ISSN 2063-5346

THE ASSESSMENT OF WATER PURIFICATION QUALITY CHARACTERISTICS (WPQC), WATER QUALITY INDEX (WQI), AND THEIR MEASUREMENT TECHNIQUES, ARID REGION OF RAWALPINDI, PAKISTAN

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Article History: Received: 01.02.2023 Revised: 07.03.2023 Accepted: 10.04.2023

Abstract

Drinking water quality is essential for public health. With the aid of the water quality index, the current research investigation aimed to monitor the quality of drinking water and assess the action of water purification plants in the surrounding areas of PMAS Arid Agriculture University Rawalpindi (WQI). A total of 150 water samples be situated gathered from 20 water purification plants. The pH, EC, TDS, free chlorine turbidity, total hardness, cations (Na, K, Ca, and Mg), anions (Cl, HCO3, SO4, NO3, and F), manganese, iron, and total hardness of drinking water were all analyzed. In terms of the assessed physicochemical character, the results showed that purified water was acceptable for consumption. The overall water purification efficacy for reducing total dissolved salts and related anions and cations was greater than 90%. TDS levels in groundwater averaged 1919 ± 806 mg/L but were reduced to 119 ± 32.9 mg/L in purified water. According to the water quality index, all filtered water samples were of high drinking quality (class I). Meanwhile, due to many dissolved salts, 80.6 percent of the contaminated groundwater sample was of poor drinking quality (class III), and 10.9 percent was of extremely poor drinking quality (class IV). Groundwater filtration improved the water quality from extremely low to poor (classes III and IV) to good (class I).

Keywords: Water Quality, Purification, physicochemical Characteristics, Drinking water regulation, quality index.

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DOI:10.31838/ecb/2023.12.s1-B.330

Introduction

It is a well-known fact that fresh water is necessary for human health. Technology growth and industrial expansion have put freshwater resources in jeopardy all over the world (Khan et al., 2021). One out of every six people on the planet lives in a country where freshwater is scarce. It has been noted that developed countries are the most affected by chemical pollution, whereas agricultural sources are associated with emerging countries. Polluted water causes health concerns and leads to water-borne infections, which can be prevented by acting at the household level. Providing safe drinking water is a difficult task for everyone. Continuing research efforts in this field have resulted in several processes/technologies during the last few decades (Binesh *et al*., 2010).

Contaminants in drinking water pose a serious threat to public health. As a result, providing safe drinking water is one of humanity's most successful public health efforts (Ashbolt, 2015). There has undoubtedly been progress in this direction in the last ten years. In a 2006 survey, it was discovered that 87 percent of the world's population drank water from controlled and recognized water sources, which was significantly higher than the similar proportion (76 percent) recorded in 1990 (Tsoukalas and Tsitsifli, 2018).

Suppliers shall manage and regulate/monitor the quality of drinking water generated using available/relevant instruments and procedures to supply consumers with safe drinking water. A "standard" is a document usually adopted by consensus by recognized (Standardisation) institutions to give directions or functions for related products or processes. It is not necessary to follow these instructions or perform these duties. "Regulation" refers to a document published by the government or authority that specifies product qualities and related processes and applicable administrative regulations that must follow. Standardization thus serves as the foundation for technical limitations. In this regard, the World Health Organization drinking water quality guidelines/standards (Organization, WHO and Staff 2004) have been widely acknowledged internationally and are reviewed in this paper. In addition, the new European Union (EU) Drinking Water Directive (DWD) was announced in December 2020, and the United States Environmental Protection Agency's (USEPA) Safe Drinking Water Act (SDWA) was assessed as part of this critical analysis.

The World Health Organization estimates that 3.4 million people (mostly children) die each year from water-related diseases (WDR) and that improving water quality can lower the global disease burden by around 4%. It's worth noting that the term "any major detrimental effect on human health, such as death, disability, disease, or disorder, induced directly or indirectly by any change in the condition, quantity, or quality of water" is broadly defined (Gunnarsdottir *et al*., 2020).

