Investigating the Drinking Water Quality and Associated Health Risks in Metropolis Area of Pakistan

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Water is the basic need of human beings with no substitute for it. This research aims to investigate the drinking water quality and dissociated risk calculations of the metropolis area in Pakistan. The present study was based on public awareness toward water quality and the real situation of water quality of filtration plants in Islamabad. A questionnaire was designed with the help of existing literature about public awareness on water quality. In the present study, 450 completed questionnaires were collected and analyzed with the help of statistical tools. To investigate the real situation of water quality in the study area, 32 samples were analyzed from installed filtration plants. The results presented that electrical arsenic, conductivity (EC), and alkalinity were higher, and 26 samples were found to be unsafe for drinking under poor water quality (water quality index >100). The hazard index of arsenic was found to be <1 in adults (7.03E+01) and children (1.06E+02) in Islamabad. The microbiological situation was included as well for health risk assessment. There is a need of comprehensive management for the sustainability of filtration plants. Public satisfaction can be enhanced by dissemination of the significant importance of water quality in annual government reports to the public via local social media, print media, and television.

Keywords: public awareness, health risk, Islamabad, water quality urbanization, urbanization, health

INTRODUCTION

Water is a basic human need, is necessary for survival, and has a significant relationship with human livelihood and good health. Many scholars have identified and analyzed the situation on public awareness about drinking water (de França Doria; Calicioglu et al., 2011; Mahler et al., 2015). There is a lot of evidence that clear public awareness about drinking water quality can help prevent contaminated water (Yang et al., 2012; Wang et al., 2016; Wang et al., 2018; Hou et al., 2021; Praveena et al., 2020). Public satisfaction of safe drinking water is also part of the World Health Organization's strategies (Chowdhury et al., 2017). Islamabad Capital Authority (CDA) installed a number of water filtration pants in Islamabad with the aim to supply clean, fresh, and safe water to the public of the said city (Sohail et al., 2019a, 2020). To supply safe water, it is necessary to have good infrastructure because water supply systems, the pressure of water, and breakdown and quantity of water can affect water quality (Chowdhury et al., 2017). Water has its own importance for economic development and human health (Sohail et al., 2019b). Organic and inorganic chemicals and heavy

metals are found in many regions of the world (Hadzi et al., 2018). Water quality of any specific area can help to determine public health, so importance of water quality cannot be ignored (Wagh et al., 2019). Pakistan, being a developing country, is also facing the same issue in many parts of the country (Muhammad et al., 2016; Amin et al., 2019). Over the last few decades, water demand has increased in the country (Talib et al., 2019). On other hand, water quality is affected due to numerous human activities like industrial and agricultural development (Sohail et al.., 2014b). Contaminants such as chemicals, microorganisms, industrial wastes, toxic substances, or wastewater in higher concentrations can become the reason for unsafe drinking water (Mahfooz et al., 2019). Contaminated water can cause the following diseases: skin diseases, kidney damage, circulatory system problems, gastrointestinal stress, cancer, blue baby syndrome, nervous system disorders, and bone damage (Rehman et al., 2018), and it is projected that many children die due to different diseases caused by contaminated water every year (Pavlinac et al., 2018). It is crucial to address water quality to improve human health (Rasool and Xiao, 2018). The world municipal population grows every year (United Nations, 2018), so population growth is also significant. Obviously, urbanization can have a positive impact on social development and the economy (Ann et al., 2014; Sohail et al.., 2014a), but unplanned urbanization and rapid change can cause a variety of issues in developing countries, including air pollution, traffic congestion, water scarcity, and the inability to meet basic needs for all (Jiao et al., 2016). This is one of the most important studies of its kind because Islamabad is Pakistan's capital city, and public awareness about the environment, including drinking water and water sources, can help to raise consumer education (Wang et al.., 2018). This paper presented the results that aimed at 1) public awareness about water quality in Islamabad, 2) calculating water quality and health risk assessment, and 3) explaining the need of additional enhancements in water quality monitoring to water treatment on a daily basis.

