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Incidence of fecal contamination within a public drinking water supply in Ratta Amral, Rawalpindi

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ABSTRACT

The aim of this study was to monitor microbial water quality and residual chlorine in drinking water supplies at the treatment plant and in the water distribution network of Ratta Amral, Rawalpindi, Pakistan. The drinking water quality in the distribution network was performed by collecting samples from water source, over head reservoir and residential taps and for analyzing chemical and microbial parameters. The samples were analyzed for physico-chemical indicators (total chlorine, free chlorine residual, turbidity, total dissolved solids and conductivity) and bacterial indicators (*total* and *fecal coliforms*). The average value of total chlorine at filtration plant was found to be ranging between 0.0 to1.3 mg/l. Chlorine residue via distribution network available at consumer end was below detectable level at all sampling sites. The study is in progress to monitor the drinking water quality in the twin cities of Rawalpindi and Islamabad.

Keywords: Monitoring; Disinfection; Water quality; Distribution network; Chlorine residual; Filtration plant; Drinking water analysis

1. Introduction

Pakistan being one of the countries of South Asia has a current population of 180 million and is expected to grow to about 221 million by the year 2025. The available water resources have been exhausted and is on the verge of becoming a water deficit country. The per capita water availability has dropped from 5,600 m^3 to 1,000 m^3. Simultaneously the quality of groundwater and surface-water is low and further deteriorating because of unchecked disposal of untreated municipal and industrial wastes [1]. In Pakistan, the vast majority of the country's inhabitants do not have access to drinkable water. Its water quality ranks as 80th out of 122 nations [2]. The global water shortage of affordable and safe drinking water is manifested in Pakistan with an estimated 44 percent of the population without access to safe drinking water. In rural areas, up to 90 percent of the population may lack such access [3]. Only three percent of Pakistan's sweet water resources are used for household purposes and drinking [4]. A study conducted by UN states that many of the 3 billion people throughout the world who have no access to proper sanitation and clean water are from South Asia [5].

Regular monitoring programs to assess the water quality at the treatment plants or in the distribution system is not practiced in Pakistan, except at few major water treatment plants which may be associated with health risks for susceptible individuals due to deterioration of microbiological water quality in distribution systems [6–9]. In urban areas, the municipal authorities believe that their prime responsibility is merely to provide water connections, irrespective of the quality for human consumption, quantity and frequency of the supplied water. The standards against which the comparison should be done are nonexistent in Pakistan [1]. Current monitoring systems are only for random testing and cannot record pollution level. Most of the reported studies in Pakistan only indicate contamination by fecal source through detecting the presence of fecal coliform in drinking water without any information on

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the level of chlorine present in the water distribution network [10].

Disinfection has proved crucial for ensuring public health in potable water treatment [11,12]. The most frequently used dose control method is to inject an overdose of chlorine at the inlet to the contact tank and adjust to the desired residual chlorine level in the effluent stream [13]. Chlorine has played a critical role in protecting drinking water supply from water borne infectious diseases [14]. Chlorination is carried out in accordance with the recommendation given by the WHO whereby underground water from wells and boreholes is dosed with either 0.3 or 0.5 mg/l chlorine depending upon the bacteriological quality of the raw water source. The maintenance of chlorine residue is needed at all points in the distribution system supplied with chlorine as disinfectant to ensure the safety of water [15].

Waterborne pathogens, including a variety of viral, bacterial and protozoan agents, account for much of the estimated 4 billion cases and 2.5 million deaths from endemic diarrhoeal disease each year [16,17]. It is estimated that 200,000 children in Pakistan die every year due to diarrheal diseases alone [3]. The Pakistan Council of Research and Water Resources assesses that 40 percent of all reported illnesses are water-related [1]. It is estimated that water related diseases cause annual national income losses of USD 380–883 million—or approximately 0.6–1.44 percent of GDP [18].

