PHYSICOCHEMICAL AND MICROBIOLOGICAL ASSESSMENT OF THE DRINKING WATER QUALITY IN URBAN AFGHAN REFUGEE SETTLEMENTS IN QUETTA

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ABSTRACT

Contamination of drinking water with microorganisms can cause waterborne illnesses that may lead to severe healthcare crises. Previous studies regarding the water quality of Quetta city reveal contamination levels that are way above the World Health Organization quality standards. Afghan refugees are one of the marginalized communities living in Pakistan. They have limited access to various facilities, including clean drinking water. Therefore, assessment of the water quality at Afghan refugee settlements of Quetta was a crucial study. The present study analyzes water samples from four Afghan refugee settlements in Quetta. A total of 20 water samples were collected from Mughalabad, Bashir Chowk, Hazara Town, and Satellite Town. Sixteen physicochemical parameters of water were analyzed, and four microbiological assays were performed. Taste and odor were unobjectionable for all samples; the color of 10 samples was objectionable; the pH of all samples was within the normal range (except one sample from Hazara Town); the maximum electro-conductivity recorded was 927 µS/cm (Bashir Chowk); turbidity values for 10 samples were higher than the normal range; and total dissolved solids were highest in the water samples from Satellite Town. The alkalinity level ranged between 1.4–3.3 mmol/L; Ca and Cl levels were within the acceptable range; HCO_3 was relatively lower in Hazara Town; CO_3 was zero; and hardness, Mg, K, Na, and SO_4 levels were satisfactory. All samples taken from the water sources were free of E. coli and fecal coliforms. However, 10 samples taken from water distributary pipelines, water cans, and household taps were positive for the presence of coliform bacteria, which is an indicator of the presence of pathogenic bacteria in the distributary system and household water storage containers. This study concludes that the water quality deteriorates upon traveling from the source to households. The study recommends a proper monitoring and regulation plan for the water distributary system to investigate the root cause of the contamination, strengthened sewage system management, installation of water filtration plants, and regular chlorination of water reservoirs in the localities. At the household level, the study recommends boiling water before consumption and disinfection of water cans and containers. This study indicates the undesirable living conditions of refugees as well as host communities residing in the area, and it could be further expanded for large-scale research as well as interventions in the field of Water, Sanitation, and Hygiene (WASH).

Keywords: Drinking Water Quality, Contaminated Water, Physicochemical Testing, Total Coliform Number, E.coli, Afghan Refugee Settlements Quetta Urban.

1. INTRODUCTION

Water is an essential component of human life on Earth. Drinkable water is one of the scarcest resources in the world, as only 3% of the 71% of the water that covers the Earth's surface is drinkable. Although water itself is constituted by the tiniest, most basic molecules, it holds remarkable properties that can aid in the construction of large biomolecules as well as their assembly (Chaplin, 2006). From microscopic organisms to human beings, water constitutes a sufficient percentage of their total body weight, i.e., about 80% of a microorganism's weight and 70% of human body weight (Gaudy, 1980). For humans, all life functions, even at the cellular level, are arrayed on the backdrop of water, which includes crucial functions such as thermoregulation, homeostasis, transport of nutrients in and out of cells, stability of the plasma membrane, and control of metabolic reactions occurring in the cells (Ball, 2008). Water keeps the human body functioning smoothly; therefore, the overall well-being of a human depends on the availability of clean, safe drinking water. Water specifically for drinking has conditions that need to be met, which require the water to be tasteless, colorless, and odorless. The quality of drinking water remains a global concern, with the availability of safe drinking water being a major problem. The quality of drinking water is evaluated by its physical, chemical, and biological parameters (WHO, 2022). The physicochemical factors include pH, turbidity, total dissolved solids (TDS), electro-conductivity, salinity, mineral concentration, and heavy metal content, while the biological factors include the presence of microorganisms, mostly pathogenic, in drinking water. The occurrence of any change outside the standard range of values for these parameters compromises water quality and is often caused by contamination, which can be anthropogenic (deforestation, dumping of industrial waste, dumping of sewage water, agricultural runoff) as well as natural (flooding, topography, acid rain, weathering of parent material). Such contaminated water is considered harmful to human health and is unsuitable for consumption (Vadde, 2018).

