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Assessment of Drinking Water Quality of a Coastal Village of Karachi

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The drinking water quality of a coastal community in Rehri village, Karachi was assessed for human consumption by studying the chemical and microbiological parameters to determine the suitability of domestic drinking water usage. Water samples were collected at household levels from storage tanks and storage containers (earthen jars), main supply line and springs present in the vicinity. Samples collected from different sources indicated that bacterial counts were high for the storage tanks than the earthen jar containers. In storage tanks 71% samples were in high to very high health risk category whereas, in earthen jars 50% samples were in low health risk category. Water samples from two springs showed that samples of Chashma spring had high bacterial count (336 MPN index/100 ml) coupled with high concentration of NO_3 (29.681 mg/l) as compared to Rehri spring (41 MPN index/100 ml, 8.417 mg/l, bacterial count and nitrate concentrations, respectively). All samples collected at household level showed that bacterial contamination exceeded the maximum acceptable concentration. Other parameters (NO_3, NO_2, NH_3 PO_4, free Cl, Ca and Mg hardness) studied including trace elements (Fe, Cu, Cr) in the drinking water were below the WHO drinking water quality guidelines. Fecal coliform, *Escherichia coli* was also detected including important pathogens *Serratia* sp. and *Enterobacter* sp. which were isolated and indicated possible fecal contamination of drinking water at all levels.

Key words**:** Coliforms, Coastal area, Drinking water, *Escherichia coli*, Nutrients, Trace metals.

Introduction

The most and widespread health problems in developing countries are water borne diseases, associated with contamination of water either directly or indirectly by microbial or chemical pollutants. The microbial contamination is by human or animal excreta, particularly feces. An estimated 2.2 million deaths in 1998 have been caused by diarrhoea, almost exclusively in the developing countries where safe drinking water is not readily available (WHO 1999) and an estimated 1.3 billion persons do not have access to safe drinking water (UNEP 1996). In Pakistan the access to safe water is available to only sixty one percent population (85% urban, 47% rural). The proper sanitation facility is only available to thirty percent population of which sixty percent are urban and thirteen and half percent are rural (Aziz 1998). In Karachi, a city of more than 10 million people forty percent of the population is living in slums and has limited water and sanitary infrastructure and poor water quality (Anon 2000).

The presence of any living bacteria in drinking water, even in small numbers, indicates, not necessarily a health hazard, but certainly a failure in the chlorination system or recontamination of the water after disinfections. The presence of 'indicator bacteria' conventionally known as fecal coliform (*Escherichia coli*) indicates fecal contamination but it does not prove that water-borne disease is occurring. *E. coli* are always present in feces; the majorities are not pathogenic, although some strains can cause diarrhoea. In testing untreated water supplies the fecal coliform are most commonly used but other groups of bacteria (such as fecal streptococci) would also indicate contamination. Muneer *et al* (2001) found variety of fecal coliforms contamination by *Streptococcus, Enterococcus, Staphylococcus, Clostridium* and *E. coli* in the drinking water in University of Punjab. Raza *et al* (1998) studied the seasonal variation of drinking water quality of Northern Areas and Chitral. They found low quality of spring water and the storage vessels (containers) were of high health risk category. Kandhar and Ansari (1998) reported that the Hyderabad dwellers were supplied unchlorinated and contaminated drinking water. Zubair and Rippey (2000) in their evaluation of shallow ground water quality in urban areas of Karachi found presence of inorganic nutrients and bacterial contamination.

Rehri village is one of the oldest coastal villages located in the southeast, 9 km from Quaidabad near Malir in Karachi, on the landward coast of the Korangi creek channel of the Indus River Delta system. The predominant occupation of the people living in this area is fishing with mangrove as a source of fuel wood and fodder. The sources of water supply to the community are from main supply line to household; to share com-

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munity taps and tank and water supplied or collected from springs. The assessment of drinking water quality of Rehri, a coastal village was done by investigating the microbiological parameters and other physical and chemical parameters of drinking water at different points, main supply line and at household storage levels and springs.

