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Monitoring of physiochemical quality of drinking water in selected areas of Bahawalpur City, Pakistan

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Abstract

The quality of groundwater is rapidly deteriorating and becoming unfit for human use in developing countries like Pakistan. Therefore the present study was conducted in Bahawalpur City, Punjab, Pakistan with the main objective to analyze and monitor the water quality in selected sample areas of Bahawalpur City. In order to meet the objective of the study, water samples have been taken from selected five residential areas in Bahawalpur City i.e. Model Town A, Model Town B, Shahdrah, Satellite Town and Islami Colony and were tested in PCRWR regional laboratory. The findings of the study clarified that the quality of groundwater, the most common source of drinking water in Bahawalpur city is rapidly being deteriorated due to various intervening factors i.e. rapid population growth, waste disposal, seepage of toxic ingredients, etc. The physiochemical analysis of the water samples of selected sites show identifiable variations in various parameters and was compared with WHO and PSQCA drinking water standards. EC, Hardness, TDS, Calcium, Chloride, Potassium, Sodium, Sulfate and Nitrate were considerably above the permissible limits in Shahdrah, Satellite. Town and Islamic Colony. Similarly, Arsenic and iron contaminations were also high than the permissible limits. Therefore, the study suggests that prompt action is required from the district government to check the bad quality of drinking water. For regular, accessible and safe drinking water supply, the government should installed more filtration plants in the city's congested areas. The collaboration of the public-private partnership should be encouraged to better water management and delivery services.

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Introduction

As a basic human right, the availability and access to safe potable water have top priority regarding secure human health. Nowadays, safe drinking water has become a chief issue worldwide because of the rapidly increasing population and pollution (Singh and Mathur, 2005). In Kurdistan region, Iraq the values of turbidity, TDS and RSC were high in some sites and on the basis on drinking water standards exposed that water in the Bawashaswar Dam needs adequate handling before supply for human consumption (Sarhat *et al.,* 2018). It is also revealed in a study conducted in Republic Ghana, that the color and turbidity levels of the water samples exceeded its acceptable limit and making the water insecure for drinking (Baako *et al.,* 2018). Another study shows that water sources utilized for drinking in Isiolo County (Kenya) were not safe for drinking and food processing operations, as their microbial Fig.s in the water sources vary significantly. This is because of the efforts that are being made for a long time to get access to secure drinking and food processing water on the community-based water sources (Onyango *et al.,* 2018; Michael *et al.,* 2015; Muhammad *et al.,* 2017).

But unluckily, the quality of drinking water in developing countries is continuously being contaminated and hazardous for human use due to fast population growth, industrial development, disposal of wastewater and chemical effluents into water sources. Notably, inappropriate disposal of municipal and industrial and wastes is one of the leading factors caused pollution of the water. It is still one of the major concerns in developing countries like Pakistan (Mohsin *et al.,* 2013; Nabeela *et al.,* 2014; Mumtaz *et al.,* 2017). In a study conducted in major cities of Punjab Province, Pakistan, it is found that 75% water samples from Multan, 60% from Bahawalpur, 45% from Sheikhupura, 31% from Lahore, 30% from Kasur and 7% from Gujranwala were highly unsafe due to the arsenic values' exceeding the WHO limits (Hagras, 2013). This is perhaps due to the quality of drinking water, which is not managed adequately in both rural and urban areas of Pakistan (Khan *et al.*, 2012).

In Pakistan, various studies pinpoint the deteriorating quality of water in many cities that are becoming unsafe and hazardous for human use. The survey results of a study conducted in district Vihari, Punjab showed that 48.6% of the respondents were agreed that drinking water of their area is not good (Khalid *et al.*, 2018). Whereas in a study conducted in Bahawalpur found that 83% of respondents were agreed that access to safe drinking water is a major problem affecting their social life (Safdar *et al.*, 2014).