The knowledge on environmental policies regarding water issues such as the National Water Policy (Draft), National Environment Policy etc. and regulatory framework like the Pakistan Environmental Protection Act 1997 do exist in Pakistan, but there is no clear strategy devised so far to implement them. Government of Pakistan in early nineties introduced National Environmental Quality Standards (NEQS) through statutory notifications as per recommendations of various advisory committees. The implementation of these NEQS is, however, proceeding at a very slow pace. The provincial government should establish a monitoring and surveillance framework and system guidelines to ensure that drinking water quality conforms to required standards.

2. Material and methods

To assess the current state of surface water quality in Rawalpindi, water samples were collected from different sites of Ratta Amral. It is the weakest point regarding water disinfection practices and overall drinking water quality in distribution network. Water from Khanpur Dam is being treated at Khanpur Filtration Plant and then supplied to the community of Ratta Amral. Samples were collected from sites including water treatment plant, over head reservoir and consumer end receiving water supply. The collected samples were analyzed for chlorine residual, (MPN: total coliform and fecal coliform), spread plate count as per Standard Methods [19,20].

2.1. Sampling sites

Table 1 shows the sampling points along with downstream distance from Khanpur Filtration Plant where chlorine was added.

2.2. Sampling

Samples were collected thrice from sampling area over a three week period (total 24 samples) to determine any variation in the results of water quality as per Standard Methods. Water samples were collected in sterile glass bottles containing 3 to 4 drops of 3% sodium thiosulphate in order to neutralize any residual chlorine. Water samples were stored in ice boxes and transported to the laboratory for microbiological and physicochemical analysis within 2 hours.

Table 1
Sampling points along with downstream distance from Khanpur Filtration Plant.

Station no.	Station name	Distance (km)	Status of chlorination
1	Khanpur FP	0	Carried out intermittently
2	OHR (Dhok Hassu)	24	No chlorination
3	House no. 1	15	BDL
4	House no. 2	0.5	BDL
5	House no. 3	0.25	BDL
6	House no. 4	0.25	BDL
7	House no. 5	0.25	BDL
8	House no. 6	0.25	BDL

FP Filtration plant, *OHR* Over head reservoir, *BDL* Below detectable level.

2.3. Chemical analysis

On site, samples were analyzed for temperature and pH (Hach pH meter sension 1), turbidity (Hach 2100) and TDS and electrical conductivity by Hach meter (sension 5) while chemical analysis for chlorine residual, free chlorine, monochloramine and dichloramines was carried out using DPD Ferrous Titrimetric method [19]. For the detection of free chlorine, 5 ml of phosphate buffer and DPD were placed in a flask with 100 ml sample; development of red color was titrated against standard ferrous ammonium sulfate (FAS). Observation was recorded as soon as the color discharges giving value of free chlorine. For determination of monochloramine 0.5 g KI was added to the above sample and was titrated against FAS. The volume of FAS used gives monochloramine in mg/l. For dichloramines 1 g KI was added in the above sample and similar procedure was repeated after 2 min standing. Similarly for total chlorine 5 ml of phosphate buffer and DPD was placed in a flask with 100 ml sample along with 1.5 mg KI and observation was noted after two minutes standing in dark.

2.4. Microbiological analysis

The total coliform and fecal coliform counts were determined by the multiple tube dilution procedure given in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Standard plate counts (SPC) were also determined as per Standard Methods [19,20].

3. Results and discussion

3.1. Water quality characteristics

The quality of water samples were tested by analyzing different physical and chemical parameters. Temperature observed at the time of collection of water samples ranged from 17.4 to 21°C at *Station # 1* and *3* respectively. Almost all water samples had temperature values above WHO limits of 12°C. Temperature is a critical parameter as far as growth of microorganisms is concerned. Bacterial growth rates, decay of disinfection residual, corrosion rates and even distribution hydraulics are all affected by water temperature [21]. The pH value measured for water samples varies from 6.95 to 7.53 at *Station # 4* and *2* respectively as shown in Table 2. All the values are well within the WHO permissible limit of 6.5–8.5. Depending on a number of characteristics of the distribution system, pH can be a strong determining factor in the bacterial and chemical quality of water. Although pH usually has no direct impact on water consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8.0 [22]. Table 2 also represents the total dissolved solids (TDS) values of samples ranging from 194.3 to 512 mg/l at *Station # 2* and *3* respectively. According to WHO the highest limits for TDS in drinking water is <500 mg/l hence based on TDS criteria most of the water samples were above WHO limits. With respect to trace metals, water with a very lower TDS concentration may be corrosive and it may leak toxic metals such as copper and lead from the household plumbing and pose a health risk. These results are in agreement as reported in National Water Quality Monitoring Program [1]. Conductivity value varies from 389 to 1023 µS/cm at *Station # 2 and 3* respectively.

