.26	5	U	2.8	0.1	35	45

of various companies	S-40	7.45	6	U	3.5	0.1	35	45
	S-41	7.50	6	U	3.5	0.1	65	60
	S-42	7.50	6	U	3.5	0.1	60	60
	S-43	7.25	4	U	2.2	0.1	38	55
	S-44	7.20	4	U	2.0	0.05	40	45
	S-45	7.30	5	U	2.8	0.1	40	45
	S-46	7.29	4	U	2.1	0.05	40	45
	S-47	7.21	4	U	2.0	0.1	40	55
	S-48	7.04	4	U	1.9	0.1	40	45
	S-49	7.35	4	U	2.5	0.05	40	40
	S-50	7.27	4	U	2.8	0.1	30	50
WHO standard	**-**	**6.5**	**6**	**U**	**6.0**	**0.3**	**500**	**200**
EPA standard	**-**	**6.5-8.5**	**15**	**U**	**0-5**	**0.3**	**500**	**250**

U=Unobjectionable; HU=Hazen units; NTU=Nephelometric Turbidity Units, Total Hardness= (Mg/L)

Table 7: Bacteriological (Microbial Examination) Analysis of water samples

Sources of Samples	**No. of samples / Codes**	**Bacteriological Count (Lab tests)**		
		Total Heterotrophic Count	**Total *Coliform***	***Enterococci* Count**
Water samples collected from water filtration units	S-1	3.0×10^1	>240	>30
	S-2	1.0×10^2	<2	Not dectected
	S-3	3.0×10^2	2	25
	S-4	5.0×10^1	2	22
	S-5	2.0×10^1	<2	15
	S-6	5.0×10^1	26	35
	S-7	1.0×10^2	8	30
	S-8	2.0×10^2	8	15
	S-9	6.0×10^1	17	35
	S-10	3.0×10^2	<2	Not dectected
	S-11	1.0×10^2	<2	10
	S-12	2.0×10^2	33	>50
	S-13	4.0×10^2	5	Not dectected
	S-14	7.0×10^2	94	>60
	S-15	2.0×10^2	<2	Not dectected
	S-16	2.0×10^2	8	20
	S-17	4.0×10^2	11	08
	S-18	1.0×10^3	220	>80
	S-19	2.0×10^2	2	25
	S-20	8.0×10^2	2	20
	S-21	2.0×10^3	350	>120

Tap water (Hand pump, well, stream and Electric pump)	S-22	4.0×10^2	<2	15
	S-23	6.0 x 104	<2	Not dectected
	S-24	4.0×10^3	17	45
	S-25	2.0×10^4	17	32
	S-26	3.0×10^2	240	>70
	S-27	6.0×10^2	2	35
	S-28	5.0×10^3	1600	>450
	S-29	4.0×10^4	>2400	Uncountable
	S-30	3.0×10^3	17	10
	S-31	2.0×10^4	<2	Not dectected
	S-32	4.0×10^3	2	10
	S-33	4.0×10^3	<2	5
Mineral Water 250ml bottled Brand of various companies	S-34	1.0×10^2	<2	Not dectected
	S-35	2.0×10^1	<2	Not dectected
	S-36	1.0×10^1	<2	Not dectected
	S-37	4.0×10^1	00	Not dectected
	S-38	4.0×10^1	00	Not dectected
	S-39	8.0×10^1	<2	Not dectected
	S-40	2.0×10^2	<2	Not dectected
	S-41	1.0×10^2	00	Not dectected
	S-42	1.0×10^1	<2	Not dectected
	S-43	1.0×10^1	00	Not dectected
	S-44	2.0×10^2	<2	Not dectected
	S-45	1.0×10^2	<2	Not dectected
	S-46	3.0×10^2	00	Not dectected
	S-47	2.0×10^1	<2	Not dectected
	S-48	4.0×10^1	2	5
	S-49	5.0×10^1	<2	10
	S-50	9.0×10^1	2	4
WHO standard	**-**	**1.0×10^2**	**Zero per 100mL**	**0 CFU**
EPA standard	**-**	**1.0×10^2**	**Zero**	**0 CFU**

Bacteriological Analysis

Water samples were also microbiologically investigated showing desperate results regarding filtered and taps water samples. All filtered and tap water samples contained *coliform* which were as high as 240 most probable number (MPN)/ml in former case and above 2400 MPN/ml in the later, which must be zero as defined by the WHO and EPA standards. Similarly, enterococci (CFU) were observed in 76% and 81% filtered and tap water samples respectively deviating the standards. It was found that mineral water brand samples S-48 to 50 (brand AbehyyatR) also showed coliform and enterococcias bacterial contaminants (Table 7).