MATERIALS AND METHODS

Study Area

Islamabad is a well-planned city and the capital of Pakistan. It is located at 72° 48′ 42.08″E and 33° 29′ 26.7″N to 33° 48′ 1.34″N and 73° 22′ 48.51″. The environment of Islamabad varies throughout the year and normally is a humid subtropical zone with five seasons and heavy rainfall expected during July with the possibility of flooding and cloudbursts. The population of Islamabad is increasing ever year because many people migrate from rural to urban areas to seek better opportunities related to employment, health, and education. The people of Islamabad rely on both groundwater and surface water (**Figure 1**).

Data Collection and Analysis

This study looked at two different types of data. A semi-structured questionnaire was used to collect data from households in Islamabad during phase 1. The questionnaire included a variety of questions about the participants' demographics as well as a knowledge score for the water quality of filtration plants in Islamabad. All farmers were informed that these data were collected solely for research purposes and that they were under no obligation to respond (Mccusker and Gunaydin, 2015) [27]. A total of 450 completed questionnaires were collected from the study area for this study. This study included a pre-test to eliminate any discrepancies. In phase 2, data on the water quality of installed filtration plants in Islamabad were collected from the Capital Development Authority. In total, 32 water filtration plants were observed in this study, and data were collected from them to determine the water quality according to the American Public Health Association (APHA, 2012), and different analyses like public awareness, health risk assessment, water quality assessment, and statistical analysis including the regression, coefficient of correlation, and principal component analysis (PCA) by using Origin (Version 9), MS Excel 2013, and SPSS 24 were conducted.

Probit Model

In this study, a probit model was used to investigate public awareness of water quality, with public awareness being defined as a binary outcome based on responses to whether or not the public is aware of water quality or filtration plants. The effect of numerous attributes of the sample response on awareness of water quality was investigated using a probit model equation. The probit model can be expressed as:

$$Y = \alpha_i + X_i\beta_i + \varepsilon_i \tag{1}$$

Y is the dependent variable (awareness level of public about water quality). Y represents public awareness of water quality, with $Y_i = 1$ indicating that the respondent is aware of water quality and $Y_i = 0$ indicating that the respondent is not. X_i is the $1 \times K$ vector of other determinants influencing the public's awareness about water quality, β_i is the $K \times 1$ vector of unidentified parameters, and ε_i is the error term.

Water Quality Assessment and Health Risk Assessment

The water quality index (WQI) was calculated for parameters (alkalinity, Cl, pH, NO_3, Na, SO_4, As, FC, TC) as per accessibility of their allocated weight (Horton, 1965),