3.2. Chlorine residual

For the estimation of total chlorine water samples were collected and was observed only at filtration plant and over head reservoir with values of 1.3 and 0.3 mg/1. No chlorine was observed at any residential tap. Similarly, value of free chlorine at filtration plant was 0.85 mg/l and at OHR it was found to be 0.25 mg/l while at consumer end it was below detectable level as shown in Figure 1. The value of monochloramine ranged from

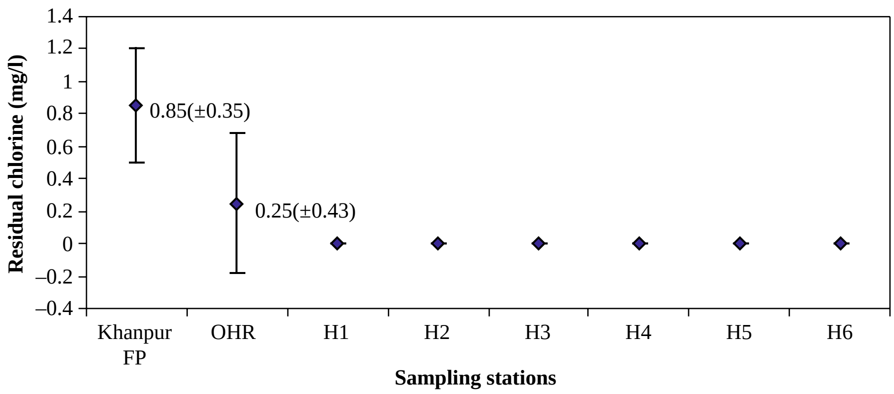

Fig. 1. Average values of free chlorine obtained at different sampling sites of Ratta Amral.

Table 2
Physico-chemical and microbial analysis of water samples collected from residential area of Ratta Amral during November 07[a].

Water parameters	Station numbers							
	1	2	3	4	5	6	7	8
Station Name	Khanpur FP	OHR	H1	H2	H3	H4	H5	H6
Temp in °C	16.4–19.5 17.4°C	17.4–21.7 20.1°C	17.8–26 21°C	19–21.8 20.4°C	19–21.6 20.4°C	18.9–22.3 20.2°C	19–22.6 20.4°C	(18–21.5) 19.4°C
pH	(7.15–7.43) 7.3	(7.45–7.64) 7.53	(7.00–7.14) 7.04	(6.86–7.05) 6.95	(7.26–7.36) 7.32	(7.00–7.29) 7.17	(7.10–7.26) 7.2	(6.92–7.28) 7.08
TDS (mg/l)	(193.7–198.4) 196.8	(191–196) 194.3	(506–517) 512	(497–511) 505	(506–515) 510	(499–513) 508	(504–508) 505	(507–519) 511
Conductivity (µS/cm)	(388–397) 394	(385–392) 389	(1013–1033) 1023	(998–1020) 1010	(1012–1032) 1022	(999–1026) 1016	(1008–1016) 1011	(1013–1038) s1022
Turbidity (NTU)	(0.31–0.66) 0.34	(0.29–0.37) 0.32	(0.30–0.50) 0.42	(0.13–0.20) 0.16	(0.25–0.58) 0.39	(0.24–0.62) 0.4	(0.34–0.52) 0.42	(0.23–0.59) 0.39
Total chlorine (ppm)	(1–2) 1.3	(0–0.9) 0.3	BDL	BDL	BDL	BDL	BDL	BDL
Free chlorine	(0.65–1.27)	(0–0.75) 0.25	BDL	BDL	BDL	BDL	BDL	BDL
Monochloramine	(0.00–0.06) 0.02	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dichloramines	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total coliform (MPN index/100 ml)	<1.1	<1.1	2.2	6.9	>23.0	12	2.2	3.6
Fecal coliform (MPN index/100 ml)	<1.1	<1.1	2.2	6.9	>23.0	12	2.2	3.6
Range 95% probability	0–3.0	0–3.0	0.26–8.1	2.1–16.8	13.5–infinite	4.3–27.1	0.26–8.1	0.69–10.6
CFU/ml	(0–6) 2	(0–11) 4	(18–56) 29	(35–127) 56	(99–162) 127	(100–166) 133	(14–80) 40	(42–99) 62