In Pakistan, about 70% of the people depend on groundwater for their household uses. But due to contamination, micro-biological pollution, poor water supply lines and damaged drainage system majority of them have not adequate access to safe drinking water (Malik *et al.*, 2010; Farrukh *et al.*, 2004). Likewise, in Faisalabad, a physicochemical study of textile wastes and groundwater revealed that the effluents emitted from the textile industries have a greater impact on groundwater quality. Resultantly, this caused many diseases among people (Taj *et al.*, 2013; Tanwir *et al.*, 2003).

The contamination of water is the main source of waterborne diseases like hepatitis, diarrhea, headache, hypertension, abdominal pain, kidney and liver problems and disastrous cardiac arrest (Shah *et al.,* 2012). A study conducted in Bahawalpur City to evaluate the sharp water decline and degrading water quality reported that due to the bad quality of water many severe waterborne diseases are common in study areas i.e. Satellite town, Shahdrah and Islami colony (Mohsin *et al.* 2013). Some common diseases found in a study in southern Sindh Province were gastroenteritis, diarrhea and vomiting, kidney, and skin problems (Memon *et al.,* 2011).

Due to poor quality of water in the Charsadda District of Khyber Pakhtunkhwa, Pakistan, majority of the residents were suffering in diarrhea (up to 59%), gastroenteritis (up to 50%), and dysentery (up to 35%) respectively (Khan *et al.,* 2013b). So, it is essential in order to cut down the health risk, government take immediate action to cease the

contaminated drinking water and should supply clean drinking water to the public (Shah *et al.,* 2012). It is therefore vital to regularly monitor the quality of groundwater (Rao *et al.,* 2012).

Thus, keeping in concern the worse situation of water contamination, this study aims to highlight the issue of bad quality of water in Bahawalpur city. Although, previously few studies have been undertaken on the water quality issue in Bahawalpur. But current study investigates the issue in accordance with analysis of the selected physiochemical parameters and make their comparsion with WHO and PSQCA standards simultaneously. Moreover, the use of GIS mapping also enhance the comprehension of the bad and deteriorated water quality areas. Therefore, the main objective of this study was to analyze and monitor the water quality in selected sample areas of Bahawalpur City and recommend few suggestions to over come the issue and make possible the availability of safe potable water.

Material and methods

Study Area

The study area Bahawalpur City is located in Southern Punjab. It lies between 27°-80' to 29°-50' north latitudes and between 70°-54' to 72°-50' east the longitudes (Fig. 1). It has a warm dry climate with a mean annual rainfall of lesser than 10 inches. Therefore, the location of Bahawalpur also contributes to aggravating the problem of safe water availability and quality. Hence the issue of water availability and particularly safe water quality has had immense value for its residents.

Collection of Water Samples and Sample Sites

In order to meet the objective of the study, water samples have been taken from selected five residential areas in Bahawalpur City i.e. Model Town A, Model Town B, Shahdrah, Satellite Town and Islami Colony (Fig. 1). These five areas have different characteristics regarding the living standards, houses outlook, residents fiscal and social conditions, infrastructure and public amenities like roads, paved streets, parks, better sanitation, and sewerage. But the quality of water is a common issue among all of these and the rest of the city. Water samples collected from electric water pumps as it the most commonly used source for drinking and other household uses.

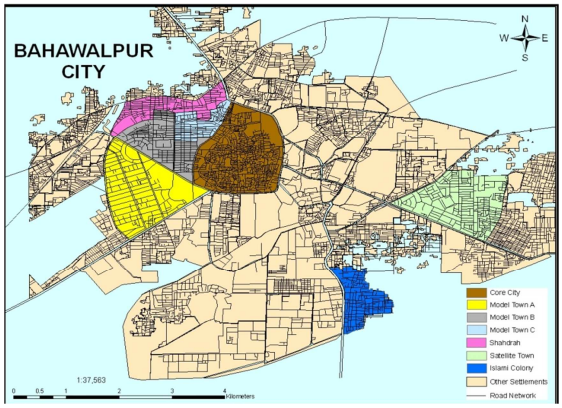

Fig. 1. Sample Study Sites in Bahawalpur City.
Source: Authors (2018).