Materials and Methods

Water distribution system was surveyed to assess the possible sources of contamination in the study area. Drinking water quality samples were collected according to distribution system and population density in different segments (*para* or Mohalla) of Rehri village. There are thirteen different *paras* (mohallas) living in this village (Qureshi and Hasnie 2001). Based on the socio-economic survey (Qureshi and Hasnie 2001) total nine household stations were sampled for assessment of drinking water quality. Additionally, two springs (water collection points for domestic use) were sampled, one from Rehri Goth and other from Chasma Ghot. In each household, samples were obtained from the main supply line (taps), household storage tanks (ST) and drinking water storage containers (EJ earthen jars) except one site where there was only a shared community storage tank (Musarani-II). Drinking water samples were collected in sterile bottles separately for analysis of microbial and chemical parameters. Samples were iced in the field and immediately brought back to the laboratory for further analyses. Water temperature, and pH were noted in field. Total Aerobic Count (TAC) and Total Coliform Count (TCC) were determined by using the most probable number (MPN) technique of serially diluted samples (diluted 1:10, 1:100 and 1:1000 with 0.01 M sterile phosphate-buffered saline) employing US-Standard Methods (APHA 1985). The estimation of bacterial densities was accomplished by comparison with McCardy's (1918). For sub-culture of coliform positive colonies to differentiate the pathogenic microorganisms in water, blue-purple colonies with a greenish metallic sheen were selected as possible *E. coli* and were inoculated in MacConkey broth and incubated at 44°C for 24 h (Cheesbourgh 1984). Those colonies that fermented lactose (as indicated by a change in the color of MacConkey broth) and produced gas and indole at 24 hours were classified as thermo-tolerant coliform *E. coli*. Concentrations were determined by colorimetric analysis following standard methods: for ammonia (Nessler method), nitrate (Cadmium reduction), nitrite (Ferrous Sulphate), phosphate (Ascorbic acid), iron (Phenantroline), chromium (Diphenylcarbohydrazide), copper (Bicinchoninate reagents), and manganese (Periodate oxidation) along with, free chlorine, calcium (Ca) and magnesium (Mg) hardness of drinking water. All parameters were analyzed using Multi-parameter bench spectrophotometer (Hanna C 100 series). All parameters studied are presented as average of three samples.

Results and Discussion

It is alarming that none of the samples collected from water taps, springs, storage tanks and earthen jars (bacterial counts range 40 to 1600 MPN index/100 ml) were free from contamination (Table 1). The main supply line water samples collected from taps at household levels were slightly better, although it also showed significant bacterial count (mean 59 MPN index/100 ml). Spring water samples were found grossly contaminated especially water sample from Chashma village spring (336 MPN index/100 ml) as compared to Rehri village spring water sample (41 MPN index/ml).

Water sample collected from storage tanks and earthen jar containers at household levels in all localities (*Paras* or Mohallas) showed significant bacterial contamination (Fig 1). Bacterial counts for total coliform and fecal coliform were much higher in storage tank samples than in the earthen jars. There was positive and significant correlation in the bacterial

Table 1
Presence of fecal coliform and pathogenic bacteria in drinking and domestic water storage tanks in Rehri village

Sample	Fecal coliform	Medically important pathogens
Dabla 1 S.T	present	*Serratia*
Dabla 1 E.J	present	*E. coli*
Dabla 2 S.T	present	*Enterobacter* sp.
Dabla 2 E.J	present	*E. coli*
Dabla 3 S.T	Absent	
Dabla 3 E.J	Absent	
Khaskheli 1 S.T	present	*E. coli*
Khaskheli 1 E.J	Absent	
Khaskheli 2 S.T	present	*E. coli*
Khaskheli 2 E.J	present	*E. coli*
Khaskheli 3 S.T	Absent	
Khaskheli 3 E.J	present	*E. coli*
Jat S.T*		
Jat E.J*		
Pann E.J*		
Chashma spring*		
Rehri spring*		
Main line	Absent	

S.T: storage tank; E.J: earthen jar container; *Fecal coliform and isolation of pathogenic bacteria was not done.