Safe, clean water and proper sanitation are problems that developing countries have been struggling with for a long time and are still fighting to tackle. One of the major threats to human health related to water consumption is fecal contamination. The fusion of sewage water with freshwater sources has been the main cause of biological contamination of water, resulting in the rise of serious illnesses. According to WHO (2019), approximately 2 million people consume water that has been contaminated with fecal waste. Mixing human or animal waste in drinking water sources causes contamination with pathogenic microorganisms, and such contaminated water becomes a vector for fatal diseases. Water-borne illnesses have become a major issue in developing countries, with growing populations placing pressure on healthcare systems as well as the economy (Malik, 2012). These illnesses vary in severity depending on their causative agents, ranging from diseases caused by commonly found opportunistic bacteria to severe diseases caused by antibiotic-resistant bacteria.

Some of the common pathogenic bacteria found in drinkable water are E. coli, Salmonella typhi, Shigella sp., Vibrio cholerae, Pseudomonas aeruginosa, Helicobacter pylori, and others, which cause diseases such as diarrhea, dysentery, typhoid, salmonellosis, cholera, hepatitis A, urinary tract infections (UTI), conjunctivitis, stomach ulcers, and illnesses that jeopardize human health and sometimes life (Cabral, 2010).

According to research published in Health Science Reports, 74 children out of 1,000 die due to diarrheal illness in Pakistan annually (Rahmat, 2023). Daily, 2,195 children die because of diarrhea around the world, a figure that exceeds the death toll caused by malaria, AIDS, and measles combined (2023). Similarly, typhoid fever, caused by the bacterium Salmonella typhi, which is commonly found in contaminated drinking water, is another severe illness affecting 20,886 per 100,000 unvaccinated children but only 9,490 per 100,000 vaccinated children in Pakistan (Tharwani, 2022). Moreover, globally, around 35 million cases of Salmonella typhi infection occur every year, resulting in approximately 500,000 deaths (Majeed, 2023).

With water being such a necessity, its accessibility remains a major issue in developing countries. Freshwater sources, being scarce, have created pressure on the masses, compelling people to obtain drinking water of questionable quality. There is substantial research on the water quality of Quetta, Balochistan. According to survey research conducted in 2014, "higher contamination" was found in drinking water, indicating interaction between water and sewer lines (Butt, 2014). Similarly, another study was conducted specifically on the hydrological quality of water available in the two major Afghan refugee camps in 2020. The study analyzed 21 hydrological parameters and found that "most of the population is not consuming safe water" (Sh, 2021). Assessing the results of these studies, the most vulnerable community is Afghan refugees, who have no access to safe drinking water. Most of the Afghan refugee population present in Quetta has no or very limited options to obtain drinking water from sources that are not contaminated with natural and unnatural pollutants, causing a rise in water-borne illnesses among Afghan refugees (2021).

Afghan refugees, being one of the most vulnerable communities in Balochistan, face issues in accessing safe, drinkable water. Additionally, there is a need to inspect water projects in refugee camps, villages, and urban settlements to guarantee safe water quality and prevent waterborne diseases. To decrease health hazards, bacterial profiling of all drinking water sources is necessary. The existing literature lacks sufficient primary studies on Afghan refugees living in Pakistan in general and the selected urban Afghan refugee settlements of Quetta, Balochistan, in particular. Moreover, physicochemical and microbiological profiling of water to identify biological contaminants and propose sustainable solutions for water treatment is a unique study that can be replicated and generalized in different regions to facilitate vulnerable communities around the world.

2. LITERATURE REVIEW

Water is a necessity for a well-functioning body, and clean and safe drinking water is the right of every individual. Water quality is determined by analyzing a set of physical, chemical, and biological characteristics. With an increase in population, anthropogenic causes of water contamination have become very common. The most serious type of contamination is biological (Baek et al., 2023). One of the main causes of biological contamination of water is human or animal waste. Contamination of water with the waste of warm-blooded animals gives rise to the risk of pathogenic microorganisms being present in that water. These pathogenic microorganisms are the etiological agents of water-borne illnesses upon consumption. One of the main causes of diarrhea in children is the use of contaminated water and unhygienic practices (Oladipo et al., 2009). According to the WHO, approximately 1.4 million people die annually due to poor sanitation practices and the consumption of unsafe drinking water.

The availability of safe drinking water is a global issue; however, developing countries are facing it to a much greater extent. Pakistan has an Environmental Performance Index (EPI) drinking water score of 28.2 (100 being the best and 0 the worst). According to a study focused on the status of drinking water quality in Pakistan (Daud et al., 2017), about 80% of the population in Pakistan consumes unsafe, contaminated water, with the main source of contamination being sewerage water.

