International Journal of Chemistry; Vol. 14, No. 2; 2022
ISSN 1916-9698 E-ISSN 1916-9701
Published by Canadian Center of Science and Education

Analysis of Water Quality Using Physico-Chemical Parameters in Different Cities of Pakistan

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Received: June 22, 2022 Accepted: August 4, 2022 Online Published: October 19, 2022

doi:10.5539/ijc.v14n2p28 URL: https://doi.org/10.5539/ijc.v14n2p28

Abstract

Present study was carried out to assess different parameters (physiochemical) of water for public health safety. 25 samples from majority of areas of Khyber-Pakhtunkhwa (KP) along with Rawalpindi and Islamabad were chosen. Total twelve parameter which include color, odour, pH, TSS (total suspended solids), TDS (total dissolved solids), Na (Sodium), K (Potassium), hardness, alkalinity, EC (Electric Conductivity), Cl (Chloride) and SO_4 (Sulphate) were assessed for each sample and were compared with WHO and other limits. Results showed that very few samples 3 out of 14 in Mardan, 5/12 in Bannu, 2/11 in Buner, 3/4 in Batkhela, 1/6 in Malakand, 2/4 in Shangla, 3/18 in Mansehra, 2/7 in Karak, 1/17 in Kohat, 2/5 in Upper Dir, 3/12 in Islamabad, 3/11 in Abbottabad and 2 out of 17 samples were found to have objectionable color and odour. None of the samples exceeded the permissible limit of WHO for pH, TDS, alkalinity, Cl and SO_4. While, other parameters like TSS was higher in 9 samples, Na in 2, K in 6, hardness in 1 and EC in 7 as compare to permissible limit. It was recommended that proper water treatment especially effective chlorination with residual chlorine be rendered at all sources in order to achieve safe water quality up to the consumer's end. However, it is also important to investigate other potential water contaminations such as chemicals and microbial and radiological materials for a longer period of time, including human body fluids, in order to assess the overall water quality of Pakistan.

Keywords: water, physic-chemical, public health, water quality, Pakistan

1. Introduction

Water is the major constituent of the world, which sustains life on earth and the human beings depend on it for their survival. The 71% area of our planet is covered by water in which only 1 percent of water is used by human beings. The 99 percent of such available water (1 percent is surface water) is located underground (Lewis et al. 1994). The importance of water for living creatures cannot be neglected because it is the major constituent of human body, raw material for photosynthesis and need for other agricultural production (Sachidananamurthy and Yajurvedi 2006). Shengji et al. (2004) claimed that 75% of communicable illnesses are resulted due to water, while Abera etal. (2011) also asserted that 80% 0f such diseases are water borne.Water plays an important part in the economy of a state in numerous fields, which include fisheries, livestock, and other industries (Tyagi et al. 2013). However, deterioration in water quality leads to the death of these organisms (Kukrer and Mutlu 2019). In Pakistan, the groundwater and canal water are mostly used for drinking purposes (Kahlown et al. 2002; Watto et al. 2004).

Today, water pollution is a serious problem threatening both seas and inland waters. Pollutants discharged into the water disturb the balance of the ecosystem as well as leading to significant problems in terms of public health by impairing the quality of domestic and drinking water (Kukrer and Mutlu 2019). Numerous factors contribute to the contamination of water i.e. increased population, industrialization, use of fertilizers in agricultural activities and other human activities. In Pakistan, water pollution is a potential risk to human health due to poor management and poor monitoring of drinking water (Khan et al. 2013). Hence, the quality of water is assessed by various parameters like color, odour, pH,

hardness, Ca (calcium), Mg (Magnesium), TSS (Total Suspended Solids), TDS (Total Dissolved Solids), Mn (manganese), Na (sodium), K (potassium), Cl (Chloride), SO_4 (sulphate) and NO_3 (Nitrate) etc (Dohare et al. 2014). The water-quality of an area is assessed by physical (EC, TDS), chemical (pH, Mn, Na, Ca, K) and biological properties (coliform bacteria) (WHO 2003). Though, some trace elements are beneficial for human beings in certain amount but their overdose may create several complications for health (Mastoi et al. 2008; WHO 2004). Nevertheless, these aforementioned properties of water decide the quality of water.

To test water before drinking, industrial use and agricultural use, it is the important to avoid the hazardous effect of contaminated water. In order to determine the physico-chemical properties of water, it is mandatory to perform physical test to measure temperature, color, odour, TDS and pH, while chemical analysis of water include alkalinity, hardness and dissolved oxygen. It is recommended that the water should pass the entire test to be considered fit for drinking (Patil et al. 2012). The physico-chemical properties included in our study are color, odour, pH, TSS, TDS, Na, K, hardness, alkalinity, EC, Cl, SO_4 described as below;

Color and odour are the two important physical properties of water, which are the direct indicators of chemical contamination of water. Agencies like WHO and some others recommend no color, odour and taste for drinking water (NSDWQ 2008; PCRWR 2005; WHO, 2003/2006; WHO 2006). The color of water is mainly attributed to the presence of ions of soluble metals, while odour, i.e. undesirable is due to excessive organic and inorganic particle present in water (Khan et al. 2013). Odour, the objectionable quality of water, is the result of presence of organic and inorganic constituents of water. Also, WHO and Standard set In Pakistan recommends color and odour free water for drinking and other uses.

The pH stands for the power of hydrogen ions concentration, which has indirect effects on human health by changing quality parameters of water i.e. metal's ability to dissolve besides providing suitable environment for pathogens (Ho et al. 2003). The corrosive nature of water is due to the lower pH (Guptaa 2009), while higher pH creates low photosynthesis, imbalance of Carbon dioxide, carbonate-bicarbonate, which in turn changes physiochemical properties of water (Karanth 1987). The microorganism growth and solubility of different metals depend on pH of water (Khan et al. 2013). Hence, pH indirectly affects human health by changing water-parameters.

TSS are the undissolved and suspended particles that can be separated via filtration of water and this parameter is used to judge the quality of any type of water like fresh water, waste water or ocean water etc. water is contaminated through poor sanitation, discharge of wastes into water resources and pants debris, which in turn increase TSS in water (Yasin et al. 2015). The increase of TSS is increased with increasing other soluble contents. There will be a greater number of suspended solids in water if the minerals are higher (EPA 2000).Nevertheless, the importance of TDS to assess water quality cannot be neglected.