$$Q_i = \left[\frac{C_i}{S_i}\right]x100 \tag{2}$$

$$SI_i = RW \, X \, Q_i \tag{3}$$

$$WQI = \sum_{i=1}^{n} SI_i \tag{4}$$

Where RW stands for relative weight, and Qi stands for quality index, which is calculated by dividing pollutant concentrations by their real values and multiplying by 100 in **Eq. 2** (Ramakrishnaiah et al., 2009). The index scores fell into the five following categories:
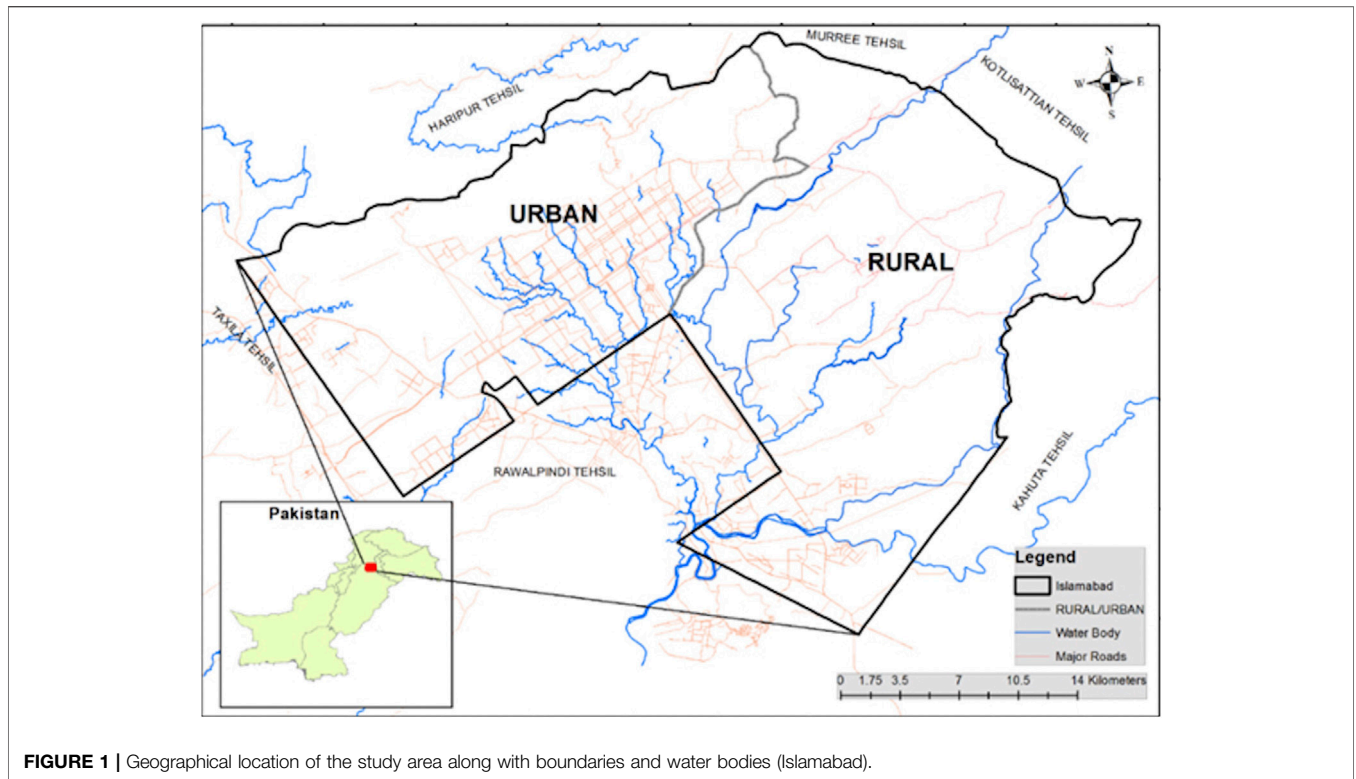
FIGURE 1 | Geographical location of the study area along with boundaries and water bodies (Islamabad).

>50 = Excellent, 50–100 = Good, 100–200 = poor, 200–300 = Very poor, <300 = Unsuitable.

Heavy metals have the potential to enter the human body and cause inhalation and ingestion (ASTDR, 2000) [31]. In the present study, Fe and As were selected and participants, regardless of gender, were assembled as two subjects (adult and children). Average daily dose (ADD) (mg/kg/d) of water consumption was calculated by USEPA (USEPA, 1989):

$$ADD_i = \frac{C_i \times IR}{BW} \qquad (5)$$

Where IR is the intake rate (2 L/day in adults and 0.63 L/day in children), C is the ith concentration (mg/L) of metal, and BW is body weight (72 kg for adults and 15 kg for children) (Sohail et al., 2019a). Based on total contents, the hazard quotient (HQ) was calculated as

$$HQ_i = \frac{ADD_i}{RFD} \qquad (6)$$

Where RfD is the USEPA's reference dose. For As, it is 0.0003 (ASTDR, 2000) and for Fe, it is 0.7 (Sohail et al., 2019b).

The hazard index is the sum of total HQ in a sample and it was computed by Khan et al. (2008).

$$HI = \sum HQ_i \qquad (7)$$

TABLE 1 | Attributes of the sample questionnaire.