Water Analysis, Discussion, and Mapping

The collected samples were tested for physiochemical and microbiological parameters in Pakistan Council of Research in Water Resources (PCRWR) regional lab to make a comparison of these with standards set by World Health Organization (WHO) in 2004 and Pakistan Standard Quality Control Authority (PSQCA) in 2010. The findings of the various parameters were discussed in the light of previous studies conducted in Pakistan's different cities to identify and make a strong comparison with permissible and exceeding limits of various parameters. The ultimate maps of the water quality of the study area were developed using ArcGIS 10.3 software to visual monitor visually.

Results and Discussion

Important parameters of drinking water quality

There are various sources of drinking water contamination in Pakistan, especially bacteriological contamination is a serious problem throughout the country. Pakistan Environmental Protection Agency (Pak-EPA) (2008) presented national standards of drinking water quality (NSDWQ).

Main parameters for determining the quality of drinking water are physical, chemical including both organic, inorganic and bacterial (Table 1).

Presence of all these parameters according to the standard defined by NSDWQ is essential for safe drinking water. Any parameter in excessive or deficient amount could pose serious threats to human health.

However, in general opinion, the quality of water for drinking purposes is determined by its faint color, brackish taste or by its bad smelling in Pakistan. But these are not the absolute parameters to determine safe quality water.

Table 1. Important parameters for safe drinking water

Standards	Parameters		
Physical	Color, taste, odor, hardness, turbidity, TDS and Ph		
Biological	E. Coli and Coliforms		
Chemical	Organic	Inorganic	Toxic Inorganic
	Pesticides, PAH (Polynuclear aromatic hydrocarbons)	Aluminium (Al), Arsenic (As), Barium (Ba), Cadmium (Cd), Chloride (Cl), Chromium (Cr), Copper (Cu).	Fluoride (F), Lead (Pb), Mercury (Hg), Nickel (Ni), Nitrate (NO_3), Zinc (Zn)

Source: Pak-EPA. (2008).

Table 2. Groundwater quality in Bahawalpur City in 2012.

Water quality parameters	Total samples analyzed	Contaminated samples	Contaminated samples (%)
Color	20	15	75
Hardness	20	1	5
Magnesium	20	11	55
Ph	20	0	0
TDS	20	0	0
Calcium	20	6	30
Sodium	20	10	50
Sulfate	2 0	1	5
Chlorine	20	2	10
Iron	20	17	85
Nitrate	20	0	0
Fluoride	20	11	55
Arsenic (ppb)	20	13	65

Source: Mehmood *et al.,* (2012).

Note: Amount of Parameters in Mg/Liter, TDS= Total Dissolved Solids.

A study conducted in Bahawalpur City concluded that 20 water samples collected from different residential areas of Bahawalpur City were tested. The physiochemical and microbiological analysis of the parameters of these samples i.e. pH, E. coli, Hardness, amount of nutrients and bacterial assessment were used for evaluation of water quality (Table 2). Results cleared that the concentrations of various physiochemical parameters were exceeding permissible limits set by WHO and PSQCA i.e. color 75%, Magnesium 55%, Calcium 30%, Sodium 50%, Iron 85%, Fluride 55%, and Arsenic 65% were contaminated respectively (Mehmood *et al.,* 2012).

Water quality of sample areas

The sample areas (e.g. Model Town A, Model Town B, Shahdrah, etc.) were mainly congested residential areas. The collected water samples from these localities have been tested in the PCRWR laboratory. The obtained report of general water quality sample areas was not satisfactory (Table 3). Out of five water samples, three were found unfit for human use either chemically or microbiologically. the In Satellite Town, water sample has been found unfit for drinking purposes in both terms chemically or microbiologically. In Model Town A, groundwater is found microbiologically contaminated. The groundwater of Islami Colony is found chemically unsafe for human use while in Model Town B and Shahdrah, it was safe with maximum acceptable values (Fig. 2 and Fig. 3). In fact, the use of GIS technology in order to demark the areas having deteriorating water now increasingly enhancing. Due to its visual effectiveness, detection, analytical capability to identify the water quality and suitability of the areas, it is employed to monitor the water

