

Drinking Water Quality Assessment in Selected Areas of Rawalpindi by Physico-Chemical and Biological Parameters

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Abstract: In this study drinking water quality of some densely populated areas of Rawalpindi was analysed. The main sources of water in the area are water filtration plants and bore tap waters. As water demand has exceeded the supply, many locals have installed bores in order to meet their water needs. The purpose of this study was to determine the quality of drinking water, and to determine whether it is related to gastrointestinal diseases. For this study, water samples were collected from filtration plants, and tap water. Both physicochemical and microbiological parameters play role in determining water quality. Hence, the pH, EC, Salts, TDS, Turbidity, Total Alkalinity, Total Hardness, Total Chloride, Calcium, Magnesium, Sodium, Carbonates, Arsenic, and microbiological parameters like *salmonella*, and *shigella*, *E. coli* and total *coliform* were analysed by standard procedures. The results showed all the parameters were within the permissible limits, except for EC and TDS, indicating that ions are present in greater amounts in water samples. In case of microbiological parameters, growth of *salmonella* and *shigella*, as well as *E. coli* was found, and permissible limit for total coliforms exceeded in few samples suggesting that water from these sources is contaminated and not fit for use. In comparison, tap water samples were found more contaminated with bacteria as compared to samples from filter plants.

Keywords: Drinking water quality, physico-chemical parameters, gastrointestinal diseases, microbiological analysis, arsenic.

Introduction

Lack of availability of potable water is an issue that is most common in the world, especially in third-world countries. The fact that poor quality drinking water can cause increasing number of gastrointestinal diseases has been well explained by previous studies (Azizullah et al., 2011; Saeed and Hashmi, 2014; Iqbal et al., 2020; Khalil et al., 2020; Jamil et al., 2018). Human settlements and activities affect the quality of water. The water reservoirs and rivers are contaminated by industrial effluents and sewage. Human development and growth exert a great amount of pressure on the water quality, its resources and access to them. Water quality includes the chemical, biological and physical characteristics of water that are altered due to human influence (Jamil et al., 2020).

Despite being blessed with glaciers, Pakistan's water resources have been stressed enormously by rapid population growth and continuous industrial development. The prolonged droughts, population growth, industrialization, pollution have further exacerbated water shortages and contamination leading to shortage of potable water. While, Pakistan has both ground and surface water resources, the availability of water per capita has fallen from 5,600 m³ to 1,000 m³ per year (Shahid et al., 2015). About

20% of population in Pakistan have access to fresh clean water, while the rest 80% rely on polluted water sources. Major sources of contamination are discharge of sewerage waste, toxins and harmful chemicals from industries and pesticides, herbicides, and fertilizers runoff from agricultural fields into freshwater (Daud et al., 2017). Due to unplanned and poor pipeline network sewerage waste seeps into clean water sources, thus causing water-borne diseases. According to a monitoring report published by the Pakistan Council of Research in Water Resources, out of 369 monitored drinking water sources (31%), were supplying safe drinking water and 253 (69%) were determined as unsafe (PCRWR, 2007).

Many water issues can easily be tackled by maintaining filtration plants, ensuring that water quality meets drinking water standards frequently. But rate of prevalence of waterborne diseases is greater in communities, where sanitary conditions are compromised and literacy rate is also low, and that people do not even take proper measures like boiling water before drinking, as shown by a study conducted in a community residing near River Ravi, Lahore (Qureshi et al., 2011). Sanitary conditions of the community and unplanned settlements along with poor drainage systems and sanitation, have caused groundwater contamination with fecal

coliforms. Since the river is major source that recharges the aquifers on which most of the population of Lahore depends, thus increasing number of people are suffering from waterborne diseases. In another study of Pakistan, with Rawalpindi and Islamabad as target locations, analysis of four different sources of drinking water was done including Water and Sanitation Authority (WASA), Capital Development Authority (CDA), boreholes and tanker water. The analysis showed that waterborne diseases prevail wherever fecal contamination exists and increasing order of prevalence of waterborne diseases was WASA, CDA, boreholes water and tanker water (Shoaib et al., 2016).