NTU = nephlometric turbidity units, CFU = colony forming units, FP = filtration plant, OHR = over head reservoir, BDL = below detectable level.
Note: Top reading in each cell refers to range and bottom reading to the mean value.
[a]Based on mean of three replicates (dated 12/11/07, 20/11/07, 27/11/07).

below detectable level to highest value of 0.02 mg/l at consumer end and *Station # 1* respectively and for dichloramines it was below detectable levels as reported in Table 2.

These results are in accordance with the study conducted by Al-Khatlb *et al*. [23] who found only 53.1% of the drinking water samples in the Jenln district of Palestine tested for free chlorine residual, within the limits of the International standards while the rest were below detectable limit.

3.3. Turbidity

The microbiological quality of drinking water can be significantly affected by turbidity. The turbidity value ranged from 0.16 to 0.42 NTU at *House # 1* and *5* respectively and are within the permissible limit of WHO i.e. <1 NTU (Fig. 2). These results are in accordance with the findings of [24,25]. Waters with high turbidity from organic sources may give rise to a substantial chlorine demand [26]. Chlorine (as hypochlorous acid) reacts readily with organic matter containing unsaturated bonds, phenolic groups and nitrogen groups, giving rise to taste- and odor-producing compounds and trihalomethanes (THMs). This could result in reductions in the free chlorine residual in distribution systems as protection against possible recontamination. Drinking water turbidity is commonly used as a proxy measure for the risk of microbial contamination and the effectiveness of the treatment of public drinking water [27].

3.4. Microbiological analysis

Detection of microbial contaminants of fecal origin is a major priority in assessing the quality of drinking water. Water from different sources that is, rivers, lakes, reservoirs and groundwater aquifers are subjected to varying degrees of fecal pollution, and consequently freshwater is a vector of transmission of many pathogenic bacteria, viruses and protozoa [28]. The presence of *E. coli* clearly shows fecal contamination [29] and indicates a possible contamination of enteric pathogens [30,31].

A critical comparison of data obtained revealed that at *Khanpur Filtration Plant* and *OHR* MPN/100 ml for total coliform was <1.1 and probability ranged from 0.0 to 3.0. Highest contamination was observed at *House # 3* with MPN/100 ml >23.0 and probability range from 13.5 to infinite followed by 12 MPN/100 ml at *House # 4* (Table 2). Most of the samples were positive for the presence of *E. coli* (fecal coliform) except the samples collected from *Khanpur Filtration Plant* and *OHR* as evident from Fig. 3.

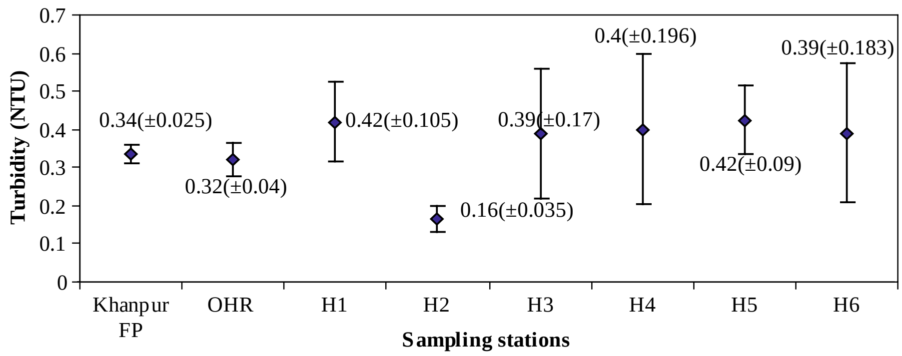

Fig. 2. Average values of turbidity obtained at different sampling sites of Ratta Amral.