These common standards, known as water quality indices (WQIs), are utilized worldwide, and are based on the National Science Foundation's WQI (Jeong et al., 2012). The index is a one-of-a-kind figure made up of the weighted contributions of eight key water quality indicators. In contrast, 2 million people do not have access to water (Troger et al., 2021). For these reasons, it is vital to evaluate and amend regulations regularly, even when an effective regulatory framework exists, to maintain the required flexibility to respond to new and unforeseen issues. In the United States, the 1996 SDWA amendment mandates that the Environmental Protection Agency (EPA) evaluate and change the national primary drinking water regulations at least every six years. The SDWA further stipulates that contaminants in drinking water must be regulated "or may occur," if pollutants occur naturally or as a result of natural, manufactured, or industrial contamination (Agency 2011). This technique, however, does not always account for any chemical or biological pollutants that may be released accidentally or purposefully into the water supply to harm users. Perfluoro alkyl substances (PFAS) were found in groundwater, surface water, and drinking water in the Veneto area of Italy in 2013, ascribed to a local chemical facility.

Hence, the present study was designed to overcome the issues of drinking water because water is an essential food item to be consumed globally by everyone. We can assume water is a vital life component for each living individual. Hence its regulatory standards must meet the required parameters/characteristics to be complying the set standards. Hopefully, the current research efforts will open the doors for scientists and researchers to explore new ways to improve drinking water standards globally.

Materials and methods

Study area and Sample collection:

Rawalpindi is a densely populated city in Pakistan, located in the country's largest province. The entire sample was collected from this city. This study was undertaken twice, once in the winter (December-18) and once in the summer (May-19), to see if there are seasonal differences in drinking water quality. To study water quality, 40 significant private water purification plants were chosen, which are geographically scattered throughout the study area. In each survey, 60 samples were taken from the selected water purification plant's untreated groundwater (before purification) and treated groundwater (after cleansing). In addition, three water purification appliances with diverse functionalities have been chosen for frequent water quality monitoring and purification performance evaluation. As a result, 150 water samples in this study cover most of the water purification plants in the chosen study area.

At each water treatment plant, samples are collected from the groundwater source and treated water outlet, packed in previously cleaned 1 l HDPE (high-density polyethylene) bottles, and stored at 4°C and in the dark until analysis. In situ water quality parameters include temperature, pH value, TDS, EC, and free chlorine; these are measured immediately during sampling. First, wash all glass materials with 10% HCl acid for 24 hours, then rinse with distilled water and water samples 3 to 5 times before use.

Water analysis:

pH, TDS, EC, and free chlorine were the key water quality indicators assessed in situ. A pH meter was used to monitor the pH and temperature in situ. A portable conductivity / TDS meter (model 470 digital, jenway UK) measured TDS and EC in mg/L and micro Siemens units per centimeter, respectively. A portable colorimeter based on DPD colorimetry was used to measure free chlorine. A turbidity meter is used to measure turbidity, expressed in (NTU) turbidity unit (Weinhold, 2012).

Perfect procedures are employed to evaluate water samples in the laboratory, according to the American water and wastewater standard inspection guidelines. The direct ultraviolet technique, the SPADNS method, and the turbidity measured approach were used to evaluate nitrate, fluoride, and sulfate in collected water samples using an ultraviolet-visible spectrophotometer (uv-1650, Shimadzu) (McCasland *et al*., 1985). For Chlorine, HCO3, Ca, and Mg (total hardness) plasma (EC, 2020) were assessed by mature titration. The photometric flame emission method measured Na and K (flame photometer, jenway, UK). An atomic absorption spectrophotometer (aa6650f, Shimadzu, Japan) was used to test Fe and Mn (Weinhold, 2012).

Water quality index computing

Based on thorough literature analysis, WQI calculations consider most of the physicochemical features of water parameters, such as pH, TDS, EC, turbidity, free chlorine, total hardness, anions (CL, HCO3, SO4, NO3, f), and cations (Na, K, CA, Mg) (Gunnarsdottir *et al*., 2020). The following empirical equation was used to evaluate water quality and calculate the WQI of each water sample collected (Jeong *et al*., 2012).

First, each measured water parameter is assigned a weight (WI) of 1 to 5 based on its relative importance in the overall quality of drinking water and the water quality requirements shown in Table 1. Secondly, each water quality parameter's relative weight (WI) is calculated using the proposed equation. The maximum importance of drinking water-relevant characteristics (TDS) is 5, while the weight of low-correlation parameters (Bicarbonate) is 2 (Khan *et al*., 2020).

Statistical analysis:

The quality of analytical data is ensured in the laboratory through control and quality assurance measures. Among them are standard operating methods, calibration using standards, blank determination, and triple analysis of water samples. The variance coefficient of the sample is usually accurate to within 3-5 percent. In addition, the ion balance error was calculated to verify the accuracy of hydro chemical analysis (organization et al., 2004). The statistical analysis was done with the help of a statistical software application (version 8.1). The data was then evaluated with a one-way analysis of variance (ANOVA) to see if there were any significant differences between the water samples gathered from the study region.