quality and its contamination issues in various localities of Pakistan (Ashraf *et al.,* 2015; Zafar *et al.,* 2017; Aleem *et al.,* 2018). Moreover, the target of government of Punjab to set-up 314 water filtration plants in province four districts namely Lahore, Kasur, Okara, and Bahawalpur were not accomplished. Although the federal government had released a huge grant of PKR 830 million for this target, yet only 22 filtration plants were been installed and functional at that time (The Express Tribune, 2015).

Table 3. Quality of drinking water in sample areas.

Station name	Quality of water	
	Chemically	Microbiologically
Model Town A	Safe	Unsafe
Model Town B	Safe	Safe
Shahdrah	Safe	Safe
Satellite Town	Unsafe	Unsafe
Islami Colony	Unsafe	Safe

Source: PCRWR (2018).

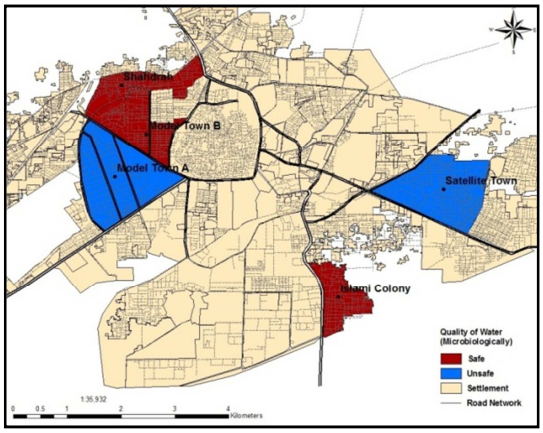

Fig. 2. Quality of water (chemically) in sample areas.

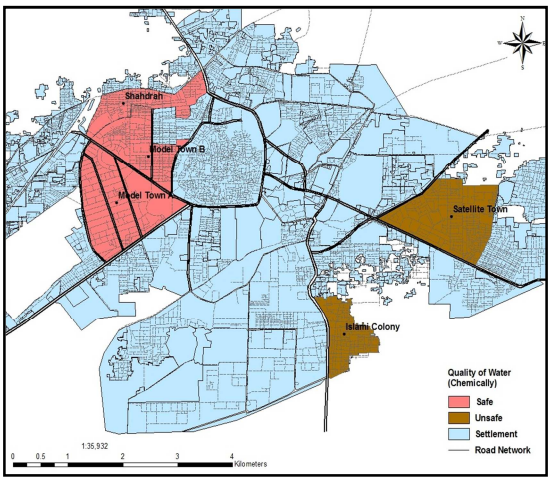

Fig. 3. Quality of water (microbiologically) in sample areas.

Analysis of physical parameters

Table 4 shows the laboratory results of sample areas groundwater. Among the physical parameters, the color of the sampled water was colorless shows no prominent coloring. The Electrical Conductivity (EC) demonstrates the concentration of ions that is determined by the dissolved solids.

The recommended EC value of WHO should not exceed 400 µS/cm while the PSQCA recommended the EC value of 1,000 µS/cm. In study areas except for Model Town B (377 µS/cm) and Model Town A (470 µS/cm), the rest of the areas have high concentrations of EC, i.e. in Shahdrah, Satellite Town, and Islamic Colony these were 1,164 µS/cm, 3,572 µS/cm, and 2,908 µS/cm respectively. Hardness another important physical parameter of water that shows the contents of the minerals normally not fatal for humans. In study areas, the Hardness was 240 (Model Town A), 190 (Model Town B), 430 (Shahdrah), 960 (Satellite Town) and 720 (Islami Colony) mg/l respectively. According to WHO and PSQCA, the maximum permissible limit of hardness in drinking water is 500mg/l.