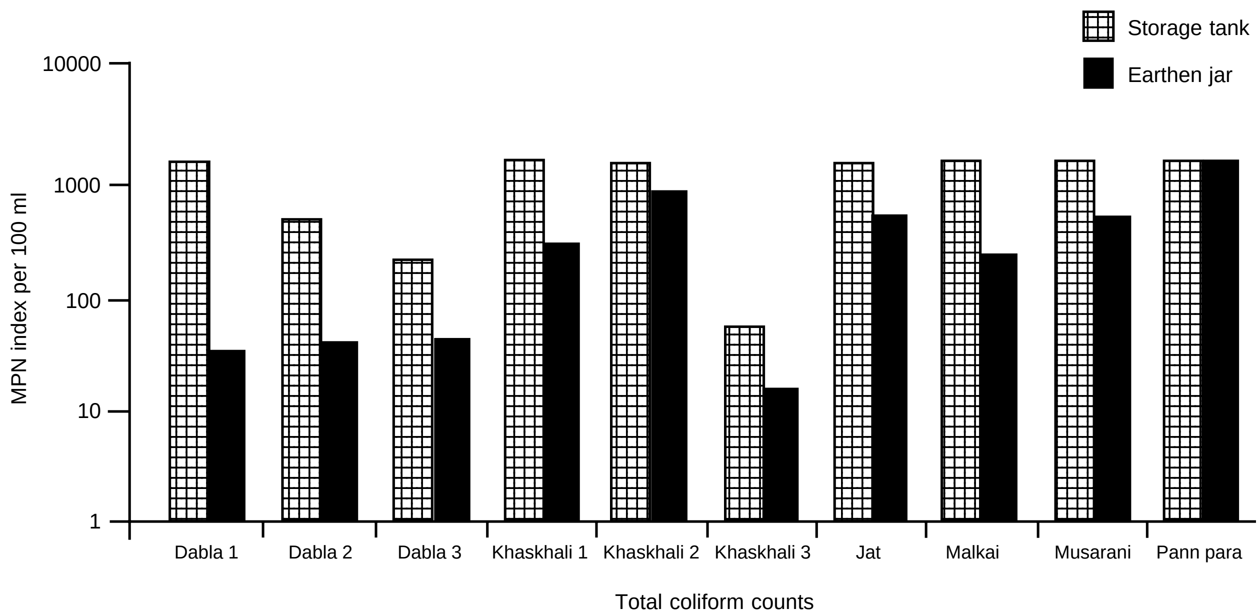

Fig 1. Comparison of drinking water bacterial counts in domestic water of different residential areas (*paras*) in Rehri village.

Table 2
Mean concentrations of nutrients (mg/l) and metals in drinking water samples of Rehri village

	WHO (1984) mg/l	Storage tank	Earthen jar	Chashma spring	Rehri spring
Ammonia		0.306	0.318	0.024	0.340
Nitrate	10.00	2.658	0.310	29.681	8.417
Nitrite		0.022	0.009	0.006	0.006
Phosphate		0.030	0.038	0.453	0.059
Total Chlorine	0.20	0.004	0.003	0.010	0.010
Calcium hardness	500.00	0.107	0.145	1.200	0.530
Magnesium hardness	500.00	7.995	7.947	0.150	0.000
Cromium-hexavalent	0.05	0.007	0.005	0.000	0.000
Copper	1.00	0.368	0.231	0.077	0.542
Iron	0.30	0.066	0.055	0.000	0.050

counts between storage tank and earthen jar (r = 0.96). Fecal coliforms were detected in samples collected from Dabla para and Khaskheli para (Table 1). Medically important pathogens *Serratia sp.* and *Enterobacter* sp. were isolated in samples collected from Dabla para and *E. coli* was also present in the samples obtained from Dabla para and Khaskheli para (Table 1). Low coliform counts were found in the main supply line sample of Dabla para and no fecal coliforms were found.