Variables	Numbers	Percentage (%)
Gender		
Male	340	75.6
Female	110	24.4
Age group		
10–25	67	14.9
26–35	140	31.1
36–45	154	34.2
46 and above	89	19.8
Education level		
High school	127	28.2
College undergraduate degree	261	58.0
Master's-PhD	62	13.8
Family members		
1–2	88	19.6
3–5	232	51.6
6-more	130	28.9

RESULTS AND DISCUSSION

The attributes of the questionnaire in Islamabad are presented in **Table 1**. Respondents were predominantly men (75.6%; women, 24.4%), with 14.9% in the 10–25 age group, 31.1% in the 26–35 age group, 34.2% in the 36–45 age group, and 19.8% in the 46 and above age group. Respondents were educated to high school and
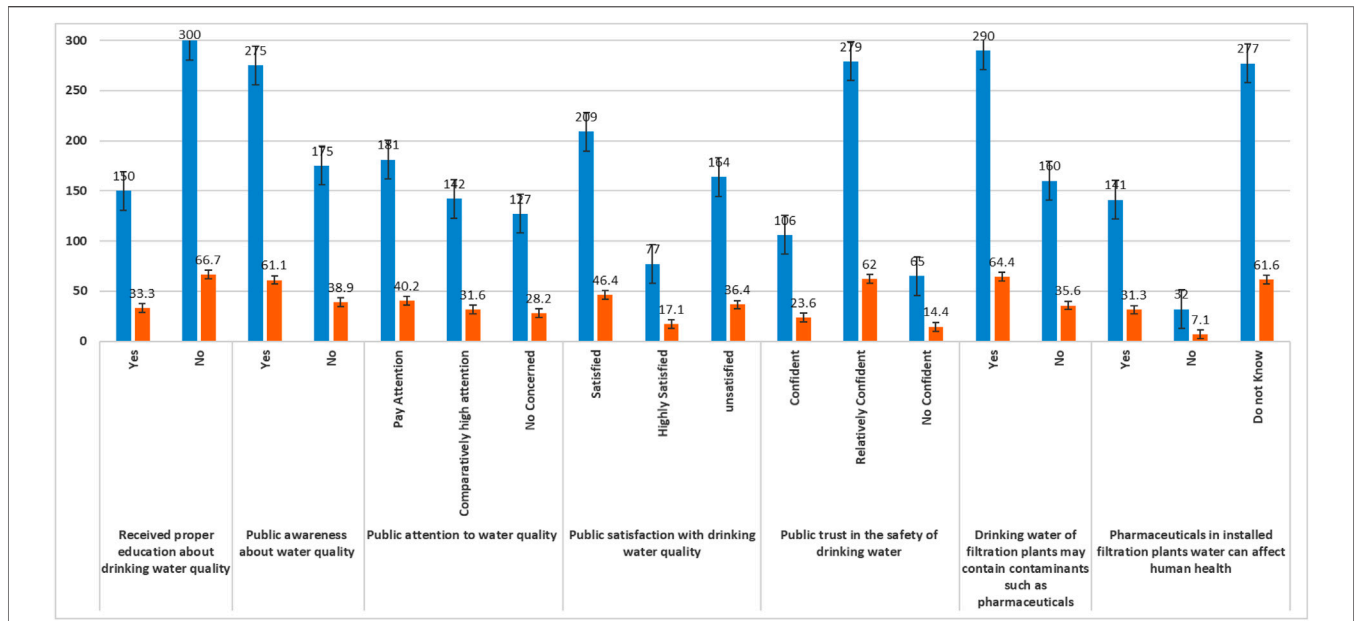
FIGURE 2 | Knowledge score about water quality of filtration plants.

TABLE 2 | Estimates of probit model: awareness of water quality.

Variables	Coefficient	Standard error	*t*-value	*p*-value
Gender	0.137	0.053	2.59	0.01**
Age	−0.058	0.023	−2.49	0.013**
Education	0.081	0.036	2.25	0.025**
_cons	0.287	0.101	2.82	0.005***

*Significance levels: * = p ≤ 0.10; ** = p ≤ 0.05; *** = p ≤ 0.01.*

college undergraduate degree educational levels. A total of 19.6% of respondents confirmed that they had one to two family members, 51.6% had 3–5, and 28.9% had six or more.