TDS is an approximation of organic and inorganic salts that are soluble in water. It is strongly recommended to test and treat water before drinking (Baig et al. 2011; Mehmood et al. 2012). It is the totality of cations (Ca^{+2}, Na^{+}, K^{+}, and Mg^{+2}) and anions (CO_3^{-2}, SO_4^{-3}, Cl^{-}, NO^{-3}, and HCO^{-3}) as the principal inorganic constituents (NSDWQ 2008). Fawell et al. (1996) asserted that TDS is the combination of inorganic salts and organic materials assimilated in water, and the best level is 300 t0 600mg/l. Walker and Newman (2011) enforced the assessment of water before consumption. Hence, TDS are the measurable constituents that are used to measure water quality and measured by water purity measuring devices.

Na and Cl are usually found in in the human body as well as raw and natural water. Na is white metallic metal found less quantity in water and its optimum amount in human body inhibits many health problems like kidneys damage, blood pressure and head ache (WHO 1984). While, Cl are white metallic beneficial for life (Duffs 1996). Human body can tolerate and adapt to small amount of Cl but in excess it can produce taste in water and pipe corrosion (Hauser, 2001). As Cl is an oxidizing agent, so it is used as disinfectant in water treatment, but its excess can cause severe complication in human (Zheng et al. 2015). So, Na and Cl are important for human body but its excess can promote problems in body, therefore the water should be treated before drinking.

K has white crystalline structure with high thermal and EC (Burkhardt and Bruning 2002) and 7^{th} most abundant element belonging to alkali group (Lewis 1997). As we know that K is an important element for human body and rarely found in drinking water. The higher quantity of this element could produce serious consequences if it exceeded the desired limit. Usually, it can be found in environment and in natural water due to water-treatment with potassium permanganate. KCl (Potassium Chloride) is used to treat hard water in many countries. Human are exposed to K-concentration due to the consumption of K-contaminated water, which does not matter for general population but it can affect some of the population i.e. heart, diabetic and kidney patients.

The presence of Calcium and Magnesium is the cause of hardness in water because its carbonates, sulphates, bicarbonates and chlorides are determinants of hardness. Such hardness is also responsible for heavy economic losses like scaling and choking of pipes and WHO (2006) and PCRWR (2005) recommends a permissible limit of 500 ppm.

Despite these economic losses, it can also cause health complication like diarrhoea, cardio and kidneys stones (Rubenowitz et al. 1998;Shakirulla et al., 2005). Saurina et al. (2002) also considered hardness as one of the important parameters to assess the quality of water. It is also considered to check hardness of water before consumption in industrial zones because it can damage high quality products (Veiro et al. 2002). Other studies also considered hardness responsible for losses in domestic and industrial use (APHA 1999; Ghizellaoui et al. 2004; Lima et al. 2004; Park et al. 2007). Hence, hardness of water should be removed which is known as softening process (Park et al. 2007; Van der Bruggen et al. 2001).

Electric conductivity and alkalinity are also important parameters of water, which can affect the water quality. The acid neutralizing capacity of water is known as alkalinity, which varies from area to area. The higher alkalinity in any area is attributed to presence of chlorides, sulphates and carbonates (Khan et al. 2013). According to Patil et al. (2012), alkalinity stabilize pH of water and its excessiveness can cause foaming in water. While, EC of water is the potency of water to carry current due to presence of ions (Muthukumaravel et al. 2010). It does affect the health of humans directly, but it needs to be determined to check the amount of other minerals like K, Ca and Na (Cidu et al. 2011; Kavkar et al. 2009; Muhammad et al. 2011). Excessiveness of EC in water may produce taste in water and the water should be tested before industrial and agricultural consumption. It can also eliminate food plants and plants that form habitats (Jia et al. 2010; Katsoyiannis and Zouboulis 2013; Heydari and Bidgoli 2012).

Water quality parameters like Cl and SO_4 are also essential parameters that can cause water unfit for drinking due to their excessiveness. As far as SO_4 is concerned, it is almost found in all kinds of water bodies and an important constituent of hardness in water. SO_4 is objectionable in water in higher amount because it can cause serious complications like gastro and intestinal problems especially in the presence of Na and Magnesium in water. Its presence in water is the result of many factors like rainfall, use of fertilizers and mixing of minerals present in granites (Khaiwal and Garg 2007). The products formed different products like Sulphur and Sulphur oxides as a result of transformation dependent on redox-potential of water (Khaiwal and Garg 2007). Its excessiveness in water may result in serious consequences like diarrhoea, gastro and intestinal problems and dehydration (Garg et al. 2009). Hence, the water with more SO_4 should be avoided and the water should be tested before drinking.

There are a lot more important parameters such as phosphates and nitrates, total coliform, fecal coliform etc, which should be analysed for drinking water in order to determine its quality. New and advance techniques for analysis at the spot of sampling should be introduced which will not only help make the analysis easy, but also reduce the errors (human plus instruments and procedure) and increase precision and accuracy.

2. Materials and Methods

Study Area

Majority of the study areas shown in fig. 1 belong to Khyber Pakhtunkhwa (KP) province of Pakistan, which is 34.95^0 N and 72.33^0 E. Geographically, it is the smallest of all provinces and located in northwest of Pakistan along with international border with Afghanistan.

Some samples were also chosen from Islamabad and Rawalpindi previewed in Fig. 1. Islamabad is the capital and ninth largest city of Pakistan with a latitude 33.73 and longitude 73.04. While, Rawalpindi is located at 33.626057^0 latitude and 73.071442^0 longitude. It is near to Islamabad and is considered a larger city with high population.