Aside from microbiological contamination, physical parameters like turbidity also affect water quality. As explained in a study that under certain levels of turbidity, there exists likeliness of association between gastrointestinal diseases and turbidity (Mann et al., 2007). In another investigation, drinking water of Islamabad from various sources like tubewells, filtration plants, and water supplies of different sectors were tested. The water was tested

for bacteriological contamination, and out of fifty-five samples, 14.5% of the samples did not meet the drinking water standards set by WHO (Ahmed et al., 2015). Research conducted in 2005 indicated that after analysing and comparing drinking water quality of Rawalpindi and Islamabad, water quality was found to be slightly better in Rawalpindi. But a lot of the samples were found to have exceeded permissible limits for TDS and microbiological parameters as set by WHO and EPA (Uzaira et al., 2005).

In another study conducted about drinking water quality and its status in Pakistan, it was found that a lot of bacterial growth was determined in water samples collected. If in a sample, *E. coli* is found that indicates there are traces of fecal contamination. In cases of drinking-water contamination, the primary causes are sewage intrusion into drinking-water systems, and chemical pollution resulting from the discharge of toxic effluents, agricultural runoff (fertilizers), and pesticide leaching, all of which migrate into water sources (Daud et al., 2017).

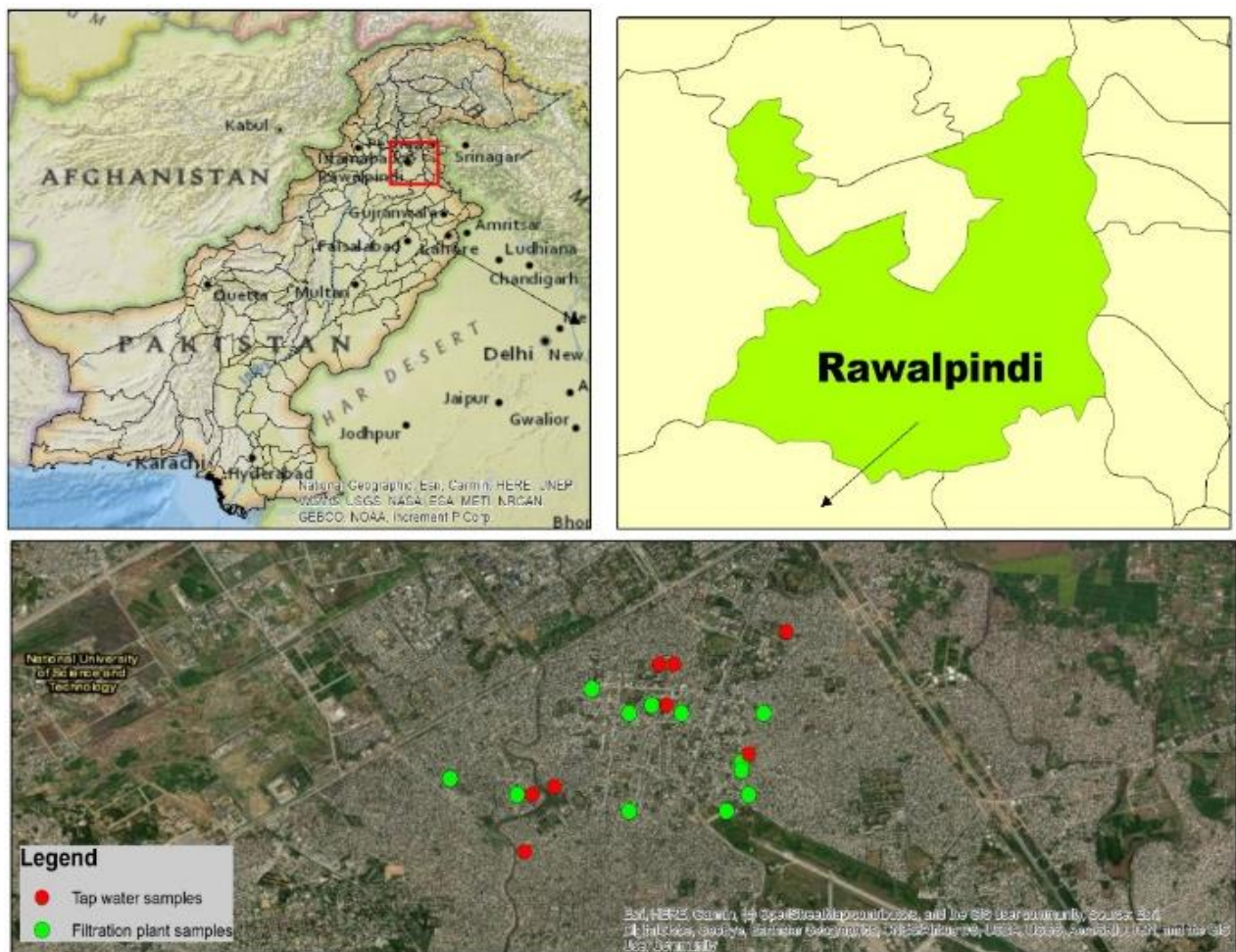


Fig. 1 Satellite image of the study area and sampling points.

Across these studies done at various locations and time, there exists reliable evidence that waterborne diseases and poor drinking water quality are related to each other. Elements that deteriorate the water quality do not necessarily have to be infectious bacteria even when concentration of physicochemical parameters cross standards set by WHO, water is considered contaminated and causes diseases like cholera, dysentery, bowel irritation and diarrhea (Nawab et al., 2016).

In this study, an attempt has been made to determine the water quality of water filtration plants located in the study area to check its prevalence with gastrointestinal diseases, and whether water plays a role in accelerating gastrointestinal diseases. It was reported in June and August of 2019, that in 2019 from May onward, number of gastrointestinal patients and those suffering from vomiting drastically increased (Qasim, 2019). Hence, densely populated areas of Rawalpindi were selected for the study. There are two main drinking water sources in Rawalpindi, surface water supplied by Rawalpindi Development Authority (RDA) and groundwater (Uzaira et al., 2005). So the current study focussed on water quality assessments of both sources of water samples by analyzing physicochemical and microbiological parameters.