According to a report by the Pakistan Council of Research in Water Resources (PCRWR) on the nationwide drinking water quality status (2023), out of a total of 435 drinking water sources across the country, 168 (39%) sources were safe, whereas 267 (61%) sources were unsafe for drinking. The same study also reported that 65% of the water sources monitored in Balochistan were unsafe due to bacteriological contamination.

Another research study comparatively analyzed groundwater and tap water to assess microbial contamination in the water distributary system of Quetta city (Khan et al., 2022). For the study, 31 samples of groundwater and tap water were collected from different areas of the city. The study found the presence of coliforms and E. coli in tap water sources. However, the groundwater samples showed an average microbial concentration of 2 or less than 2 per 100 ml Colony Forming Units (CFU), indicating strong evidence of contamination within the water distributary system. The study was not focused on Afghan refugees but was a generalized assessment of the water quality of Quetta city.

A recent study conducted in Quetta city (Taj et al., 2024) analyzed 240 drinking water samples taken randomly from all zones of the city. The study found the presence of coliform bacteria in 68.3% of the samples. Samples were collected from schools, hotels, and homes, each showing a different percentage of coliform bacteria.

The Afghan refugee community is already one of the most vulnerable communities, facing economic, political, and social burdens. Balochistan is ranked second among provinces with the greatest number of Afghan refugees residing there (Adamec et al., 2012). This community is living under extreme conditions, with access to few or no opportunities (Pandey & Ilavarasan, 2019). Similar to the 80% population of Pakistan, the Afghan refugee community also has access to unsafe drinking water, with hygiene and sanitation conditions being even worse.

A study conducted by Muhammad Ziad et al. (2014) assessed the drinking water quality of Afghan refugee camps in Haripur, Azad Jammu and Kashmir (Ziad, Khalid, Naz, & Shah, 2014). The study was based on 21 water samples randomly collected from hand pumps, containers, and tube wells of the Panian-1 Afghan refugee camp. The results showed that the water sources were contaminated and did not meet the safe water quality standards prescribed by the World Health Organization. The scope of the study was limited to the Panian-1 refugee camp.

Another study evaluating the quality of drinking water at two Afghan refugee camps, namely Saranan and Surkhab, was conducted in 2021 (Sh, 2021). In this study, 21 hydrological parameters were analyzed, and Total Coliform tests revealed that most of the population was consuming unsafe water.

3. METHODOLOGY

3.1 Study Area

3.1.1 Mughalabad

It is a residential area in Quetta city, in the province of Balochistan, and lies between 30°09'08.9"N 67°01'22.3"E. Approximately 24,600 Afghan refugees reside in Mughalabad.

3.1.2 Bashir Chowk

This area is located in Quetta city of Balochistan and lies between 30°09'52.5"N 66°58'53.0"E. The population of Afghan refugees in Bashir Chowk is approximately 42,979.

3.1.3 Hazara Town

Hazara Town lies between 30°10'48.9"N 66°57'38.1"E, near the western bypass in Quetta city of the Balochistan province, with an Afghan refugee population of approximately 207,046.

3.1.4 Satellite Town

Satellite Town lies between 30°09'46.0"N 67°00'22.3"E in Quetta city of Balochistan and is home to approximately 18,800 Afghan refugees.

3.2 Sample Collection

A total of five samples were collected from each site in duplicate for physicochemical and microbiological analysis. From each location, samples were taken from the water source, the pipeline and tap water from the nearest house, and the pipeline and tap water from a farther house. Mughalabad and Bashir Chowk had no proper water distributary systems; therefore, samples were taken from water cans used by people to transport water to their houses.

Sterile 500 ml containers were used to collect samples for microbiological analysis, while 500 ml unused plastic bottles were used to collect samples for physicochemical analysis. Samples were labeled, stored in a cool storage box, and transported to the microbiological laboratory for immediate analysis.

3.3 Physicochemical Parameter Analysis

Table 1. Methods used for the analysis of physicochemical parameters.