Figure 2 shows the results of the knowledge score for water quality of filtration plants in Islamabad. Generally, only 33.3% of respondents received proper education about drinking water quality, although about 61.1% of people were aware of water quality and 38.9% were not aware of water quality in the study area. About 40.2% said they paid attention and 31.6% said they paid comparatively high attention to water quality of filtration plants installed in Islamabad and 28.2% had paid no attention to water quality. In terms of public satisfaction with drinking water quality of installed filtration plants, 46.4% were satisfied, 17.1% were highly satisfied, and 36.4% were unsatisfied. About 64.4% said filtration plants' drinking water may contain contaminants and 35.6% were not sure. The last question asked if "pharmaceuticals in installed filtration plants' water can affect human health", 61.6% of respondents said they were not sure about it, 31.1% said yes, and 7.1% said no (**Figure 2**). This showed that the respondents know about water quality and associated factors but lack knowledge of pharmaceutical residues. This finding correlated with some other similar studies like that of Kusturica et al. (2020) that specified that people, mainly in

developing countries, lack proper knowledge of pharmaceutical residues in households. Hence, bodies such as water agencies, governments, and NGOs should strengthen the awareness about health impacts of drinking water contamination to the public.

Table 2 shows the estimates of the probit model. The probit model method was used for the features related to public awareness about water quality (**Table 2**). Among explanatory determinants, gender presented significance (*p*-value of 0.01 and coefficient of 0.137). It showed that men in the study area were more aware of water quality compared to women. The variable age showed a significant relation (*p*-value of 0.013 and coefficient of −0.058). For example, as the respondents' age increased, the public were more aware of water quality. We can say that people have more experience and information as they age. The other variable education level a showed significance level as well (with a *p*-value of 0.025 and coefficient of 0.081). This means that if the education level of the public increases, they have more exposure to the dangers of water quality.

Calculation Analysis of Water Quality

Table 3 describes the concentrations of water limits in this study area. The average concentrations of electrical conductivity (641.3 ± 171), alkalinity (256 ± 86), and arsenic (0.75 ± 0.3) in Islamabad were found to be higher than the acceptable limits set by the World Health Organization (WHO) (WHO, 2011). The remaining parameters (Mg, pH, hardness, TDS, Ca, Na, HCO_3, Fe, Cl, K, SO_4, NO_3) were all found to be within acceptable limits. In Pakistan, anthropogenic and overpopulation activities may be the primary cause of water contamination (Mahfooz et al., 2017). The main reason for the high level of contamination is high levels of arsenic in the aquifer and geohydrological system (Mehmood et al., 2017). The suitability of water quality in this study area is very poor; out of 32 sites in Islamabad, only one was completely

TABLE 3 | Concentrations of water parameters in filtration plants.

| Sr #	Parameters	Islamabad (n = 32)		WHO permissible limit (2011)
		Range	Mean ± SD	
1	As (mg/L)	0.06–1.63	0.75 ± 0.3	0.01
2	Fe (mg/L)	0.04–1.09	0.56 ± 0.44	--
3	pH	6.85–7.82	7.20 ± 0.22	6.5–8.5
4	Ca (mg/L)	40–96	70.93 ± 17.1	75
5	Cl (mg/L)	5–42	15.2 ± 7.74	250
6	Hardness (mg/L)	170–360	272 ± 57.7	--
7	K (mg/L)	0.4–2.5	1.38 ± 0.48	--
8	Mg (mg/L)	7–44	23 ± 9.1	--
9	TDS (mg/L)	211–539	354 ± 93	1,000
10	Na (mg/L)	5–53	23.90 ± 13.1	--
11	NO_3 (mg/L)	1–10	3.12 ± 2.35	--
12	Alkalinity (mg/L)	30–360	256 ± 86	120
13	EC (ms)	384–980	641.3 ± 171	250
14	HCO_3 (mg/L)	110–360	266 ± 77.6	--
15	SO_4 (mg/L)	20–85	40 ± 16.9	250
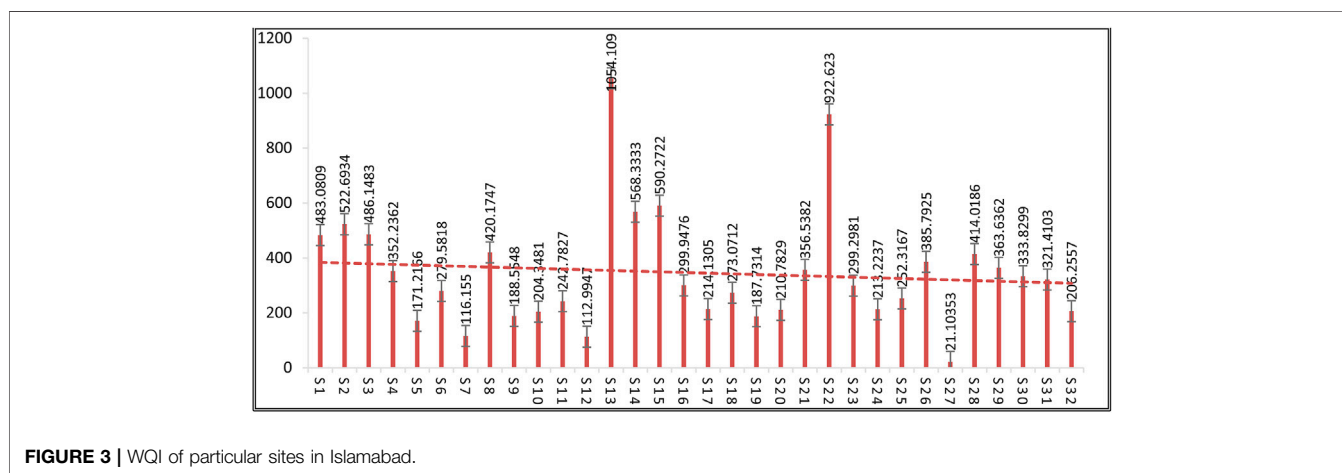
FIGURE 3 | WQI of particular sites in Islamabad.