Materials and Methods

Water samples from twenty different densely populated areas of Rawalpindi including Commercial Market, Satellite Town, Murre Road, Khayabane Sir Syed and Pirwadai were collected. Eleven of these samples were taken from filtration plants, some of which were installed by RDA under Punjab Government, and some were owned by private companies. While, nine samples were taken from tap waters that people drilled to meet their water requirement. From each site, samples were collected in two bottles, polystyrene bottles for physicochemical analysis and sterilized bottles for biological analysis. Total seventeen water quality parameters were selected to determine water quality status in the area. Out of these thirteen are physicochemical, while four are biological characters, that were analyzed. All the parameters were analyzed in the university laboratory using standard protocols (APHA 2012 ; Rice, 2012). After analyzing water samples, the results were compared with WHO and Pak EPA permissible limits. For accuracy, all the tests were run thrice, and then mean was taken to get the average value.

Physico-Chemical Analysis

Physical parameters like pH, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS),

and salt concentrations in water samples were measured using a digital multimeter (Hanna Instrument Model-HI 8424). While, turbidity of the samples was measured using a turbidity meter.

For analysis of chemical parameters like hardness, alkalinity, sodium, chlorides, calcium and magnesium, carbonates titration standard method was used. Total salts were determined both through titration and by using digital multimeter. Arsenic being one of the most harmful metalloids existing in water bodies, when present in water, long-term exposure can lead to cancer, high blood pressure, nerve vessels issues, heart problems as well as skin diseases. For determining arsenic presence in samples, Arsenic Test Kit was used and the results were compared with permissible limit set by WHO i.e. 0.01 mg/l (WHO, 2018).

Microbiological Analysis

The analysis of biological parameters was done within 24 hours of sample collection. All the equipment including petri plates, stainer and spreader were sterilized by using standard protocol. For biological assessment of drinking water, the methods used for detection of fecal contamination are Total Plate Count method (Spread plate method) and Gram Staining. In spread plate method, a solidified agar plate, was basically used and the water sample containing bacteria was spread onto the plate which caused bacterial colonies to grow on agar (Odeyemi et al., 2010). Agar for detection of different types of bacteria is also different. For determination of salmonella and shigella, Salmonella Shigella (SS) agar was used, and for *E. coli*, Eosine Methylene Blue (EMB) agar has been used.