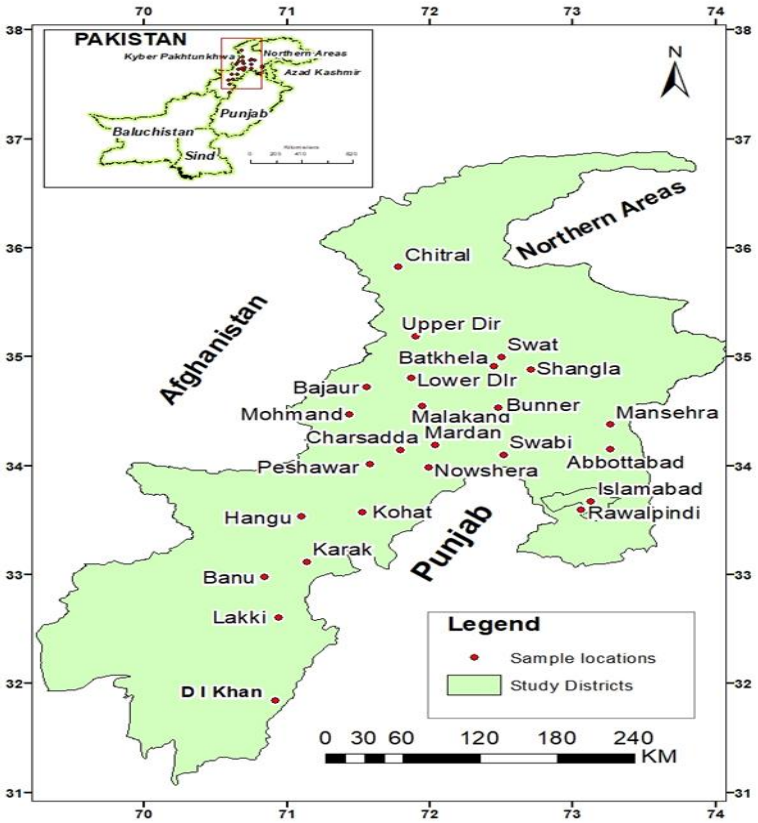

Figure 1. Location map showing areas from where water samples were collected

Water Sampling

Water samples were taken from different areas of KP, along with Islamabad and Rawalpindi. In Pakistan, the groundwater and canal water are mostly used for drinking purposes (Kahlown et al. 2002; Watto et al. 2004).

All the sampling procedures were implemented for each sample of water with proper precautions. The bottles used for water samples were cleaned and dried in order to avoid contamination. The samples were tagged to be recognised and were stored in refrigerators for further analysis (Khan et al. 2013; Lenore et al. 1998).

Physico-chemical analysis of water

Color and odour of water are assessed via sense organs. pH meter (Mettler Delta 320, England) was used to calculate pH of samples. EC was measured in laboratory by using conductivity meter (Jenway 4060, England). TSS and TDS were measured according to methods prescribed by APHA (1999) and Sawyer et al. (1994) by filtration.

Chemical properties of water like hardness was determined as mg $CaCO_3$/L, by EDTA titrimetric method, using eriochrome black-T indicator and standardized solution of ethylenediaminetetraacetic acid (EDTA). The concentration of sodium (Na+) and potassium (K+) were measured by the flame photometric method (model JANWAY PFP7).

3. Results and Discussions

Physico chemical properties of water

Use of pure water is considered safe for human health and always a matter of concern. This is a serious issue in Pakistan and for this reason this study is carried out to analyse the water quality parameters in areas of KP, Islamabad and Rawalpindi.

The contamination of water is directly assessed by the color and odour of water. Different water checking agencies recommends no color and odour in water (WHO 1996; Lenore 1998; WHO 2003; PCRWR 2005; WHO 2006: NSDWQ 2008). While, other parameters like pH, TSS, TDS, harness, alkalinity, Cl and SO_4 are also contaminants found in water.

Color and odour of water

As we know that pure or natural water is colorless and odourless but its color and odour indicate the presence of contaminants in water. Khan et al. (2013) have alleged that odour is resulted due the presence of organic and inorganic particles in water and odour is due to the presence of soluble ions. Our findings revealed that majority of the samples

collected were colorless and odourless except very few samples collected from Mardan, Bannu, Buner, Batkhela, Malakand, Shangla, Mansehra, Karak, Upper Dir, Islamabad, Abbottabad and Chitral. All samples collected from Swabi, Nowshera, Bajaur, Mohmand Agency, DI Khan, LakiMarwat, Hangu, Lower Dir and Rawalpindi were free from color and odour.

Statistically, 3 out 0f 14 in Mardan, 5/12 in Bannu, 2/11 in Buner, 3/4 in Batkhela, 1/6 in Malakand, 2/4 in Shangla, 3/18 in Mansehra, 2/7 in Karak, 1/17 in Kohat, 2/5 in Upper Dir, 3/12 in Islamabad, 3/11 in Abbottabad and 2 out of 17 samples were found to have objectionable color and odour. Hence, color and odour in water is due to the presence of ions, organic and inorganic metals (Khan et al. 2013). Previous results (Ali and Akhtar 2015; Hamid et al. 2013) found color and odour free water, while (Butt and Khair 2014) found the water of Quetta having bad taste and foul smell plus odour. Butt and Khair (2014) found water with bad taste, smell and odour, while the water of Gigit Baltistan was found free of color and odour (Ali and Akhtar 2015).

pH of water samples

Although, pH does not directly affect humans but it can affect the metals solubility in water besides providing favourable environment for disease causes agents. The lower pH of water results in acidic taste of water (USEPA 1977). Hence, current study revealed the highest recorded pH with mean of 7.86 and mean SD 0.23 for LakkiMarwat, while lowest for DI Khan i.e. 6.31with SD 2.32 as shown in Fig. 2**.** According to WHO (2011) and NSDWQ (2008), pH of drinking water should be 6.5-8.5. Our study results were within WHO limits. Previous studies conducted at Gilgit Baltistan (Ali and Akhtar 2015), Khyber (Yousaf et al. 2016), Nagar Valley (Ali et al. 2012) and Quetta (Khan et al. 2015) were found to have normal pH recommended by WHO, hence support our findings. The lower photosynthesis is the result of increased pH of water. Other factor that affect pH of water include Carbon dioxide imbalance and carbonate and bicarbonate imbalance, which are resulted due to physiochemical conditions (Karanth 1987).