Results and Discussion

Groundwater quality

The descriptive statistics of groundwater quality parameters are shown in Table 3. The water temperature varies between 20.5 and 34.5 degrees Celsius, with an average of 25.3 degrees Celsius. The average temperature of the water samples obtained in May 2019 (28.7- 3.35°C) is substantially high when compared to the water samples collected in December 2018 (21.1 2.17°C). Groundwater samples had turbidity values ranging from 1.11 to 1.74 NTU, with an average of 1.29 to 0.14 NTU (Table 3). The pH of the water samples tested ranged from 7.77 to 8.70, with an average of 8.15 to 0.17. The PH value is a crucial indicator of water quality and pollution levels. The pH levels observed in this study have repercussions within the range of international requirements (6.5-8.5). Free chlorine (Cl2) concentrations range from 1.03 to 1.16 mg/L, with an average of 1.08 to 0.03 mg/L.

TDS values varied from 850 to 5514 mg/L, with an average of 1919 806 mg/L; CD concentrations averaged 3192 1341 S/cm, with a range of 1417 to 9174 S/cm. The groundwater samples obtained in May 2019 (range: 1162 – 5513 mg / L) exhibit greater TDS (and EC) values than the water samples collected in December 2018 (range: 850 – 4024 mg / L). Excessive groundwater extraction for agricultural and domestic purposes may be to blame for the transitory shift in water salinity (peyravi et al., 2020). TDS values below 1000 mg/L, between 1000 and 2000 mg/L, and above 2000 mg/L are found in exactly 1.7 percent, 68.3 percent, and 30 percent of groundwater samples, respectively. Because all TDS readings exceed the permitted limit of 500 mg / L according to drinking water standards, these findings suggest that groundwater in the study region cannot be utilized for drinking without additional filtration (da Luz and Kumpel,2020; Elimelech, 2006). According to the observation, the high salinity of groundwater is caused by the excessive extraction of groundwater in the selected study areas (Aly et al., 2015).

High salinity in groundwater (TDS > 1200 mg/L) can cause excessive scale formation in boilers and other household appliances, posing a health risk. According to a comparable study, most groundwater wells in the study area were relatively saline, which could be attributable to excessive pumping and dry conditions (Nuccetelli et al., 2012).

Groundwater anions:

Table 3 shows the results of anions (CL, HCO3, SO4, no, and F) measurements in the collected groundwater samples. The chloride (CL) concentration ranges from 254 to 2358 milligrams per liter, with an average of 676 ±370 milligrams per liter. The chloride value of groundwater samples taken in December 2018 is low (average 645 ±317 mg / L) when compared to water samples collected in May 2019 (average 708 419 mg / L) (Table 3). The bicarbonate content in the groundwater samples tested ranged from 131 to 229 mg/L, with an average of 192± 20 mg/L. Chloride and bicarbonate concentrations in almost all groundwater samples obtained were over the permissible limits of 250 mg/L and 125 mg/L, respectively. (Organization et al., 2004).

The average sulphate concentration in the collected groundwater is 277 70.4 mg/L, ranging from 168 to 597 mg/L. The sulfate concentration of the water samples obtained in May 2019 (186-596 mg / L) is substantially higher than in December 2018 (167-425 mg / L). Sulfate is an essential ionic component, and the concentration found in 58.3 percent of water samples exceeds the acceptable drinking water standard of 250 mg/L. In another study, the average sulphate concentration in groundwater collected from Khamis Mushait (KSA) was 524± 125 mg/L, with 60% of the water samples having a concentration higher than 200 mg/L. (Agency, 2011). The primary sources of sulphate in groundwater are human activities and the dissolution of sulfated rocks like gypsum.

The average nitrate and fluoride values in the collected groundwater samples are 6.31 ±2.27 mg-N / L and 1.99 0.28 mg / L, respectively, ranging from 1.635 to 15.6 mg-N / L and 1.54 1.94 mg / L. Between the water samples collected in December 2018 and May 2019, there was no notable change in nitrate and fluoride readings. Furthermore, nitrate was found in 13.3%, 83.3 percent, and 3.3 percent of the groundwater samples collected. Below 5 mg / l, values range from 5 to 10 mg / l, and over 10 mg / l. On the other hand, the results revealed that fluoride levels in the collected groundwater samples were lower than one mg/L, 1.5 mg/L, and more than 1.5 mg/L at 61.7 percent, 31.6 percent, and 6.7 percent, respectively. The comparatively high nitrate concentrations found in this study could be linked to various human activities in the study area, such as rapid population growth and related activities, including urbanization, agriculture, and industrial development (Valcarcel rojas et al., 2020).