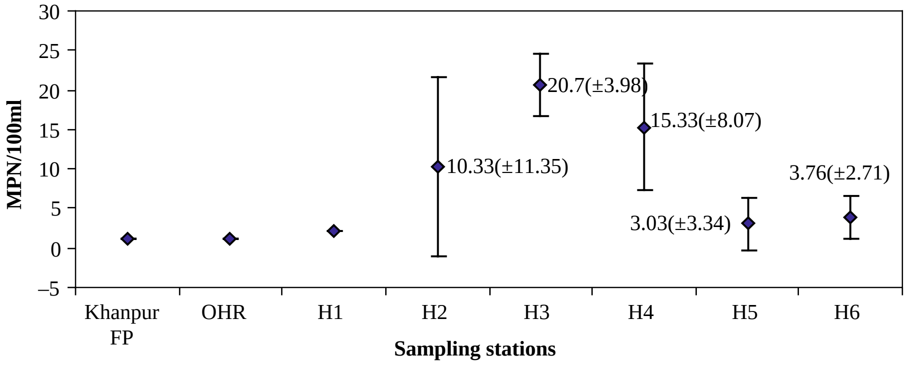

Fig. 3. Average values of *Coli form* count obtained at different sampling sites of Ratta Amral.

A relationship between MPN and residual chlorine shows sixty five percent of the variation in total coliform concentration for the presence of chlorine residual in water distribution network. As the chlorine concentration increases coliform count decreases (Fig. 4). These findings are in accordance with the study conducted by Al- Khatlb *et al*. [23] who found only 69.6% of the drinking water samples tested for fecal coliform were within the WHO limits, while the rest of the samples were highly contaminated. According to WHO bacteriological water quality standards treated water entering the distribution system must be 0/100 ml for *E. coli* and total coliform bacteria , so the results are not in accordance with the standards and water is not fit for drinking purposes.

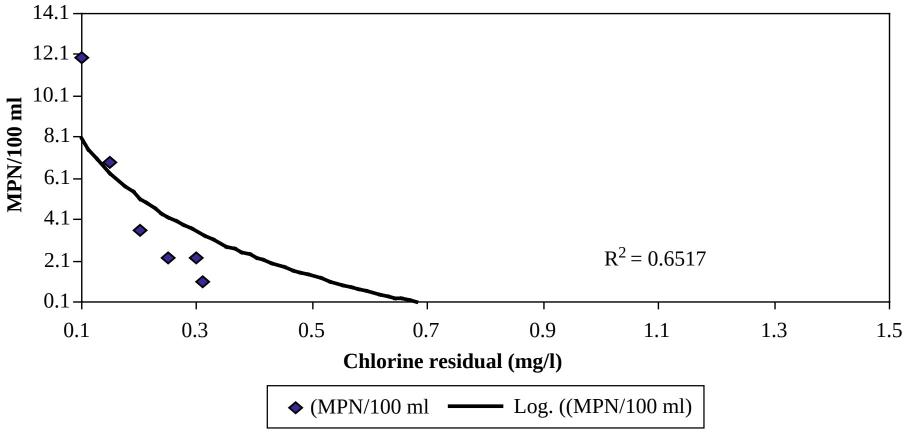

Fig. 4. Relationship between total chlorine and fecal coliform at different sampling points.