Parameters	Method Used
Taste-Odor-Color	Physical Sensory Test
PH	PH meter (Jenway 350pH)
Electro-conductivity (μS/cm)	EC meter (Hanna HI 99300)
Turbidity (NTU)	Turbidity meter (Lovibond PC 63741)
Total Dissolved Solids (TDS) (mg/L)	TDS meter (Hanna HI 99300).
Hardness (mg/L)	Complexometry, EDTA Titration (APHA, 1998)
Calcium (Ca) (mg/L)	Complexometry, EDTA Titration (APHA, 1998)
Sodium (Na)-Potassium (K) (mg/L)	Digital Flame Photometer (DG Flame DV 7101)
Chloride (Cl) (mg/L)	Silver Nitrate Titration (APHA,1998)
Bicarbonate (HCO_3) (mg/L)	Titrimetry (HCl) (APHA, 1998)
Carbonate (CO_3)	Stoichiometry (HCl) (APHA, 1998)
Sulphate (SO_4) (mg/L)	Colorimeter (Hach DR890 Colorimeter, program No. 91)
Alkalinity (mmol/l)	Calculation (Standard Method, APHA,1998)
Magnesium (Mg) (mg/L)	Calculation (Standard Method, APHA, 1998)

(μS/cm) =Micro Siemen per centimeter, (NTU)= Nephelometric Turbidity Unit, (mg/L) = milligrams per liter, (EDTA) = Ethylenediamine tetra-acetic acid, (HCl) = Hydrochloric acid, (mmol/L) = millimoles per liter (APHA, 1998).

3.4 Microbiological Analysis

3.4.1 Total Viable Count

A 100 μl water sample was spread on sterile nutrient agar plates and incubated at 37°C for 24 hours to obtain maximum bacterial colonies (Mahto & Goel, 2008).

3.4.2 Enumeration of Total Coliform

A 100 ml sample was passed aseptically through a membrane filtration unit containing a 0.45 μm pore-size cellulose nitrate membrane filter (MF) inside a BSL-II biosafety cabinet. The membrane filter was then placed on sterile L.E.S. m-Endo agar plates and incubated at 37°C for 24 hours to obtain maximum bacterial colonies (APHA, 1998).

3.4.3 Enumeration of Fecal Coliform

A 100 ml sample was passed aseptically through a membrane filtration unit containing a 0.45 μm pore-size cellulose nitrate membrane filter (MF) inside a BSL-II biosafety cabinet. The membrane filter was then placed on sterile m-FC agar plates and incubated at 44.5°C for 24 hours to obtain maximum bacterial colonies (APHA, 1998).

3.4.4 Enumeration of Thermotolerant E. coli

A 100 ml sample was passed aseptically through a membrane filtration unit containing a 0.45 μm pore-size cellulose nitrate membrane filter (MF) inside a BSL-II biosafety cabinet. The membrane filter was then placed on sterile membrane–Thermotolerant Escherichia coli (m-TEC) agar plates and incubated first at 35°C for 2 hours and then at 44.5°C for 24 hours to obtain maximum bacterial colonies (APHA, 1998).

4. RESULTS AND DISCUSSION

4.1 Taste–Odor–Color

The taste and odor of all samples were unobjectionable; however, the color of 10 samples was objectionable as per WHO standards. These included four samples from Mughalabad, two samples from Bashir Chowk, two samples from Hazara Town, and two samples from Satellite Town (Table 4.1). Suspended particles such as organic matter or salts alter the color of water.

4.2 pH

pH plays an important role in water quality as it is correlated with corrosive properties, microbial growth, toxicity, and nutrient availability. As per WHO standards, the pH of drinking water should lie within the range of 6.5–

8.5 for it to be considered safe. The pH of all water samples was within the recommended range except for one sample from Hazara Town (Table 4.1).

4.3 Electroconductivity

Electroconductivity is a measure of a solution's ability to conduct electricity. It is directly proportional to the presence of salts and ions in water. The maximum value for EC recommended by WHO is 400 µS/cm, and except for Hazara Town, all locations had EC values above the recommended limit. EC values vary with geology, and water with a higher EC value is not necessarily harmful for human consumption but indicates the presence of inorganic compounds, minerals, and salts (Table 4.1).

4.4 Turbidity

Turbidity is a measure of the cloudiness of water, which usually indicates the presence of contaminants such as sediments, microbial growth, and other impurities. The analytical results showed that 10 samples had turbidity values higher than the WHO recommended limit. These included four samples from Mughalabad, two samples from Bashir Chowk, two samples from Hazara Town, and two samples from Satellite Town (Table 4.1).