The results clear that the Hardness value was above permissible limits in Satellite town and Islami Colony whereas, in Model Town A, Model Town B, and Shahdrah the value of Hardness was under the permissible limits. The Total Dissolved Solids (TDS) is the accumulation of a number of inorganic and organic salts in the water i.e. potassium, magnesium, chlorides, sodium, etc. The WHO and PSQCA permissible limits of TDS in water are 1,000 mg/l. The obtained results of study areas clear that TDS found 301 (Model Town A), 241 (Model Town B), 745 (Shahdrah), 2,268 (Satellite Town) and 1,861 (Islami Colony) mg/l respectively.

These results show that TDS was in within the permissible limits in Model Town A, Model Town B, and Shahdrah whereas in Satellite Town and Islami Colony the value of TDS considerably high than the WHO and PSQCA standard limits. A study conducted in Tehsil Mailsi, district Vihari, Punjab concluded

that the share of TDS in groundwater was above 81.5% than the WHO allowable limit (Abbas *et al.,* 2014). Similarly, the pH values in study areas were in Model Town A (7.55), Model Town B (7.83), Shahdrah (7.5), Satellite Town (7.43) and Islami Colony (7.71) respectively. According to WHO and PSQCA standards, the pH should not be within 6.5-8.5. Hence, the pH values of the study areas were in within the recommended value. Khan *et al.,* (2013) conducted a study in selected urban areas of district Mardan (KPK). Samples were collected from the various groundwater sources i.e. hand pumps, tube wells, and open wells. Different physical parameters i.e. odor, color, taste, temperature, EC, turbidity, TDS and pH were tested. Results showed that TDS, hardness, taste, and EC of drinking water was crossing the WHO and PSQCA allowable limits. Similarly, Mumtaz *et al.,* (2017) conducted a study in selected sampling locations of Tandojam city (Sindh) and found that the laboratory analysis of the various water quality parameters exposed high variations in the groundwater i.e. TDS, hardness, sodium, chloride, and magnesium, etc. was considerably beyond the WHO permissible limits.

Analysis of chemical parameters

Among the chemical parameters, the Calcium (Ca) values in study areas were 48 (Model Town A), 36 (Model Town B), 100 (Shahdrah), 264 (Satellite Town) and 144 (Islami Colony) mg/l respectively. According to WHO standards, the range of Calcium should not be exceeded 75 mg/l while the PSQCA recommends the Calcium value of 100 mg/l. These results suggest that the range of Calcium in study areas was exceeded in three areas (Shahdrah, Satellite Town and Islami Colony) and permissible in two areas (Model Town A and B). Chloride (Cl) that is obtained from hydrochloric salts and essential in metabolic activity and other human body functions (Mohsin *et al.,* 2013). In study areas, the amount of Chloride was found 19.5 (Model Town A), 10 (Model Town B), 127 (Shahdrah), 450 (Satellite Town) and 287 (Islami Colony) mg/l respectively.

The permissible limits of WHO and PSQCA for Chloride is 250mg/l. Thus the values of Chloride were higher in Satellite Town and Islami Colony whereas it was in permissible limits in Model Town A, Model Town B, and Shahdrah.

Table 4. The Physiochemical parameters results of groundwater in sample areas.

Parameters	Model Town A	Model Town B	Shahdrah	Satellite Town	Islami Colony
Physical Parameters					
Color	Colorless	Colorless	Colorless	Colorless	Colorless
EC	470	377	1,164	3,572	2,908
Hardness	240	190	430	960	720
TDS	301	241	745	2,268	1,861
Ph	7.55	7.83	7.5	7.43	7.71
Chemical Parameters					
Calcium	48	36	100	264	144
Chloride	19.5	10	127	450	287
Magnesium	29	24	44	73	87
Potassium	5.6	3.8	5.5	12.1	10.2
Sodium	27	14	87	396	341
Sulfate	42	24.57	133. 35	1,020	865
Nitrate	0.4	0.3	0.70	1.001	2.78
Other					
Microbiology	+ve	-ve	-ve	+ve	-ve

Source: PCRWR (2018) Note: Amount of Parameters in Mg/Liter= Mg/l, TDS= Total Dissolved Solids.