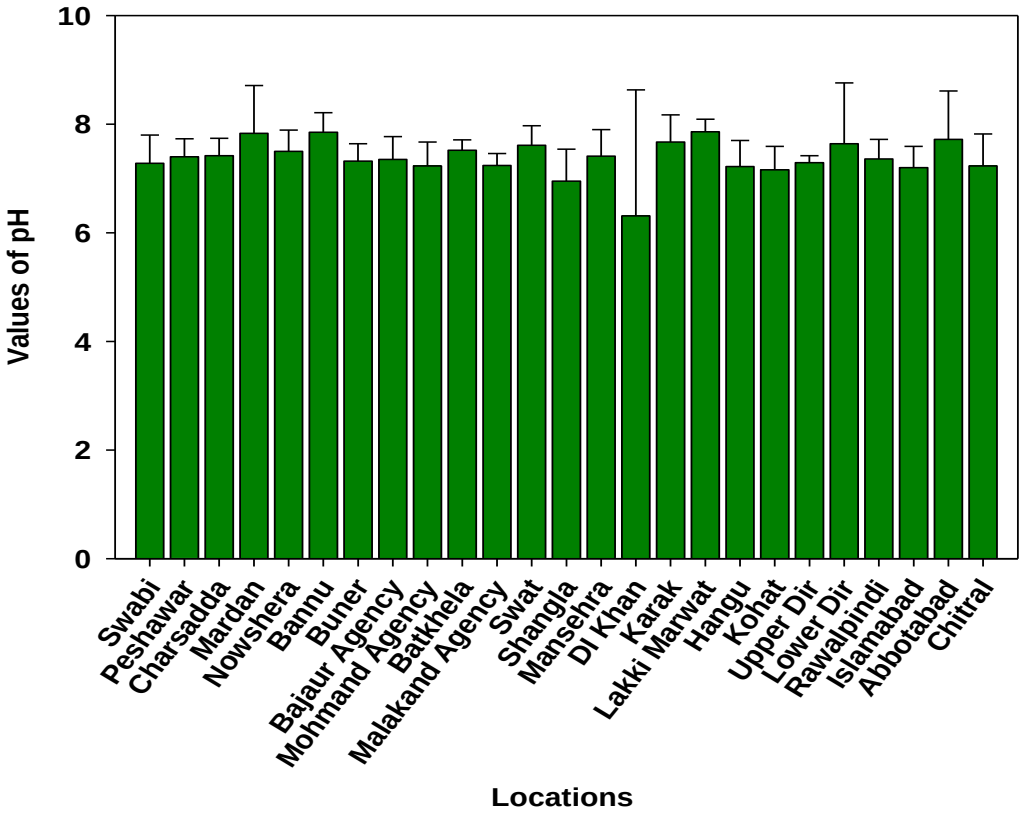

Figure 2. pH values of drinking water in different cities of Pakistan

Total suspended solid of water

TSS is also one of the parameters of water, which is used to assess the quality of water and the results portrayed in Fig.

3. Current results revealed that the mean TSS for Karak (16.93) with SD 14.41 surpassed other areas, while lowest was calculated for Mohmand Agency with mean SD 2.72. The results revealed that out of 25 samples only 9 samples out of 25 were within the recommended level of 5 mg/kg (NSDWQ 2008; WHO 2011).

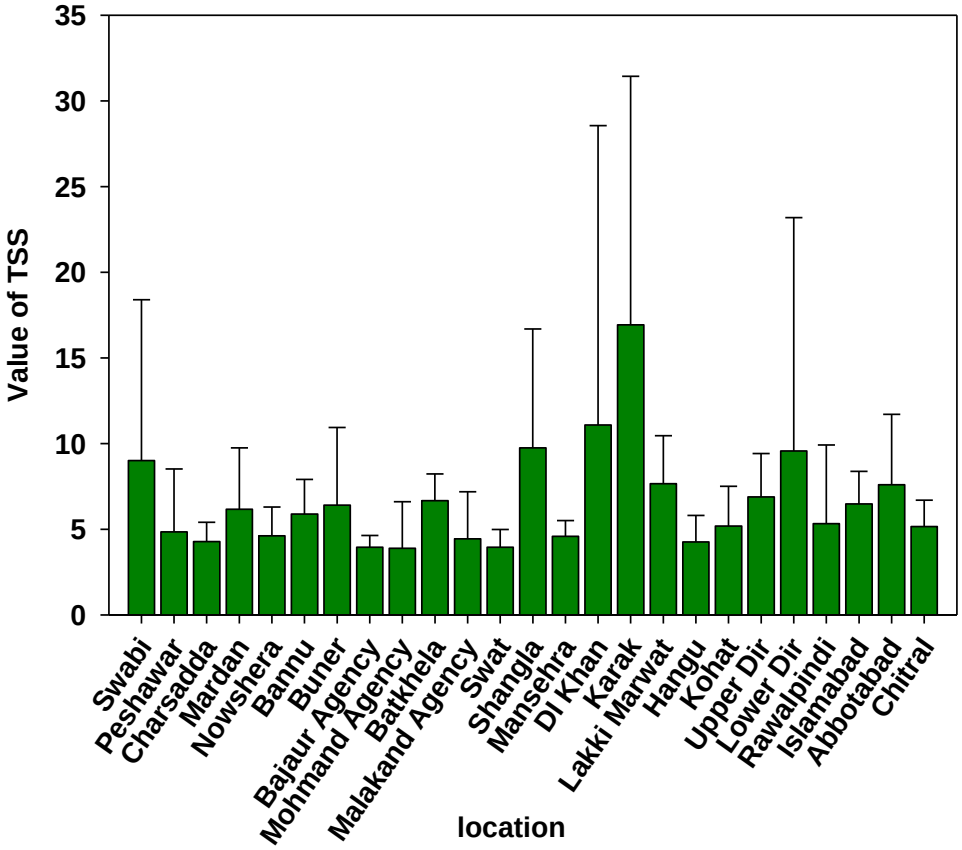

Figure 3. Levels of total suspended solids in drinking water of different cities of Pakistan

Previously, studies regarding water parameters, higher TSS than permissible limit were found in samples from Peshawar (Ali et al. 2012; Amin et al. 2012), while other found TSS in acceptable limit (Nasrullah et al. 2006). The excessive TSS is concerned with poor sanitation, which in turn toxify water with waste disposal and plant fossils (Yasin et al. 2015). Also, the excess is reported due to presence of soluble contents in water. USEPA (2000) assigned higher TSS due to the presence of more mineral in water.

Total dissolved solids

Water TDS of samples is the totality of $Ca2^{+}$, Na^{+}, K^{+}, and $Mg2^{+}$ cations and CO_3^{2-}, SO_4^{2-}, Cl^{-}, NO_3^{-}, and HCO_3^{-} anions as the major inorganic constituents (NSDWQ 2008). The present investigation has analysed the collected samples for TDS presented in Fig. 4. Results showed the highest calculated value of TDS was for Abbottabad (mean= 943.11, SD= 911.05), while lowest for Mansehra (mean= 259.96, SD= 131.82). The WHO has recommended 1000 mgL−1 as the upper and lower permissible levels (WHO 2011), while Fawell et al. (1996) considered TDS level between 300 and 600 mg/L to be good. Our calculated findings were within the permissible limit. Previously, studies conducted in Faisalabad city (Zulfikar et al. 2016) and Southern-Lahore (Hayder et al. 2009) were consistent with our findings. While, TDS was higher in majority of samples in Faisalabad (Nasir et al. 2016), Sargodha, Sheikhupura, Rawalpindi and Faisalabad (Soomro et al. 2011).