The mean pH was 7.8 and 7.9. The mean temperature was 25°C and 25.7°C, respectively for ST and EJ. The temperature and pH showed no significant difference between samples collected from storage tanks (ST) and earthen jars (ET).

Table 2 shows the mean concentrations of ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4), iron (Fe), copper (Cu), chromium VI (Cr), chlorine (Cl), calcium (Ca) and magnesium (Mg) hardness in drinking water collected from domestic storage tanks (ST), earthen jar (EJ) and springs. The mean concentrations of Cl, Cr, Cu, Fe, NO_3, NO_2 and Mg hardness were found high in storage tanks as compared to the earthen jar containers (Table 2). The higher concentrations in storage tanks in comparison to earthen jars reflect integration and accumulation over time as water in the earthen jars is utilized and replaced daily. The mean concentrations of NH_3, PO_4 and Ca hardness were slightly high in the earthen jars. Water samples collected from two springs, showed NH_3, NO_2, PO_4, Cl, Cr, Cu and Fe were negligible. Concentration of NO_3 was high (29.681 mg/l) for Chashma Ghot spring indicating contamination and exceeded the minimum allowable limits. Nitrate concentration was high (8.417 mg/l) in water sample

Table 3
Pearson correlation matrix for drinking water samples

	Ammonia	Nitrate	Nitrite	Phosphate	Chlorine	Ca hardness	Mg hardness	Cromium-hexavalent	Copper
Nitrate	-0.320								
Nitrite	-0.165	-0.135							
Phosphate	-0.276	0.940	-0.105						
Chlorine	-0.445	0.530	-0.306	0.513*					
Ca hardness	-0.398	0.787	-0.353	0.752*	0.470				
Mg hardness	0.689*	-0.415	0.318	-0.332	0.456	-0.647*			
Cromium-hexavalent	0.212	-0.384	0.612	-0.313	-0.356	-0.617*	0.849*		
Copper	0.465	-0.230	0.213	-0.373	-0.106	-0.445	0.647*	0.563*	
Iron	0.047	-0.376	0.259	-0.516	-0.153	-0.530	0.565*	0.733*	0.733*

*Significant at P > 0.05

collected from Rehri village spring but was within the permitted limits (Table 2). Concentrations of Ca hardness were high in both Chashma and Rehri springs (1.2 and 0.53 mg/l), whereas concentrations of Mg hardness were high in storage tanks and earthen jars (Table 2).

The (Pearson) correlation matrix showed all metals were positively and significantly correlated (Table 3). The concentrations of PO_4, Cl and Ca hardness were positively correlated with NO_3 concentration (r = 0.94, r = 0.53 and r = 0.79, respectively). There was positive correlation between Cl and PO_4 (r = 0.51, Table 3). Ca hardness was negatively correlated with Cr, Cu and Fe, where as Mg hardness was negatively correlated with Ca hardness (r = -0.65) and positively correlated with NH_3, Cr, Cu and Fe (r = 0.69, r = 0.85, r = 0.65 and r = 0.57, respectively).

Water quality analysis of drinking water samples collected from different sources at house hold level showed that 71 percent samples from storage tanks were in high to very high health risk category (>500 MPN index/100 ml) and only 50 percent samples from earthen jars were in low health risk category (Feachem 1980). Three categories related to water quality with respect to fecal coliform counts 100/ml are less than 100 is satisfactory, between 100 to 1000 strong contamination and health risk, and greater than 1000 seriously pathogenic (Zubair and Rippey 2000).

The high bacterial counts and fecal counts indicate fecal contamination of drinking water possibly leading to gastro enteric diseases. High incidence of diarrhoeal diseases has been reported from Karachi with increased death rates (Zubair and Rippey 2000) and during epidemiological and socio-economic surveys of Rehri village (Qureshi and Hasnie 2001). High incidence of diarrhoea diseases in summer were also reported by Aga Khan Health Service, Gilgit, along with peak fecal contamination suggesting possible linkage between drinking water and diarrhoea diseases (Raza *et al* 1998).