Whereas, gram staining technique was adopted to differentiate bacteria by physical and chemical properties of the bacterial cell wall. Gram-positive bacteria basically contain a thick cell wall composed of peptidoglycan and therefore, are stained purple when crystal violet stain/dye is added, while, gram-negative bacteria possess a thinner layer and therefore, do not retain the purple stain. However, they are counter-stained pink when safranin is added (Griegersen, 1978).

Results and Discussion

Physical Parameters

The results of the physical parameters of filtered water and tap (bore) water have been presented in Tables 1 and 2, respectively. The values of pH in both filtered water as well as tap water were found within permissible limit i.e., 6.5-8.5. According to

WHO, permissible limit for EC in drinking water is 400 $\mu\text{S}/\text{cm}$. Electrical Conductivity in filtered water ranged from 528 to 775 $\mu\text{S}/\text{cm}$, while the EC in tap water was found to be between 514 to 783 $\mu\text{S}/\text{cm}$. All samples were found to have exceeded the permissible limit for EC, (Table1, 2).

Total dissolved solids primarily represent presence of various kinds of minerals in aqueous solution. Permissible limit of TDS for drinking water according to both NSDWG and WHO is 500 mg/l. TDS in filtered water ranged from 375 to 550 mg/l, while the TDS in tap water ranged between 365-556 mg/l. Samples 10 and 11 from filter plants and samples 2 and 7 from tap water exceeded permissible limit for TDS. While, rest of the 16 samples were under permissible limit.

Dissolved salts cause salinity in water. Salts concentration is directly proportional to TDS in water. Higher is the concentration of salts, greater will be the electrical conductance and vice versa. All the samples collected had salt concentration exceeding the permissible limit set by WHO i.e 200mg/l.

Chemical Parameters

The results of the chemical parameters of filtered water and tap (bore) water have been presented in Tables 3 & 4. Alkalinity of an aqueous solution basically denotes the ability of an aqueous solution in neutralizing acids. The permissible limit for total alkalinity (TA) for drinking water is 200 mg/l. The obtained alkalinity in filtered water ranged from 39.6 to 71.4 mg/l, while the alkalinity of the tap water ranged between 35.4 to 50.2 mg/l. Thus, samples collected from both filtration plants and tap

water have alkalinity under the permissible limit, (Table 3, 4).

Total hardness (TH) is the chemical parameter that describes the concentration of dissolved minerals, mainly calcium and magnesium in water. Since these two minerals are the major cause of hardness in water, the permissible limit of hardness for drinking water according to PSQCA is 500 mg/l. The samples collected from water filtration plants consisted of hardness ranging from 2.26 to 3.7 mg/l. While the tap water showed hardness ranging from 2.6 to 4.3 mg/l. The values of total hardness of samples from both filtration plants and tap water were found within the standard limits.

Calcium concentrations in filtered water ranged between 0.12 to 1.12 mg/l, whereas, the tap water showed calcium concentrations ranging from 0.04 to 0.84 mg/l, showing that calcium concentration in all samples is within the permissible limit, i.e. 100 mg/l. Similarly, in both types of samples, magnesium concentration is within the standard limit.

Chlorides and sodium indicate water salinity. The permissible limits for chlorides and sodium in drinking water are 250 mg/l and 200 mg/l, respectively. In all of the twenty samples collected from filtration plants and tap water, chloride and sodium concentration are found within standard limits set by WHO.

Carbonates and bicarbonates also cause hardness in water. The permissible limit for bicarbonate (HCO_3) in drinking water is 500 mg/l. In all the samples collected from filter plants or tap water, NaHCO_3 , Na_2CO_3 , HCO_3 and CO_3 , concentrations were under permissible limits. Moreover, no visible

Table 1. Results of the physical analysis of filtered water samples.