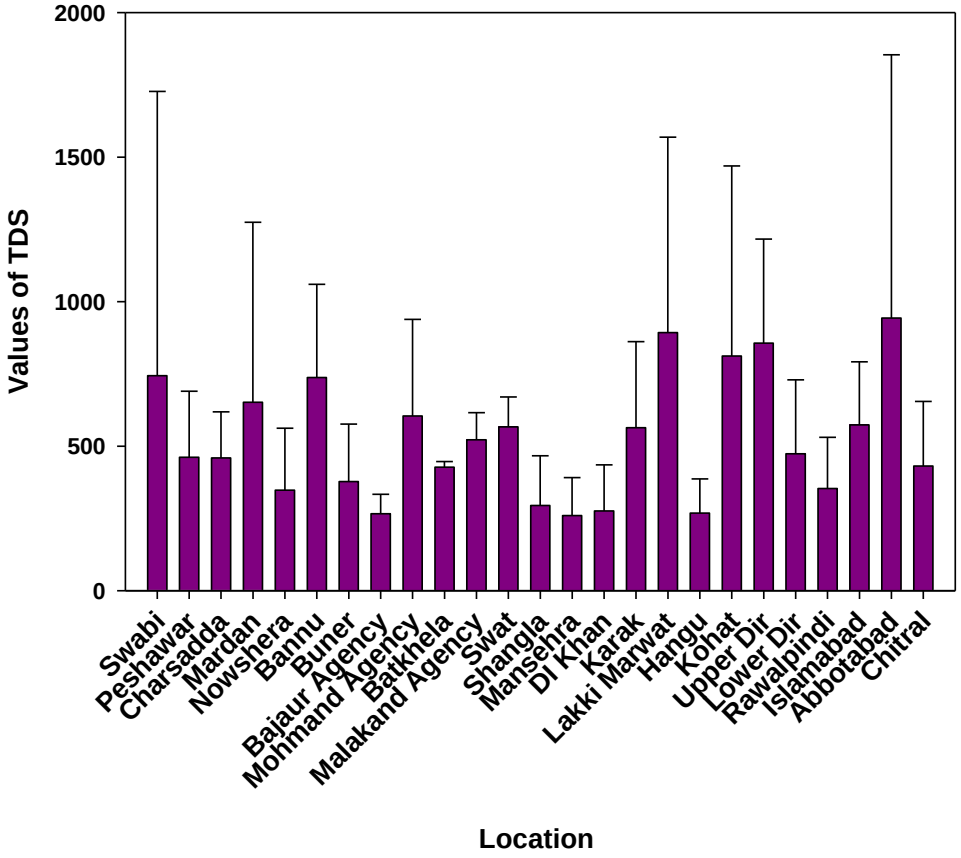

Figure 4. Levels of total dissolved solids in drinking water of different cities of Pakistan

Sodium in water

Water Na is an essential metal inside the body but its excessive ingestion can cause serious threats to human health. Our results presented in Fig. 5 revealed that the Na was highest in Chitral with SD 223.64, while the least in Rawalpindi (mean= 13.68, SD= 10.49). Also, only 2 samples i.e. Chitral and Upper Dir exceeded the permissible limit set by WHO i.e. 200 mg/L (WHO 2011).

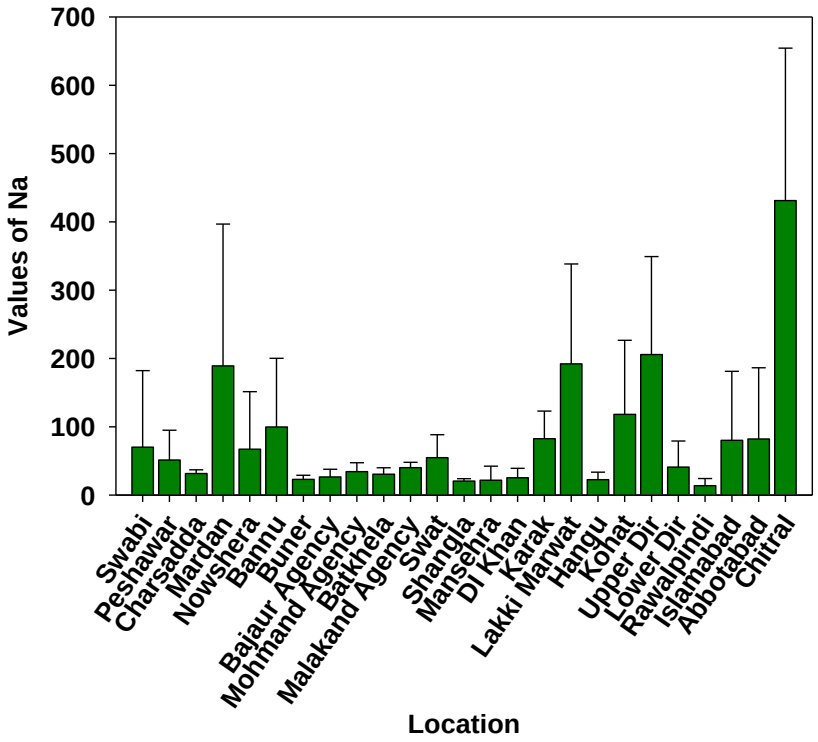

Figure 5. Concentration of Sodium in drinking water of different cities of Pakistan

Previous studies conducted to assess Na-concentration in water revealed that excessive Na was found in KallarKahar and Manchar Lakes (Arain et al. 2008; Mastoi et al. 2008; Raza et al. 2007), Hyderabad (Laghari et al. 2004), Lahore and Nagar Pakar (Haldar and Islam 2015), Kalu Kuhar (Siddique et al. 2005) and other areas of Pakistan (PCRWR 2005). The main factors that contributed the higher Na were salinity of water and its brackish nature (Raza et al. 2007). Also, ions exchange reaction of Ca and carbonates due to alkalinity of water resulted in excessive Na (Farooqi et al. 2007).