DISCUSSIONS

On the basis of evidence from epidemiological and microbiological investigations, the prevalence of coliform and enterococci in Rawalpindi/Islamabad was caused by contaminated municipal water supply system. In the case study, illness was significantly associated with drinking tap and poor filtered water. Enterococci and coliform strains were recovered from both gastroenteritis patients and water samples. Isolation of the microbes from both the water and the patients, and finding an association between consumption of municipal water samples and illness in an analytical study, provides strong evidence that the issue was waterborne (see Table 2 and 4).

Although the exact mechanism for contamination remained unknown, investigation of the water supply system suggested several contributing factors including the accumulation of contaminants near Rawal Lake, deposition of household wastes near filtration units, nonfunctional UV rods and unchanged/old filters in filtration plants. Tahir in (1989) reported that the water supply system of Islamabad and Rawalpindi is polluted. It was found that 76% samples in Islamabad and 82% samples in Rawalpindi were contaminated due to bacterial presence. Though community wide waterborne outbreaks caused by coliform species have been reported previously, however the associated study conducted in multicultural federal capital area of Pakistan explored the filtered and ground tap water systems, showing higher water coliform number and enterococciin this study.

Response rates among both cases and controls were high, and therefore non-response bias probably did not affect the results of the case control study. Controls were from the same postal code area as cases, and mostly had the same source of household water, leading to risk of overmatching with possible underestimation of drinking water as risk factor. The case-control study questionnaire was sent to 175 cases and 250 controls. One hundred and fifty cases (response rate, 85.7%) and 190 controls (response rate, 74%) completed the questionnaire. This study highlights the coliform and enterococcias an important waterborne pathogen. Of 220 individuals, 180 cases were found with gastroenteritis, which visited the hospital compared with monthly 60% average cases of gastroenteritis. This problem caused considerable impact, and direct and indirect costs because of consultations, treatments, and loss of productivity. Ako AA *et al*., in (2009) studied the water-borne diseases and their causes in the Douala, Cameroon. Water-borne disease occurrence was observed to follow a seasonal pattern with peaks occurring between the months of January and May followed by drops between June and October and rose again from November. Children below 5 years were found to be more vulnerable to diarrhea, gastroenteritis, amoebic dysentery while persons between 15-44 years were more vulnerable to typhoid and cholera. Physico-chemically, water samples had turbidities varying between 5.5-86 NTU, pH values between 4.2 and 7.1 and zero residual chlorine. Bacteriological analysis showed that the total coliform count was averagely 74/100 ml, the faecal coliform count was 43/100 ml and the faecal streptococci count was 27/100 ml.

Similarly all filtered and tap water samples contained coliform, which were as high as 240 Most Probable Number/ml in former cases and above 2400 Most Probable Number/ml in the later. Enterococci were counted in 76% and 81% filtered and tap water samples respectively. As it has been reported that the major carriers of water borne bacterial gastroenteritis are the members of the Enterobacteriaceae that include the genera Escherichia, Salmonella, Shigella, and Yersinia, therefore sanitary and unhygienic conditions may remain a potent threat. Rotaviruses present the greatest threat of the viruses with Hepatitis A and E viruses. Waterborne protozoan disease, that

can be endemic in many developing countries, is caused predominantly by *Cryptosporidium parvum, Entamoebahistolytica* and *Giardia duodenalis*.

CONCLUSIONS

As it is evident from this work that gastroenteritis is caused by water borne pathogens including prevalence of coliforms and enterococci which may be due to improper disposal of refuse, contamination of water by sewage, surface runoff, therefore programmes must be organized to educate the general populace on the proper disposal of refuse, treatment of sewage and the need to purify our water to make it fit for drinking because the associable organisms are of public health significance being implicated in one form of infection or the other. As it has been investigated from this study, in areas lacking in filtered and fresh water as in rural dwelling, educative programmes must be organized by researchers and government agencies to enlighten the villagers on the proper use of surface water. Similarly, the safety of these systems should clearly be improved including construction of offence around the lake, control of human activities to prevent sewage from entering water body, sterilization of water with ultraviolet light, installation of new filters or routine chlorination of the water to prevent the prevalence of bacterial pathogens and further cases of gastroenteritis in the city.

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