Samples	pH	EC ($\mu\text{S}/\text{cm}$)	Salts (mg/l)	TDS (mg/l)	Turbidity (NTU)
Standard Values	6.5-8.5	400	200	500	<5 NTU
F1	7.48	531	277	376	0
F2	7.4	579	303	410	0
F3	7.51	567	296	402	0
F4	7.61	547	285	388	0
F5	7.59	616	323	437	0
F6	7.45	553	290	393	0
F7	7.58	561	295	399	0
F8	7.64	528	277	375	0
F9	7.49	613	321	434	0
F10	7.44	775	410	550	0
F11	7.36	719	379	510	0
Mean Values	7.5	599	314.18	423.7	0

Table 2. Results of the physical analysis of tap water samples.

Samples	pH	EC (μ S/cm)	Salts (mg/l)	TDS (mg/l)	Turbidity (NTU)
Standard Values	6.5-8.5	400	200	500	<5 NTU
T1	7.58	625	328	443	0
T2	7.54	760	403	542	0
T3	7.19	514	269	365	0
T4	7.58	547	286	388	0
T5	7.45	573	300	407	0
T6	7.35	602	316	428	0
T7	7.73	783	414	556`	0
T8	7.73	620	326	440	0
T9	7.46	554	305	409	0
Mean Values	7.51	619.77	327.44	442	0

Table 3. Results of the chemical analysis of filtered water samples.

Samples	T. A (mg/l)	T.H (mg/l)	Ca ⁺² (mg/l)	Mg ⁺² (mg/l)	Na ⁺ (mg/l)	Cl ⁻ (mg/l)	Carbonates (mg/l)			
							NaHCO ₃	Na ₂ CO ₃	HCO ₃	CO ₃
Permissible Limit	200	500	100	30	200	250	-	-	500	-
F1	50.2	2.8	1.12	1.68	53.59	82.59	6.97	8.798	5	4.98
F2	40	3.18	0.32	2.86	51	79	7.25	9.145	5.264	6.18
F3	43	3.12	0.22	2.9	46	70.9	8.4	10.6	6.1	5.178
F4	39	2.68	0.36	2.32	46	70.9	7.921	9.99	5.75	6
F5	43.2	2.82	0.58	2.24	55.5	85.08	7.56	9.54	5.49	5.65
F6	40	3.16	0.22	2.94	49.67	76.57	7.98	10.07	5.795	5.4
F7	35.4	2.66	0.12	2.54	45.22	69.69	7.728	9.752	5.612	5.7
F8	43	2.26	0.34	1.92	35.25	54.34	6.972	8.798	5.063	5.52
F9	41.8	3.48	0.5	2.98	62.1	95.71	8.5344	10.7696	6.1976	4.98
F10	36.8	3.6	0.5	3.1	96.6	48.89	8.257	10.4198	5.996	6.096
F11	39	3.7	0.3	3.4	72.68	112.022	7.442	9.3916	5.4046	5.89
Mean Values	40.95	41.03	3.04	0.416	49.727	55.78	76.88	7.72	9.75	5.6

Table 4. Results of the chemical analysis of tap water samples.

Samples	T. A (mg/l)	T.H (mg/l)	Ca ⁺² (mg/l)	Mg ⁺² (mg/l)	Na ⁺ (mg/l)	Cl ⁻ (mg/l)	Carbonates (mg/l)			
							NaHCO ₃	Na ₂ CO ₃	HCO ₃	CO ₃
Permissible Limit	200	500	100	30	200	250	-	-	500	-
T1	71.4	3.56	0.84	2.72	29.9	46.08	7.47	9.434	5.429	5.34
T2	40	3.5	0.56	2.94	65.15	100.42	8.65	10.918	6.28	6.18
T3	39.6	2.94	0.04	2.9	34.5	53.175	6.82	8.6178	4.96	4.878
T4	43.6	2.6	0.6	2	38.18	58.84	8.484	10.706	6.161	6.06
T5	45.8	2.7	0.42	2.28	27.6	42.54	9.68	12.224	7.035	6.9198
T6	42	2.8	0.66	2.14	49.68	76.57	5.65	7.1338	4.105	4.03
T7	45	4.3	0.32	3.98	88.12	135.87	5.376	6.784	3.904	3.84
T8	42	3.1	0.54	2.56	58.88	90.75	6.07	7.6638	4.41	4.338
T9	40	3.84	0.74	3.1	71.3	109.895	6.493	8.19	4.715	4.638
Mean Values	45.5	3.26	0.52	2.38	51.48	79.35	7.18	9.1	5.22	5.14

Table 5. Results of the microbiological analysis of filtered water samples.