Potassium in Water

Water K is very important for human body and its daily intake of 0.1 percent via water was estimated, which is considered important for normal body functioning (Lattore et al. 1997).

Our results shown in Fig. 6 shows that the highest value of K belongs to Mansehra (mean= 375.73, SD= 247.41), while lowest belongs to Mohmand Agency (mean=2.60, SD= 2.44). Out of 25 samples, only 6 samples were found to have higher values beyond permissible limit i.e. 75 mg/L (WHO 2011).

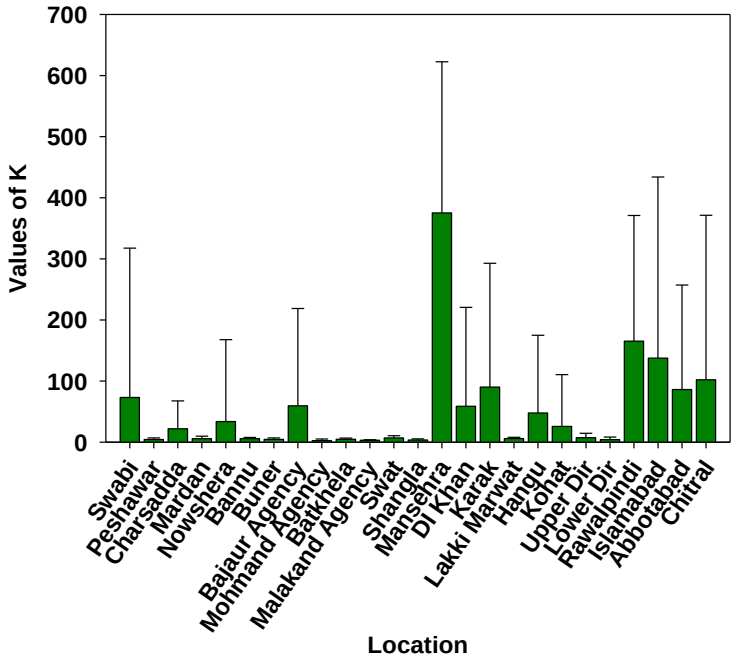

Figure 6. Concentration of Potassium in drinking water of different cities of Pakistan

Similar to Na, K is also noted higher in our study in fewer areas that exceeded the normal level of WHO i.e. 75 mg/L (WHO 2011). Tariq et al. (2008) asserted that European Union recommends 12 mg/L as permissible limit for K. Previously, 36-46% areas surpassed the permissible limit in Faisalabad and 20% in Kasur (PCRWR 2005).

Results show that the concentration of potassium in study areas ranges from 20.83 to 27.51 mg/L. All regions with an average value vary between 3.73 to 11.41 mg/L. Present investigation was similar with reports made by other researchers' study (Aremu et al. 2011; Edimeh et al. 2011). These results did not meet the WHO standards and may become diseases associated from potassium extreme surpassed. When we compare to this result, it is less than the report of these researchers.

Hardness of water

Hardness of water is mainly attributed to the presence of Ca and Magnecium and their cations and ions (Entezari et al. 2009; Soltanieh et al. 1999; Kabay et al. 2002; Yildizet al. 2003).

Our results indicated in Fig. 7 shows that hardess was higher in Bannu (mean=521.48, SD= 222.70), while lower in Mardan (mean= 145.24, SD= 162.94). Overall result indicates that only 1 sample exceeded the WHO recommended level i.e. 500 mg/L (WHO 2011).

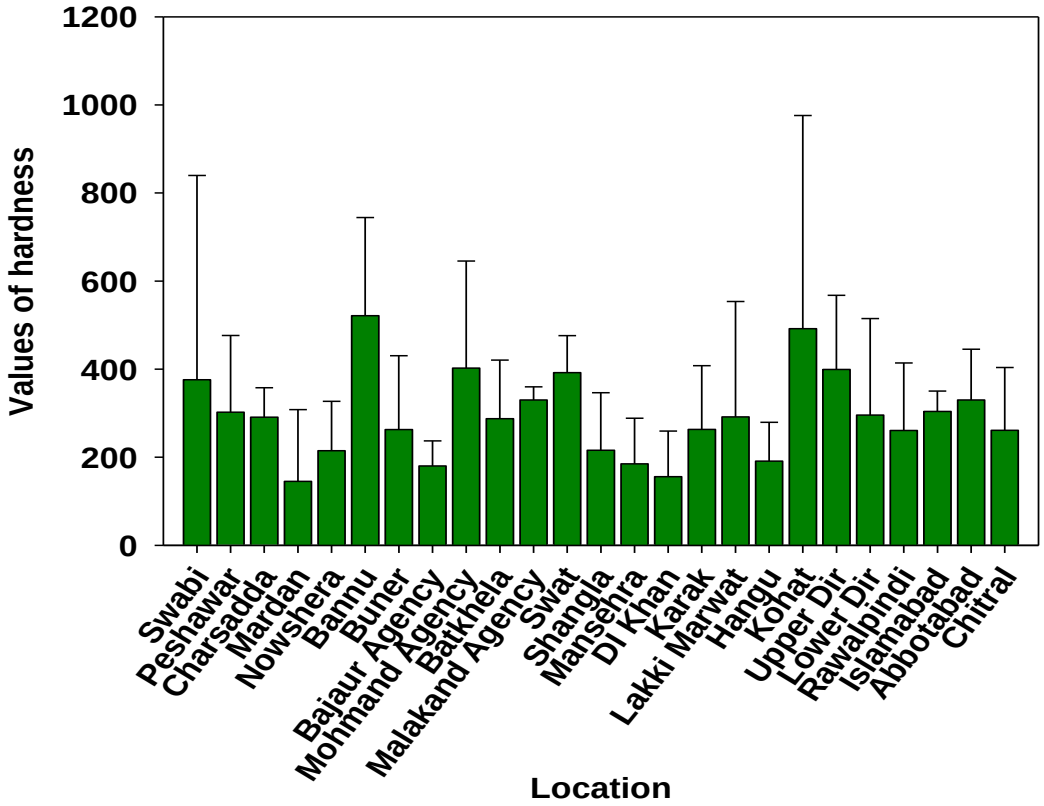

Figure 7. Concentration of Sodium in drinking water of different cities of Pakistan

Previous studies in Manganpeta mine (Prasad et al. 2014), Southern Sindh (Memon et al. 2011) and Faisalabad City (Farah et al. 2002) found higher hardness than permissible limit.