**TABLE 4 |** Health risk assessment of children and adults.

Hazard quotient (HQ)				Hazard index (HI)	
As		Fe			
Children	Adult	Children	Adult	Children	Adult
1.06E+02	7.03E+01	3.38E-02	2.24E-02	1.06E+02	7.03E+01

safe to drink, and five others were deemed to have poor water quality (100–200 WQI value). At the same time, 10 sites had extremely poor water quality, and 16 were unfit for human consumption (**Figure 3**) (Sohail et al., 2020). Several studies (Al-Mutairi et al., 2014; Sohail et al., 2021a; Sohail et al., 2021b) have examined the link between population growth and low WQI.

Table 4 shows the real situation related to health hazard calculation. The real values of the hazard quotient (HQ) in arsenic were found to be <1 in water samples in adults (7.03E+01) and children (1.06E+02). It showed that the amount of arsenic was more than the safe level and hazardous

for children and adults. Fe was found within the safe limit (HQ < 1) in both children and adults. The hazard index (HI) was higher in adults (7.03E+01) than children (1.06E+02) (**Table 4**). Though, the total values suggest hazards can occur and the populace is at high risk. HQ > 1 in children was apparent in analogous conditions. The fact that children can be more susceptible than adults (Sohail et al., 2021a) showed that the HQ in inhabitants and locals suggests that the hazard quotient for diverse metals found no hazard to residents (Sohail et al., 2020).

Figure 4 shows the relationship of TDS with anions, cations, the relationship of As and Fe, and principal component analysis (PCA) in Islamabad water samples. These analyses provide a mechanism for prediction and can help to determine the nature of the association between diverse variables. In the current study, Pearson's correlation was utilized for parameters, which indicated that a robust positive correlation also occurs among TDS and EC and showed a positive relationship with hardness, Mg, alkalinity, HCO_3, Cl, Na, NO_3, Ca, and SO_4 and are more significant relationship pairs. The relationship of TDS with cations

FIGURE 4 | Relationship of TDS with (A) cations, (B) anions, (C) relationship of As and Fe, and (D) principal component analysis (PCA) in Islamabad water samples (Sohail et al., 2020).