4.5 Total Dissolved Solids (TDS)

TDS is a measure of the combined concentration of organic and inorganic substances dissolved in water. It is linked to the taste, odor, hardness, scalability, and corrosivity of water. The TDS values of water at all selected locations were acceptable as per the prescribed WHO limits.

4.6 Hardness

The hardness of water refers to the presence of minerals in water, particularly calcium and magnesium. It can alter the taste and odor of water and may cause gastric disorders in humans. Analytical results from all locations showed satisfactory values for hardness.

4.7 Calcium

Calcium concentrations were acceptable in all water samples.

4.8 Sodium

Higher concentrations of sodium in water may raise health concerns for people with high blood pressure and cardiovascular diseases. Sodium is present in water in the form of cations, which react with other anions to form salts such as sodium chloride (NaCl). The concentration of sodium at all selected locations was within the WHO-defined limit, i.e., below 200 mg/L.

4.9 Potassium

All samples had potassium concentrations below the recommended limit of 12 mg/L.

4.10 Chloride

Chloride is a naturally occurring anion in water, and its concentration varies with location and water source. Higher chloride concentrations can be harmful to people with high blood pressure. The chloride concentration was below the standard limit for all samples; however, it showed an increasing trend in Satellite Town.

4.11 Bicarbonate

Bicarbonate (HCO_3^-) concentration is directly linked to the pH and alkalinity of water. Bicarbonate concentrations were relatively lower in Hazara Town compared to the other selected locations (Table 4.2).

4.12 Carbonates

Carbonate (CO_3^{2-}) concentration at all four sites was zero.

4.13 Sulphate

Sulphate (SO_4^{2-}) is a naturally occurring ion in water, and higher concentrations can cause gastrointestinal and respiratory issues. Sulphate concentrations were acceptable at all selected locations and were below the WHO-defined limit.

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4.14 Magnesium

Magnesium is an essential mineral present in water and an important nutrient for human health. All samples showed satisfactory concentrations of magnesium.

4.15 Alkalinity

Alkalinity is the capacity of water to neutralize acids and buffer pH changes. Alkalinity values at all studied locations were acceptable.

4.16 Total Viable Count

Total Viable Count (TVC) represents the total number of living microorganisms present in a sample and is used by water quality monitoring agencies to evaluate the microbiological quality of water. TVC values for all samples were very high, with nine samples surpassing the standard limit for causing infection. These included three samples from Mughalabad, one sample from Bashir Chowk, three samples from Hazara Town, and two samples from Satellite Town (Table 4.3).

4.17 Total Coliform

Total coliform bacteria are a group of closely related gram-negative bacteria selected as indicators for the presence of harmful microorganisms. They belong to the family Enterobacteriaceae and are present in soil as well as human or animal waste. Coliform bacteria are selected as indicators of contamination for two main reasons: first, their presence in drinking water indicates contamination by surface sources or human or animal waste; second, these organisms are generally not harmful themselves and can be easily eliminated by boiling or disinfection. According to WHO standards for safe drinking water, no coliform bacteria should be present.

Out of the 20 water samples, 10 samples tested positive for coliform bacteria, indicating contamination. Samples collected directly from water sources, i.e., tubewells, were all negative. However, some samples taken from water distributary pipelines, water cans, and household taps tested positive. Four samples from Mughalabad, two samples from Bashir Chowk, two samples from Hazara Town, and two samples from Satellite Town were positive for coliform presence (Table 4.3).

These results suggest that water sources were uncontaminated and safe; however, contamination occurred within distributary pipelines and household water storage and handling systems, which can lead to water-borne illnesses. Similar findings were reported in another study conducted in two Afghan refugee camps in Balochistan (Sh, 2021), where water sources were free of contamination but became contaminated during distribution and storage under poor conditions.

4.18 Fecal Coliform

Fecal coliform bacteria are a subgroup of coliforms found exclusively in the intestines of warm-blooded animals. Although they are generally not harmful, their presence indicates contamination of water by human or animal waste, either directly through excreta or indirectly through the mixing of sewage water with drinking water. According to WHO guidelines, no fecal coliform bacteria should be present in drinking water.

All water samples from the four selected locations were negative for fecal coliform bacteria.