Alkalinity of water

The acid neutralizing capacity of water is known as alkalinity, which varies from area to area. The higher alkalinity in any area is attributed to presence of chlorides, sulphates and carbonates (Khan et al. 2013)

Current results in Fig. 8 showed that alkalinity was higher in Upper Dir (mean= 355.32, SD= 106), while lower in Mansehra (mean= 101.88, SD= 27.45) shown in Fig. 7. None of the sample exceeded the permissible limit set by WHO i.e. 500mg/L (WHO2011; NSDWQ 2008).

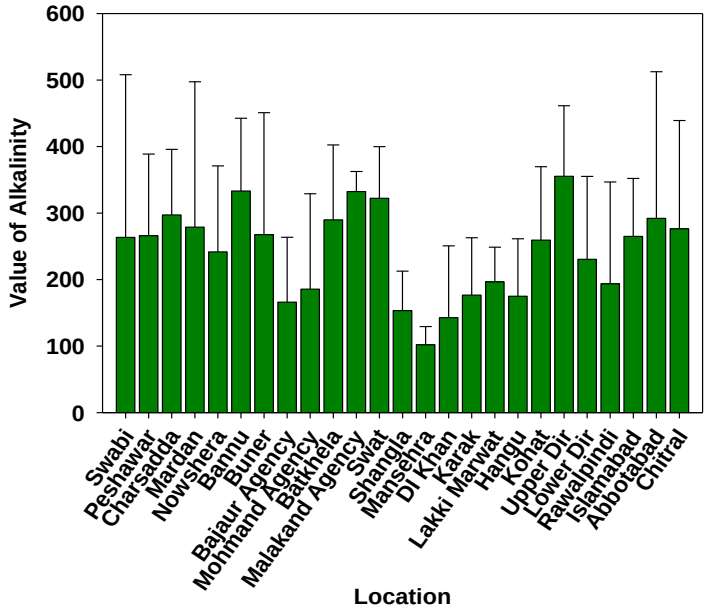

Figure 8. Alkalinity level in drinking water of different cities of Pakistan

Consistent results were found in Swabi (Ali and Akhtar 2015), Islamabad (Mehmood et al. 2014) and contradictory findings were obtained in urban areas of Faisalabad (Farid et al. 2012). Alkalinity is varied from areas to area because it depends on geography of an area, and least likely to be affected by water discharge from industries. High alkalinity is also due to the presence of mineral of Cl, SO_4, carbonates and its availability in ground water.

Electric conductivity of water

It is the capacity of water to carry an electric current in the presence of dissolved metals such as Ca, Cl, and Magnesium.

Our study results shown in Fig. 9 showed EC in collected samples, which revealed a highest level in Buner (mean= 1465.15, SD= 3069.12) and a lowest EC in Mansehra (mean= 150.59, SD= 84.21). 7 out of 25 samples exceeded the maximum permissible limit set by WHO (WHO 2004) and NSDWQ (NSDWQ 2004).

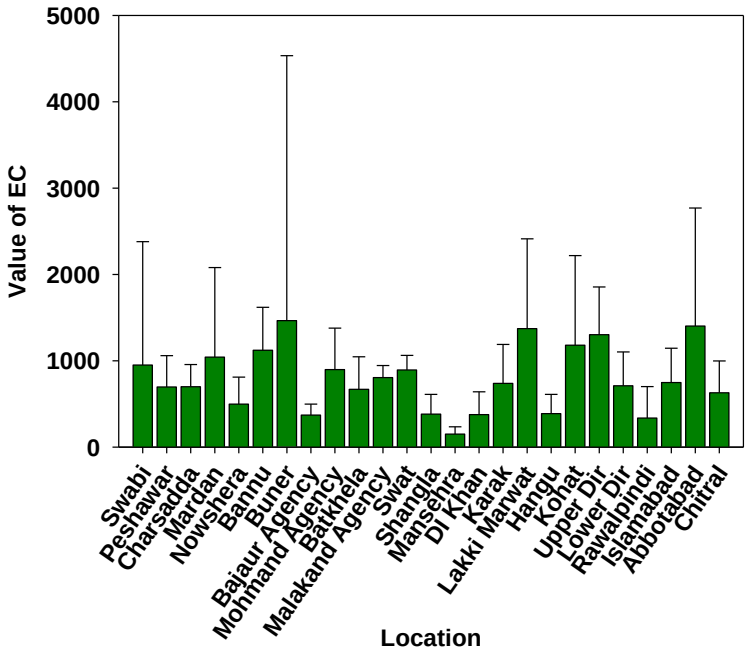

Figure 9. Electric Conductivity in drinking water of different cities of Pakistan

According to NDWQS (2004), the maximum allowable level of conductivity is 1000 µS/cm. So, the previous studies in Rawalpindi (Hasmi et al. 2009), Nagar Valley (Gilgit) (Ali et al. 2012) and Karachi (Hussain et al. 2014) revealed that EC was found within prescribed limit.The higher alkalinity in any area is attributed to presence of chlorides, sulphates and carbonates (Khan et al. 2013).

Chloride in water

Cl is usually found in in the human body as well as raw and natural water. Our results indicated in Fig. 10 shows that Cl was higher in Abbottabad (mean= 133.76), SD= 216. 52), while lower in Shangla (mean= 16.88, SD= 3.61). None of the samples exceeded the permissible limit i.e. 250 mg/L (WHO 2011). Also, in Pakistan the desirable limit for Cl is 200-600 mg/L (APHA 1998; PCRWR 2005; WHO 2006).