FIGURE 5 | Populace rate in Islamabad city.
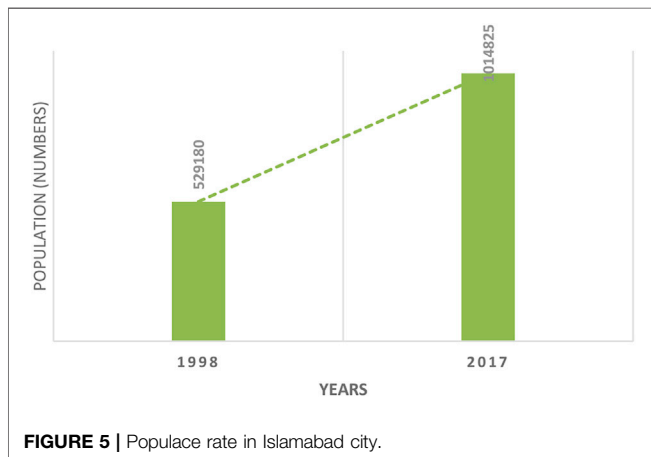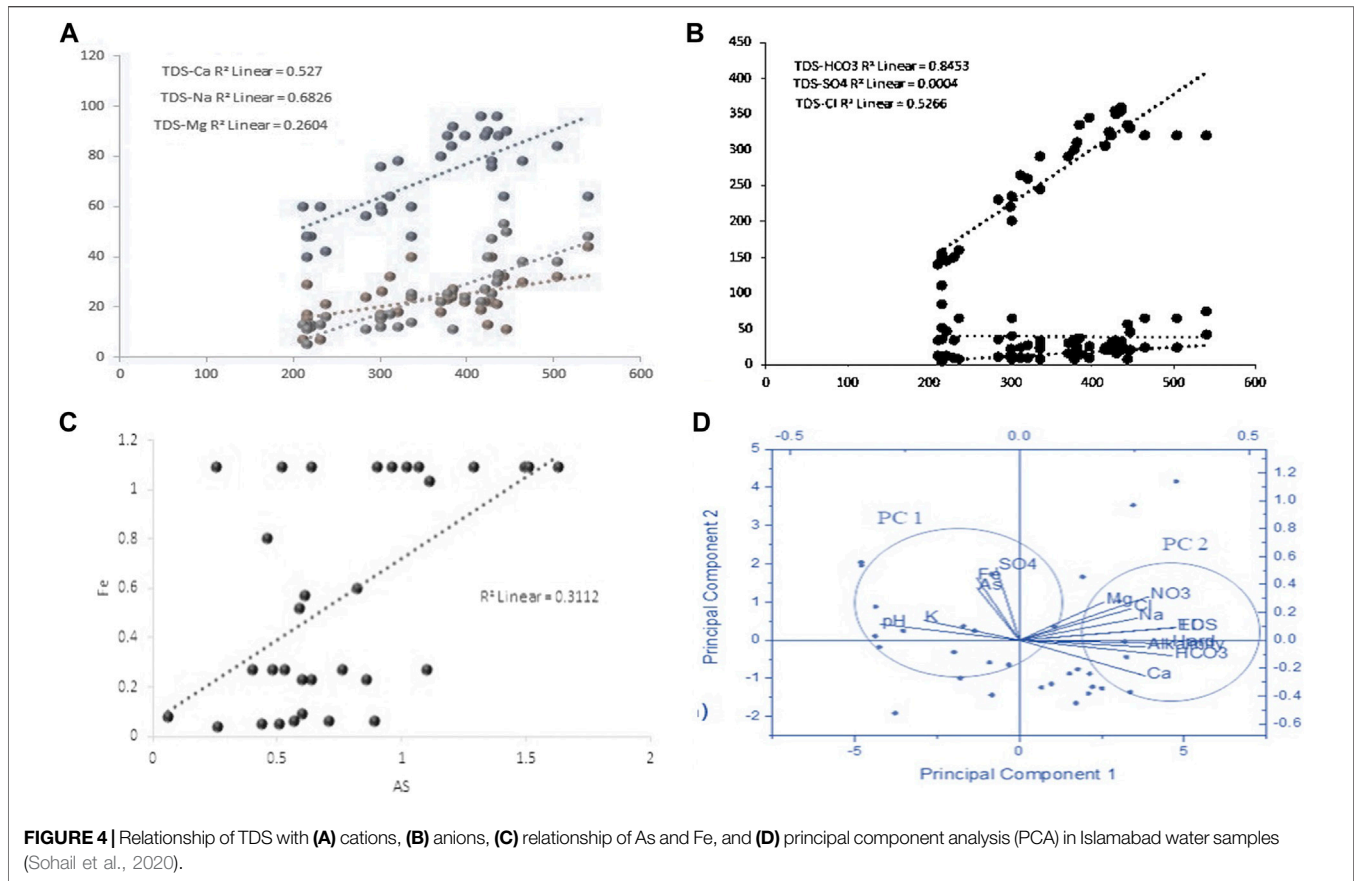
(Figure 4A) showed a significance positive correlation with the R2 value of Na^+ (0.682), Ca^{2+} (0.527), and Mg^{2+} (0.260), and there was a positive relationship between TDS and anions, including the R2 value of Cl^- (0.526), HCO_3^- (0.845), and weakly with SO_4^{2-} (0.0004) (Figure 4B). The outcome showed that As had a positive connection with Fe (R2 = 0.311) (Figure 4C) (Sohail et al., 2020). Figure 4D shows the PCA for filtration plants' water samples. The values of K, pH, As, and Fe lie in PC1 with negative values exposing high variance, while some other parameters lie in PC2 with positive values, low variance, and are closer and more reliant on each other. The percentage alterations varied: EC (14.66%), pH (54.6%), TDS (8.01%), hardness (3.27%), Ca (6.80%), Mg (4.90%), HCO_3 (1.77%), alkalinity (2.75%), NO_3 (0.16%), Cl (1.36%), Na (1.11%), K (0.54%), SO_4 (0.04%), Fe (0.01%), and As (0.02%) (Piper, 1944; Jain et al., 2018; Sohail et al., 2020).