Magnesium (Mg) is also an important element crucial for organisms body functioning. As per the WHO, the permissible limit of Magnesium is 150 mg/l while PSQCA set the admissible limit of Magnesium 100mg/l. In study areas, the magnesium values were found 29 (Model Town A), 24 (Model Town B), 44 (Shahdrah), 73 (Satellite Town) and 87 (Islami Colony) mg/l respectively. These values suggest that the Magnesium was under the permissible limits of WHO and PSQCA. Potassium (k) another important element for living organisms and highly reactive with water was found 5.6 (Model Town A), 3.8 (Model

Town B), 5.5 (Shahdrah), 12.1 (Satellite Town) and 10.2 (Islami Colony) mg/l respectively. According to WHO, the permissible limit of Potassium is 12mg/l whereas PSQCA recommended limit is 10mg/l, therefore the values of Potassium were found under the permissible limit except in Satellite town where it is slightly higher (12.1mg/l) than the permissible limits. Sodium (Na) is a very crucial element for humans for the prevention of various fatal diseases (e.g. kidney stone, headache, hypertension, etc). Sodium values were found 27 (Model Town A), 14 (Model Town B), 87 (Shahdrah), 396 (Satellite Town) and 341 (Islami Colony) mg/l respectively. The WHO permissible limit for Sodium is 200mg/l while PSQCA allows a maximum limit of 50mg/l.

The obtained values clear that the Sodium in drinking water in three study areas was very under the maximum limit (Model Town A and Model Town B) while in Shahdrah, Satellite Town and Islami Colony it crosses the permissible limits significantly that could be dangerous for humans. Sulfate (SO_4) is the highly dissolute form of sulfuric acid in water. In study areas Sulfate found 42 (Model Town A), 24.57 (Model Town B), 133.35 (Shahdrah), 1,020 (Satellite Town) and 865 (Islami Colony) mg/l respectively.

The WHO and PSQCA recommended the permissible limit of Sulfate 250mg/l but results show that Satellite Town and Islami Colony have high Sulfate concentration in drinking water that might be caused several diseases whereas, in Model Town A, Model Town B, and Shahdrah have lower Sulfate concentrations. Nitrate (NO_3) is an important parameter in water that could be caused diseases i.e. blue baby syndrome in infants (Mohsin *et al.,* 2013). In study areas, Nitrate found 0.4 (Model Town A), 0.3 (Model Town B), 0.70 (Shahdrah), 1.001 (Satellite Town) and 2.78 (Islami Colony) mg/l respectively. The WHO suggests the permissible limit of Nitrate is 10mg/l and PSQCA recommends 1.0mg/l in drinking water. The derived results exhibit that the Nitrate in drinking water of study areas was in permissible limits except for Satellite Town and Islami Colony where it crosses the PSQCA limits. Lastly, the microbiological results of study areas show that only the drinking water of Model Town A had positive regarding its microbiology whereas rests of the four areas have negative microbiology in their drinking water as Mehmood *et al.,* (2012) reported that about 75% of water samples were influenced by coliform bacteria in Bahawalpur city.

Indeed, the groundwater quality in Pakistan now becoming a serious menace for the citizens and significant concerns are rising on the quality and quantity matters and its related waterborne diseases. Various studies have identified this burning issue in an explicit view. For instance, a detailed study conducted by Khan *et al.,* (2012) urban and rural areas of Kohat district to examine the quality of drinking water. Various physicochemical parameters including pH, TDS, chloride, calcium, magnesium, hardness, etc. were analyzed. The results of parameters showed variations from the WHO and PSQCA standards. Wells and tanks were the most polluted sources among various sources, Ullah *et al.,* (2009) found that in Sialkot, an industrial city of Punjab, Pakistan the concentrations of Sulphate, Chloride, EC, TDS, hardness, iron, etc. were above the allowable limits set by WHO. Khalid *et al.,* (2018) conducted a study in Vihari district of Punjab, Pakistan to examine the various physiochemical parameters and concluded that the levels of EC, TDS, Nitrate, Potassium, Calcium, Chloride and Sodium were crossed the WHO standards. Kandhro *et al.,* (2015) conducted a study in Nawabshah City, Sindh, Pakistan to analyze the various physiochemical parameters. Results show that the values of parameters in the majority (70%) of groundwater samples were beyond the prescribed levels established by WHO. Thus, out of 60 water samples, just four samples were fit for human use.