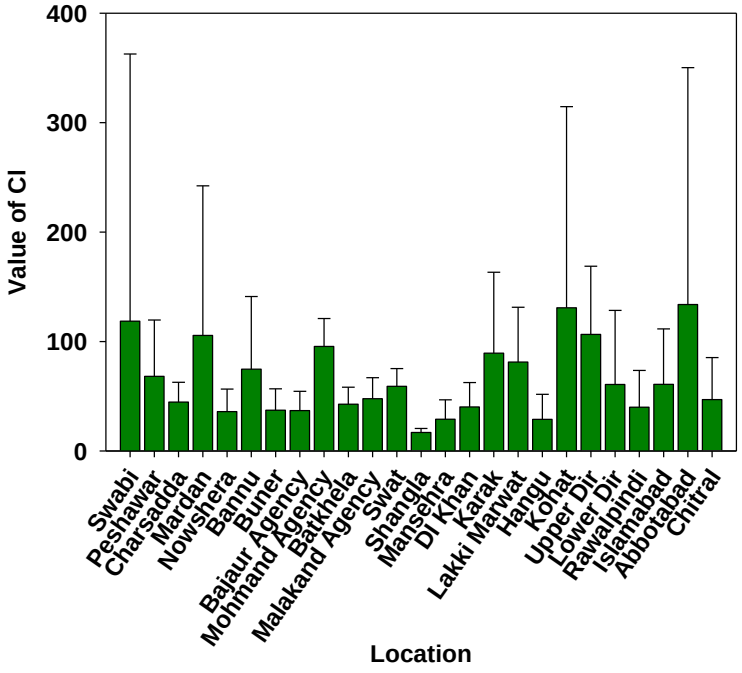

Figure 10. Concentration of Chloride in drinking water of different cities of Pakistan

Cl concentration ranges 51-58 mg/L in Pashat, Danqool, Shahgoo and Batmalai (Jehan et al. 2019), while lower Cl was reported by Khan et al.(2013) and (Singh et al. 2017). Cl is one of the main anions found in natural water. The processes responsible for Cl in groundwater are erosion and watering of crystalline rocks. Sodalities, apatite, micas and hornblende are chief minerals that contribute Cl to groundwater. High concentration of Cl in natural water may result from contamination by sewages, seawater and saline residues in the soil (Hem 1985).

Sulphates in water

As far as SO_4 is concerned, it is almost found in all kinds of water bodies and an important constituent of hardness in water. The results regarding SO_4 was shown in Fig. 11, which reveals that SO_4 was highest in Mardan (mean= 157.74, D= 233.83), while lowest in Buner (mean= 30.05, SD= 16.62). None of the samples surpassed the normal or desirable limit set by WHO i.e. 250 mg/L (WHO 2011).

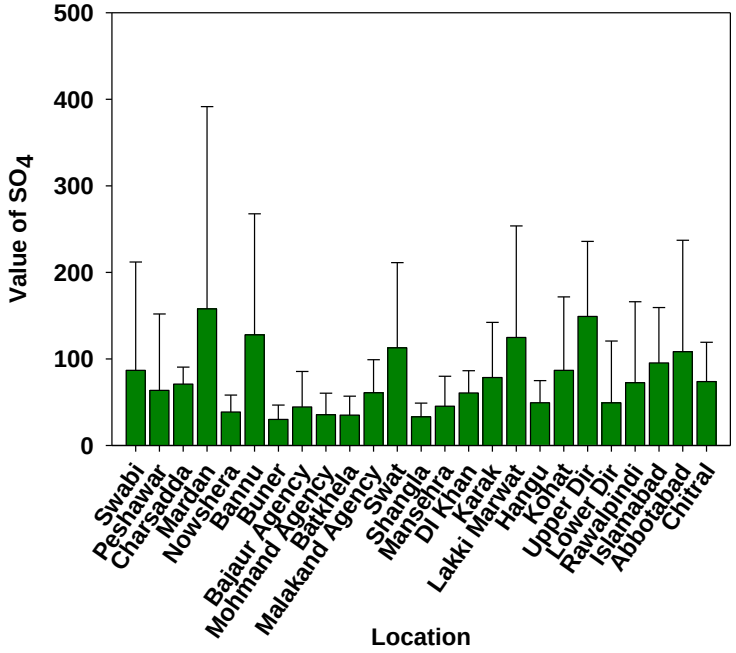

Figure 11. Concentration of Sulphates in drinking water of different cities of Pakistan

Analysis of water from Faisalabad (Farid et al. 2012), Charsadda (Khan et al. 2014) and Karachi (Alamgir et al. 2015) showed $SO_4$was higher than permissible limit of WHO.SO_4 presence in water is the result of many factors like rainfall, use of fertilizers and mixing of minerals present in granites (Khaiwal and Garg 2007). Its excessiveness in water may result in serious consequences like diarrhoea, gastro and intestinal problems and dehydration (Garg et al. 2009).

4. Conclusion

Present study was aimed to assess the physico-chemical parameters of water from KP along with Rawalpindi and Islamabad. Many samples were taken from each site and their mean and SD were calculated. Very few samples were found contaminated with these parameters. Some samples show objectionable color and odor (Mardan, Bannu, Buner, Batkhela, Malakand, Shangla, Mansehra, Karak, Upper Dir, Islamabad, Abbottabad and Chitral). The highest recorded pH with mean of 7.86 $\pm$ 0.23 for Lakki Marwat, while lowest for DI Khan i.e. 6.31 $\pm$ 2.32. Results revealed that the mean TSS for Karak 16.93 $\pm$ 14.41 surpassed all other areas. The highest calculated value of TDS was for Abbottabad 943.11 $\pm$ 911.05 while lowest for Mansehra 259.96 $\pm$ 131.82. For Na^+ only 2 samples i.e. Chitral and Upper Dir exceeded the permissible limit set by WHO. The highest value of K belongs to Mansehra (mean= 375.73, SD= 247.41). Bannu water has highest hardness among all other areas (mean=521.48, SD= 222.70). Alkalinity was higher in Upper Dir (mean= 355.32, SD= 106), while lower in Mansehra (mean= 101.88, SD= 27.45). For EC highest level was recorded in Buner water (mean= 1465.15, SD= 3069.12) and a lowest EC in Mansehra water (mean= 150.59, SD= 84.21). The Cl concentration was higher in Abbottabad (mean= 133.76), SD= 216. 52), while lower in Shangla (mean= 16.88, SD= 3.61). SO_4 was highest in Mardan (mean= 157.74, D= 233.83), while lowest in Buner (mean= 30.05, SD= 16.62). Reasons contributed to contamination sources vary for each parameter. The major issues which affect the groundwater quality are the dissolution of minerals, like feldspar, biotite, muscovite, calcite and dolomite. Anthropogenic pollutants like use of extensive agrochemicals and the population growth has also affected the land use pattern, which has subsequently affected the quality of the water resources Lack of waste management practices in waste dumping, seepage management and unnecessary use of pesticides and fertilizers have also deteriorated water quality. Furthermore, there is a need for remedial measures for the removal of contaminants in drinking water on governmental scale.

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