Population Growth

Pakistan is facing huge urbanization with a decrease in the rural area population from 61.4% in 2014 to 60.1% in 2016 and an increase in the urban area from 38.5% in 2014 to 40% in 2016. As per government censuses in 1998 and 2017, the inhabitants of Islamabad city numbered 529,180 in 1998, and increased to 1,014,825 in 2017 (Sohail et al., 2020) (Figure 5). The increase in the population of Islamabad may be due to the availability and easy access of basic services that promote community, economic, and equality opportunities. Young people migrate to big cities for good education, medical care, and due to increased employment opportunities (Sawas, 2013). One other reason of high urbanization in Islamabad is refugees from Afghanistan, they came to Pakistan and most of them settled in or nearby Islamabad (Kugelman, 2013). It can be very

challenging for the local government to offer all basic needs to all local settled people while having limited resources (Sawas, 2013).

Source: Pakistan Bureau of Statistics, population census 1998 and 2017 GoP (Sohail, M. T., 2020).

DISCUSSION AND CONCLUSION

The present study was about public awareness of health risk assessment and water quality in Islamabad, Pakistan. As per public response, most respondents felt they were well aware (61.1%) of health safety and water quality and drinking water of filtration water plants, and about 40.2% of respondents paid attention to local water quality. Only 46.4% of respondents were very satisfied with their drinking water quality, 17.1% were highly satisfied, while 36.4% were totally unsatisfied and it must be a concerning point for relevant authorities. Educational level and specific education related to water quality and health assessment could affect public awareness of drinking water quality. Among all explanatory determinants, gender (*p*-value of 0.01 and coefficient of 0.137), age (*p*-value of 0.013 and coefficient of −0.058), and educational level of the public (with *p*-value of 0.025 and coefficient of 0.081) were significant with water quality. Results of all parameters were compared with WHO allowable boundaries for drinking water, and alkalinity, EC, and arsenic were higher, and at the same time, arsenic was the main reason for

water contamination. Health hazards with values of 1.06E+02 among children can be a big challenge. The water quality index was calculated and most of the samples that were poor quality were found to be unsafe. Proper supervision should be taken for filtration plants installed in Islamabad. Public satisfaction can be enhanced by dissemination of the status of water quality in government reports via social media, print media, and television. This study was carried out in Islamabad, Pakistan, the implications of this study may be used for this city and for similar regions.

AUTHOR CONTRIBUTIONS

This idea was given by MS. ME and SR and EE collected literature review, while NA and HI read and approved the final version.

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