Sample No	Total counts on Nutrient Agar (CFU/ml)	Salmonella Shigella Agar (SS) (CFU/ml)	Eosin Methylene Blue (EMB) agar (CFU/ml)
Permissible Limit	<500 CFU/ml	0 CFU/ml	0 CFU/ml
F1	7	0	0
F2	4	0	0
F3	15	0	0
F4	54	0	5
F5	2	0	0
F6	208	57	0
F7	5	1	0
F8	44	0	0
F9	1	0	0
F10	7	0	0
F11	31	0	0

Table 6. Results of the microbiological analysis of tap water samples.

Sample No	Total counts on Nutrient Agar (CFU/ml)	Salmonella Shigella Agar (SS) (CFU/ml)	Eosin Methylene Blue (EMB) agar (CFU/ml)
Permissible Limit	<500 CFU/ml	0 CFU/ml	0 CFU/ml
T1	12	0	0
T2	139	26	36
T3	18	0	9
T4	4	2	0
T5	103	2	0
T6	65	0	0
T7	21	0	4
T8	18	0	0
T9	42	0	0

difference was noted in concentrations of both carbonates and bicarbonates in filtered and tap water samples.

Arsenic

Arsenic was not found in any of the water samples. The permissible limit of arsenic i.e. 0.01mg/l set by WHO was met.

Biological Parameters

Gram staining: On performing gram staining it was found that all the samples contained gram-positive bacterial colonies.

Microbial counts: Bacterial growth of samples collected from filtered samples and tap water samples are shown in Tables 5 & 6, respectively. The CFU count on Nutrient Agar (NA) for all the samples was overall higher than the other media (SS and EMB). In samples taken from filter plants, the highest number of colonies grown was found in

sample F6. The values for total coliform and SS were found to be 208 and 57, respectively. While 5 colonies growth was found on EMB agar belonging to sample F4.

In samples collected from tap water, 139 colonies for total coliform, 26 colonies of SS, 36 on EMB colony growth were found in sample T2. On average, water from tap water was found to be more contaminated as compared to filtered water. In filter plant water samples, only two samples showed growth of *E. coli*, salmonella, and shigella, while in case of tap water samples, three samples showed growth of *E. coli*, salmonella and shigella, and the rest showed high bacterial count. From the microbial analysis, it is visible that some samples are unfit for drinking purpose, as they show high microbial growth due to potential risk of gastrointestinal diseases (Saeed and Hashmi, 2014; Jamil et al., 2018).

There are two main sources of water in Rawalpindi, surface water and groundwater. Water to filter plants

located in the study area is supplied by Rawal and Khanpur dams, and in a study, Rawal Lake was found contaminated with total coliforms as well as fecal coliforms, indicating fecal contamination. Reason for this contamination was dumping of poultry waste as well as improper management of sewage water. This can be a possible source of bacterial contamination when such contaminated water is supplied to filter plants by improper sewerage pipelines. The pipelines are neither maintained nor checked for leakage, while mixing of sewerage waste with clean water pipeline can also be a possible reason for the contamination (Mashiatullah et al., 2010).

Conclusion

In the present study, collected water samples from Rawalpindi areas, filtration as well as (bore) tap water were utilized for obtaining water quality information of the study area. The physiochemical and biological analysis results of the filtered and tap water samples were compared with the drinking water standards.

It is concluded that none of the physical parameters exceeded the permissible limits of given standards except TDS, EC and total salts, which were found in high concentrations. The microbiological analysis revealed that in most of the samples, exceeded the permissible limits for *E. coli*, *salmonella* and *shigella*. While total coliform count was also high in many water samples. Water samples taken from tap waters (bore) had higher microbiological growth as compared to those taken from filter plants, indicating that the tap water when compared to filter water is less suitable for drinking purpose. This study concluded that the concentration of most of the physicochemical parameters were far below the permissible limit, while concentration of microbiological parameters exceeded the permissible limits

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