4.19 Thermotolerant E. coli

Escherichia coli (E. coli) is a type of fecal coliform found in the gut of warm-blooded animals. Generally, E. coli is not harmful; however, some strains are pathogenic and can cause illnesses such as diarrhea, dysentery, abdominal pain, and fever. Thermotolerant E. coli can survive at higher temperatures for longer periods and therefore persist in water. E. coli is routinely monitored by water quality assurance agencies.

All water samples analyzed in this study were negative for thermotolerant E. coli. However, a study conducted on the drinking water quality of the Panian-1 refugee camp in District Haripur, Azad Jammu and Kashmir (Ziad et al., 2014), reported contamination with both coliform bacteria and E. coli.

Table 2. Water Quality Results of Physical Parameters.

Name of Site	Source	Color	Taste	Odor	Turbidity	pH	EC
		Unobj*	Unobj*	Unobj*	5 NTU*	6.5-8.5*	400 µS/cm*
Mughal Abad	Tube well	Unobj.	Unobj.	Unobj.	0.2	7.94	457
	Pipeline	Obj.	Unobj.	Unobj.	9.9	7.89	482
	Tap	Obj.	Unobj.	Unobj.	8.2	7.86	475
	Water Can	Obj.	Unobj.	Unobj.	8.6	7.99	411
	HH tap	Obj.	Unobj.	Unobj.	6.8	7.86	478
Bashir Chowk	Tube well	Unobj.	Unobj.	Unobj.	2.5	7.92	914
	Water Can	Unobj.	Unobj.	Unobj.	0.8	7.96	641
	HH tap	Obj.	Unobj.	Unobj.	13.6	7.99	646
	Water Can	Obj.	Unobj.	Unobj.	8.7	7.93	919
	HH tap	Unobj.	Unobj.	Unobj.	0.7	7.92	927
Hazara Town	Water supply	Unobj.	Unobj.	Unobj.	0.8	7.95	322
	Pipeline	Unobj.	Unobj.	Unobj.	0.7	7.9	290
	HH tap	Unobj.	Unobj.	Unobj.	0.7	7.9	287
	Pipeline	Obj.	Unobj.	Unobj.	8.7	8.93	288
	HH tap	Obj.	Unobj.	Unobj.	7.7	7.92	292
Satellite Town	Tube well	Unobj.	Unobj.	Unobj.	1.6	7.65	858
	Pipeline	Unobj.	Unobj.	Unobj.	1.3	7.69	872
	HH tap	Unobj.	Unobj.	Unobj.	1.3	7.88	818
	Pipeline	Obj.	Unobj.	Unobj.	8.9	7.99	871
	HH tap	Obj.	Unobj.	Unobj.	8.9	7.61	868

* Guideline values by the WHO for drinkable water (WHO, 2022). Unobj= Unobjectionable= colorless, odorless, and tasteless

Table 3. Water Quality Results of Chemical Parameters

Name of Site	Source	TDS 1000 ppm*	Ca 200 mg/L*	Hardness 500 mg/L*	Mg 50 mg/L*	Alkalinity 10 m.mol/L	HCO$_3$ NGVS* *	CO$_3$ 200 mg/L*	Cl 250 mg/L*	Na 200mg/L*	K 12 mg/L*	SO$_4$ 250 mg/L*
Mughal Abad	Tube well	277	26	150	21	2.1	105	0	57	45	1	64
	Pipeline	296	34	165	19	2.2	110	0	61	46	1	68
	Tap	291	32	160	19	2.2	110	0	59	46	1	67
	Water Can	250	24	135	18	2.0	100	0	46	41	1	59
	HH tap	293	32	160	19.44	2.2	110	0	60	47	1	67
Bashir Chowk	Tube well	579	62	255	24	3.3	165	0	140	114	1	138
	Water Can	392	38	175	19	2.5	125	0	88	76	1	94
	HH tap	396	38	175	19	2.5	125	0	89	77	1	96
	Water Can	584	62	255	24	3.3	165	0	142	116	1	139
	HH tap	590	66	260	23	3.3	165	0	143	116	1	141
Hazara Town	Water supply tanker	193	21	125	18	1.5	75	0	39	23	1	46
	Pipeline	177	20	105	13	1.4	70	0	34	25	1	41
	HH tap	172	20	105	13	1.4	70	0	32	23	1	40