The low bacterial counts in the main water supply system and springs indicate that these water sources were less contaminated in comparison to water samples collected at house hold level in the storage tanks and earthen jars, where handling of water may contribute to the source of contamination. In most of the households, the water storage tanks or earthen jars were near the cattle sheds and open toilets (personal observations), which increases the likelihood of fecal contamination. Moreover, the counts were significantly higher in all cases than the recommended WHO guidelines for drinking water. The WHO microbiological criteria for potability is <1 thermo-tolerant coliform 100/ml water. The same guideline also says that the total coliform bacteria must not be detected in any 100 ml sample, and for treated water in a larger distribution system must not be present in 95 % of samples taken throughout the year (WHO 1999). Kandhar and Ansari (1998) reported that the Hyderabad dwellers were supplied un-chlorinated and contaminated drinking water and the total suspended solids (40 to 2250 mg/l) and fecal coliforms (66 to 170 per100 ml) were high in summer in the drinking water in Hyderabad. They also found iron and hexavalent chromium higher than WHO guideline values (Kandhar and Ansari 1998).

The presence of fecal coliform and *E. coli* indicate water contamination with human or animal wastes. Disease causing microbes (pathogens) in these wastes can cause diarrhoea, cramps, nausea, headaches or other symptoms. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems.

The spring water at Chashma Goth was highly contaminated with fecal coliform. The unprotected springs are likely contaminated due to human and animal activities in the surroundings. Zubair and Rippey (2000) found high level of contamination of ground water with nitrate and fecal coliform in urban areas of Karachi and suggested that ground water quality was likely affected by wastewater infiltration.

In some cases water quality deteriorates in the distribution system itself due to cross contamination. The communities living in the coastal areas are directly discharging their domestic and sewage wastes through surface drains that are mixed with various other urban sources and run perennially. Many water distribution lines are either a few centimeter distances with sewerage lines or are nearly submerged in the ground saturated with the sewerage discharge (Zubair and Rippey 2000). Some of these lines when subjected to leakages result in cross contamination (personal observation at the site).

The water supplied to the Rehri village appeared to be comparatively clean at the heads from main supply line whereas the water supply or distribution gets contaminated in the project area by multiple sources and at multiple points including cross contamination of water distribution system by the wastewater channel in the vicinity. The high contamination in storage containers is simply due to unhygienic ways and water handling practices. Earthen jars, covered with lids and had daily replacement of water had lower contamination levels than the storage tanks that integrated and accumulated contamination level over time. The quality of drinking water was certainly not fit for drinking without boiling or disinfections with chlorination. Luby *et al* (2000 and 2001) used plastic water storage vessel with home chlorination as a potential inexpensive, sustainable means to achieve cleaner water. An inexpensive, home-based water decontamination and storage system was tested in a pilot project in a low-income neighborhood of Karachi. The baseline drinking water samples among intervention households were found contaminated with a mean 9397 cfu per 100 ml of thermo-tolerant coliform compared to a mean 10,990 cfu per 100 ml from controls (Luby *et al* 2001). It is possible that in Rehri village, a specifically designed water storage container and at home chlorination of water acceptable to the communities is introduced that would markedly improve water quality and ultimately the health.

Conclusion

The study patently highlighted the problems of water quality in a coastal village. Even where water supply from source is relatively pure the point where water is used, the likelihood of contamination is high. It is therefore, imperative that a programme of water and sanitation should encompass not only the supply, but also take into account the knowledge, attitude and practices of the community for relevant interventions as required. A regular sanitary survey will help in identifying the potential source of contamination. However, the preferred method to provide quality drinking water in Karachi would be not only to develop but also maintain effective municipal water purification, delivery and sanitary sewerage systems.

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