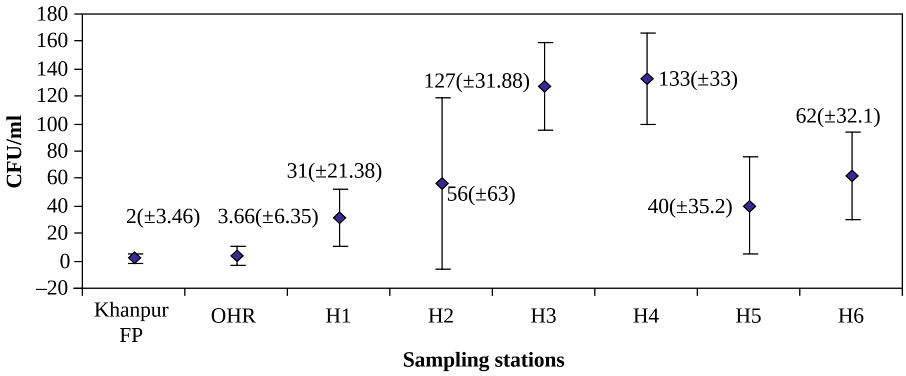

Fig. 5. Average values of SPC counts obtained at different sampling sites of Ratta Amral.

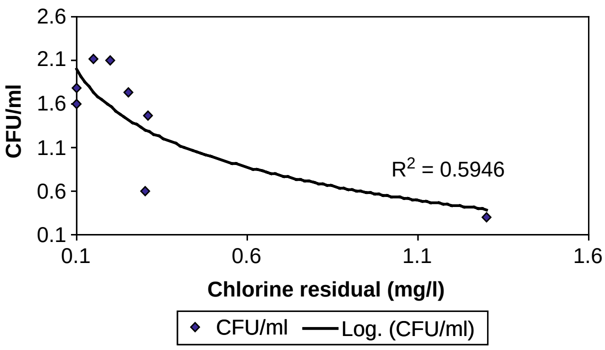

Fig. 6. Relationship between total chlorine and SPC at different sampling points.

The viable count was measured by the standard plate count (SPC) technique using nutrient agar as the growth medium and reported as colony forming unit CFU/ml. The total viable count was 133 CFU/ml at *Station # 6* followed by 127 CFU/ml at *Station # 5* and lowest count were found to be at *Station # 1* (Fig. 5). These results are inline with the study conducted by Le Chevallier *et al*. [32] who enumerated and characterized standard plate count bacteria in chlorinated and raw water supplies and isolated nearly 700 SPC bacteria. Relationship between total chlorine and CFU/ml at different sampling stations is shown in Fig. 6. The water samples collected have revealed higher counts indicating contamination and poor chlorination of drinking water. R2 i.e. coefficient of determination shows 59% variation between microbial contamination and chlorine residual different sampling points, which is a relatively weak relationship between the two variables.

4. Conclusion

Considering the deteriorating water quality status, the study aimed to assess the current water status of Rawalpindi and to relate the chlorine dose with microbial contamination. It is expected that the monitoring results would lead to remedial measures for improving the existing drinking water quality situation. It can be concluded that:

- The samples were collected from eight different sampling points from water distribution network of Ratta Amral, Rawalpindi including Khanpur filtration plant.
- Total residual chlorine varied largely among different sampling points, ranging from lowest value of 0 mg/l at all residential taps to the highest value of 1.3 mg/l at *Station # 1*.
- At *Station # 1 and 2* total coliforms were less than 1.1 MPN/100 ml while at *Station # 5* highest count of greater than 23 MPN/100 ml was observed.
- The samples were also tested for fecal coliforms and were found positive at all stations except at *Station # 1* and *2*. *Station # 5* was found to be the most contaminated due to cross connection of drinking water with sewage.
- Physiochemical water quality parameters such as pH, temperature and electrical conductivity were found within the permissible limits of WHO standards except total dissolved solids which were above the limits.
- During the survey it was noticed that Khanpur filtration plant was not carrying out chlorination regularly and was also not meeting the standards of 2 mg/l of total chlorine residue at distribution source.
- Microbial count was inversely proportional to chlorine residual whereas a direct relationship was observed with turbidity. As the chlorine concentration increased, microbial counts decreased while increase in turbidity resulted in an increase in microbial contamination.
- Based upon the results of this study it is recommended that regular monitoring of residual chlorine concentration and total coliforms in the water distribution system should be carried out to ensure that the chlorine residual of 0.2–0.5 mg/l is available at the consumer end.

Acknowledgements

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