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	Pipeline	175	20	105	13	1.4	70	0	33	24	1	41
	HH tap	177	20	105	13	1.4	70	0	35	25	1	40
Satellite Town	Tube well	535	46	230	28	3.2	160	0	132	110	1	122
	Pipeline	545	48	230	27	3.3	165	0	134	114	1	122
	HH tap	511	44	220	27	3.1	155	0	126	106	1	114
	Pipeline	548	48	230	26.73	3.3	165	0	134	115	1	124
	HH tap	546	48	235	27.945	3.3	165	0	133	113	1	124

* Guideline values by the WHO for drinkable water, **No Guideline Value Set

Table 4. Water Quality Results of Microbiological Analysis

Name of Site	Source	Total Viable Count CFU/ml $<10^6$	E. Coli (CFU/ml) 0*	Total Coliform (CFU/ml) 0*	Fecal Coliform (CFU/ml) 0*
Mughal Abad	Tube well	18×10^4	0	0	0
	Pipeline	3.5×10^6	0	5	0
	Tap	3.9×10^4	0	3	0
	Water Can	8.7×10^6	0	4	0
	HH tap	2.7×10^7	0	7	0
Bashir Chowk	Tube well	5.4×10^3	0	0	0
	Water Can	2.8×10^4	0	0	0
	HH tap	3.5×10^6	0	12	0
	Water Can	6.3×10^5	0	5	0
	HH tap	2.8×10^4	0	0	0
Hazara Town	Water supply tanker	3.6×10^3	0	0	0
	Pipeline	2×10^4	0	0	0
	HH tap	1.2×10^7	0	0	0
	Pipeline	4.6×10^6	0	6	0
	HH tap	2.1×10^7	0	8	0
Satellite Town	Tube well	2.3×10^3	0	0	0
	Pipeline	8×10^3	0	0	0
	HH tap	1.2×10^4	0	0	0
	Pipeline	2.1×10^7	0	6	0
	HH tap	4.9×10^7	0	9	0

* Guideline values by the WHO for drinkable water (WHO, 2022)

5. CONCLUSION AND RECOMMENDATIONS

Afghan refugee communities in Balochistan face challenges in accessing safe, drinkable water. Water projects in refugee camps, villages, and surrounding areas need to be examined to ensure water quality. To reduce health hazards, bacterial profiling of all drinking water sources is necessary. The existing literature lacks sufficient primary studies on Afghan refugees living in Pakistan in general and in Balochistan in particular. Moreover, microbiological profiling of water to identify biological contaminants and propose sustainable solutions for water treatment is a unique approach that can be replicated and generalized in different regions to support other forcibly displaced populations around the world.

The present study analyzed water samples from four Afghan refugee settlements in Quetta. A total of 20 water samples were collected from the sites. Sixteen physicochemical parameters were analyzed, and four microbiological assays were performed. The taste and odor of all samples were unobjectionable; however, the color of 10 samples was objectionable. The pH of all samples was within the normal range except for one sample from Hazara Town. The maximum electroconductivity recorded was 927 µS/cm at Bashir Chowk. Turbidity values for 10 samples were higher than the normal range, and total dissolved solids were highest in water samples from Satellite Town. Alkalinity levels ranged between 1.4 and 3.3 mmol/L. Calcium and chloride levels were within acceptable ranges. Bicarbonate (HCO_3^-) concentrations were relatively lower in Hazara Town, carbonate (CO_3^{2-}) concentrations

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were zero, and hardness, magnesium, potassium, sodium, and sulphate levels were satisfactory. All samples collected directly from water sources were free of E. coli and fecal coliforms. However, 10 samples taken from water distributary pipelines, water cans, and household taps tested positive for coliform bacteria, indicating the presence of pathogenic bacteria in the distributary system and household water storage containers.

Based on the findings of this study, microbiological contamination is likely occurring within water distributary pipelines, household water storage, and handling systems. Although the underground water analyzed in this study was free of coliform bacteria, contamination occurred as the water traveled from one point to another. Consequently, this contaminated water poses a health risk to the population. The contamination may be occurring due to leakage in underground water pipelines, where drinking water may come into contact with sewage water.

A proper monitoring and regulation plan for the water distributary system is strongly recommended, and strategies should be implemented to investigate the root causes of contamination. A more reliable sewage system should be provided for these localities. Installation of water filtration plants and regular chlorination of water reservoirs can reduce the risk of water-borne diseases among residents. To address contamination at the household level, boiling water before consumption is highly recommended, and disinfection of water cans and storage containers is also advised.