Iron and arsenic contamination in drinking water

Apart, Arsenic and iron contamination are also the main water contamination in Bahawalpur City. The permissible limits of Iron as per WHO and PSQCA standards are 0.5mg/l and 0.03mg/l respectively. Iron accumulation increases from 0.65mg/l to 1.16mg/l in 2 years in Model Town A. while in

Satellite Town, it increases from 1.70 to 5.28 in 2011 (Table 5). Arsenic causes serious health issues (skin problems, cancer) due to high levels of toxicity worldwide particularly in developing countries i.e. Pakistan, Bangladesh and others (Jiang *et al.,* 2013; Shankar *et al.,* 2014). In Pakistan, a recent study evaluated 228 groundwater sources in 6 villages and found that about 89% of water sources were exceeding the WHO prescribed limit of Arsenic 10mg/l (Rasheed *et al.,* 2017).

It is also estimated that the many developing countries throughout the world crosses the WHO permissible limit of Arsenic 10 ppb to above 50 ppb (Chakraborti, 2016). The WHO and PSQCA permissible limits of Arsenic are 10mg/l or parts per billion (ppb) and 0.01mg/l or part per million (ppm) respectively. In study areas, the accumulation of arsenic marks an increase from 30 ppb in 2002 to 61 ppb in 2004. In 2002 and 2004 water samples have been collected from the same points and are tested by PCRWR. In 2011 samples were collected from different points and were tested in different ways. Regardless of minor variations in all results, one thing is common; that all samples from different sample areas have iron and arsenic contamination well above the acceptable range of WHO and PSQCA. Thus, The high amount of iron and arsenic contamination makes water unfit for human use.

Table 5. Arsenic and iron contamination in sample areas in different years.

Area name	Iron (mg/l) contamination			Arsenic (ppb) contamination		
	2002	2004	2011	2002	2004	2011
Model Town A	0.65	1.16	0.72	30	53	40
Model Town B	-	-	3.47	-	-	50
Shahdrah	-	-	3.3	-	-	70
Satellite Town	5.7	1.70	5.28	30	61	-
Islami Colony	-	0.78	3.7	-	50	60

Source: PCRWR (2002), PCRWR, (2004), Mehmood *et al.,* (2012).

Conclusion and suggestions

The findings of the study suggest that the quality of groundwater, the most common source of drinking water in Bahawalpur city is rapidly being deteriorating due to various intervening factors i.e. rapid population growth, industrial augmentation, waste disposal, seepage of toxic ingredients, etc. The physiochemical analysis of the water samples of selected sites shows identifiable variations in various parameters i.e. EC, Hardness, Calcium, Sodium, Sulfate, Nitrate, Iron, Arsenic were considerably above the permissible limits set by WHO and PSQCA in different study areas and posing serious health concerns for residents. Particularly, the values of iron and arsenic were much higher in Satellite Town groundwater that is highly alarming for water consumers. Moreover, Microbiological results of the drinking water were also negative except Model Town A and Satellite Town where these were positive. Thus, making groundwater unsafe and hazardous for human use. Therefore, the prompt action is required from the district government to check the bad quality of drinking water. For regular, accessible and safe drinking water supply, the government should installed more filtration plants in the city's congested areas. Additionally, in order to achieve a more efficient supply of quality drinking water, the collaboration of the public-private partnership should be encouraged. The private sector should provide facilities in better water management via home delivery services and selling of tested bottled water at an affordable price.

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