6. ACKNOWLEDGMENT

REFERENCES

Adamec, L.W., (2012). Historical Dictionary of Afghanistan. *4th ed published by Scarecow U.K.* pg. 375.

APHA, AWWA, WEF, STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 20TH EDITION, AMERICAN PUBLIC HEALTH ASSOCIATION, NEW YORK (1998).

Baek, S. U., Lee, W. T., Kim, M. S., Lim, M. H., Yoon, J. H., & Won, J. U. (2023). Preventive & Social Medicine. *Journal of Korean Medical Science*, *38*(37), e284.

Ball, P. (2008). Water as an active constituent in cell biology. *Chemical reviews, 108(1)*, 74-108.

Butt, M. &. (2014). Cost of Illness of Water-borne Diseases: A Case Study of Quetta. *Journal of Applied and Emerging Sciences*, 133-143.

Cabral, J. P. (2010). Water microbiology. Bacterial pathogens and water. *International journal of environmental research and public health, 7(10)*, 3657-3703.

Chaplin, M. (2006). Do we underestimate the importance of water in cell biology?. Nature Reviews Molecular Cell Biology, 7(11),. *Nature Reviews Molecular Cell Biology*, 861-866.

Daud, M. K., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., ... & Zhu, S. J. (2017). Drinking water quality status and contamination in Pakistan. *BioMed research international*, *2017*(1), 7908183.

Gaudy, A. F. (1980). *Microbiology for environmental scientists and engineers. (No Title).* McGraw-Hill International Book.

Khan, T., Malik, M. A., Malghani, G., & Akhtar, R. (2022). Comparative analysis of bacterial contamination in tap and groundwater: A case study on water quality of Quetta City, an arid zone in Pakistan. *Journal of Groundwater Science and Engineering*, 153-165.

Majeed, I. K. (2023). Salmonella Meningitis in a Young Child from Pakistan: A Case Report. *Journal of Medical Case Report*, 1-5.

Malik, A. Y. (2012). Water-Borne Diseases, Cost of Illness and Willingness to Pay for Diseases Interventions in Rural Communities of Developing Countries. *Iranian Journal of Public Health*, 39-49.

Oladipo, I. C., Onyenike, I. C., & Adebiyi, A. O. (2009). Microbiological analysis of some vended sachet water in Ogbomoso, Nigeria. *African Journal of Food Science*, *3*(12), 406-412.

Pandey, S. and P.V. Ilavarasan (2019). People, information and culture: Locating forms of capital by Afghan Sikh refugees in India through ICTs. *Technological Forecasting and Social Change* 146331-338.

Rahmat, Z. S. (2023). The Rise of Diarrheal Illnesses in the Children of Pakistan Amidst COVID-19 : A Narrative Review. *Health Science Reports*, 1-8.

Sh, Z., Aziz, M., & Sheikh, A. N. (2021). Evaluation of Available Drinking Water for Afghan Refugees Life Style in North West Balochistan. *Pakistan Journal of Science*, 154-160.

Taj, M. K., Ali Khan, M., Hussain, A., Azam, S., Khan, S., Zafar, A., Jaffer, S., & Ahmed, B. (2024). ISOLATION AND IDENTIFICATION OF COLIFORM BACTERIA FROM DRINKING WATER OF QUETTA BALOCHISTAN. Journal of Population Therapeutics and Clinical Pharmacology, 31(4), 19–25. https://doi.org/10.53555/jptcp.v31i4.5288

Tharwani, Z. H. (2022). Typhoid in Pakistan: Challenges, Efforts, and Recommendations. *Infection and Drug Resistance*, 2523-2527.

Vadde, K. K. (2018). Assessment of water quality and identification of pollution risk locations in Tiaoxi River (Taihu Watershed), China. *Water, 10(2)*, 183.

WHO. (2019). *National systems to support drinking-water: sanitation and hygiene: global status report 2019: UN-Water global analysis and assessment of sanitation and drinking-water: GLAAS 2019 report.* Geneva: World Health Organization.

WHO. (2022). *Guidelines for drinking-water quality: incorporating the first and second addenda.* World Health Organization.

Ziad, M., Khalid, S., Naz, A., & Shah, W. (2014). Assessment of Drinking Water Quality in Afghan Refugee Camp, District Haripur, Pakistan. *Journal of Science and Technology, University of Peshawar*, 23-30.