Groundwater cations:

Table 3 shows the results of cationic amounts (Na, K, Ca, and Mg) measured in the collected groundwater samples. The sodium and potassium concentration ranges are 118 to 989 mg / L and 17.1 to 218 mg / L, respectively, with average values of 324 132 mg / L and 51.0 30.7 mg / L. The Na and K values in the water samples collected in May 2019 are greater than those in the water samples collected in December 2018. The permitted limits for sodium and potassium in drinking water are 200 mg/L and 12 mg/L, respectively, while 95 percent of the sodium values and practically all measured potassium values are higher than these limits. (Organization et al., 2004).

The average calcium content in groundwater samples collected is 159 68.9 mg/L, with a range of 83.5 to 460 mg/L, while the measured magnesium value is 20.3 to 142 mg/L, with an average of 53.7 24.9 mg/L. In addition, groundwater samples collected in December 2018 showed increased calcium and magnesium concentrations (an average of 173± 74.9 mg / L). In comparison, groundwater samples obtained in May 2019 (an average of 144 ±60 mg / L) had a concentration of 60.9±19 mg / L, 46.5± 28.2 mg / L and 46.5± 28.2 mg / L, respectively). Calcium and magnesium contents were over the permissible limits of 100 mg/L and 50 mg/L in 93.3 percent and 46.7 percent of groundwater samples, respectively.

The hardness value in the collected CaCO3 groundwater samples are, on average, 612 to 254 mg/L, ranging from 345 to 1504 mg/L. The average hardness value of the groundwater samples taken in December 2018 is 678 232 mg / L (546± 261 mg / L), compared to the groundwater samples collected in May 2019. Because 58.3 percent of the tested samples have values greater than the acceptable advisory threshold of 500 mg / L, these data show that collecting groundwater samples from the designated study location is extremely problematic. Water with a hardness of more than 500 mg/l will use more soap and detergent and cause the heating container to scale. (Valcarcel Rojas et al., 2020).

The average iron and manganese concentrations in the collected groundwater samples are 115 ±92.2 mg/L and 36.9 ±18.9 mg/L, respectively, with Fe concentrations ranging from 27.2 to 311 mg/L and Mn concentrations ranging from 7.49 to 89.9 mg/L. The average iron value of the groundwater samples obtained in May 2019 is greater (147 103 mg / L) than the groundwater samples collected in December 2018 (82.3 68 mg / L). The iron concentration in specifically examined water samples (6.7%) was above the maximum permitted limit of 300 mg/L, while all measured magnesium values were below the maximum allowable limit of 100 mg/L. A comparable study found that 26.7 percent of groundwater samples in the study area exceeded the maximum permissible iron limit. The two primary sources of iron and manganese in groundwater are the disintegration of parent rock in contact with the aquifer and the corrosion of metal pipelines. These substances can leave stains and emit a metallic odor (Troger et al., 2021).

Overall groundwater quality:

TDS, EC, anions (CL, HCO3, and SO4), and cations (Na and K) concentrations in groundwater samples obtained in May 2019 are greater than those collected in December 2018. The arid climate in the region, the increased evaporation rate, the rise in agricultural drainage and groundwater extraction and usage in the summer, and the subsequent seawater intrusion may all contribute to the higher TDS and significant ions in groundwater in the summer (Baken et al., 2018). The average calcium and magnesium concentrations and total hardness of groundwater samples collected in December 2018 are higher than those in May 2019, which could be attributed to limestone parent rock disintegration during the rainy season's off-season. Groundwater samples taken in northern and eastern villages had higher TDS, anion, and cation concentrations than groundwater samples obtained in Rawalpindi's core city, as evidenced by the f significance value of ANOVA (Table 3).

Most groundwater samples collected include TDS values, anions (CL, HCO3, SO4, NO3), cations (Na, K, CA, Mg), and overall hardness concentrations that exceed the permissible limits for drinking water. According to prior studies, these findings show that groundwater in the study area needs to go through more purification operations before it can be properly used for drinking or household uses. The improvement of anthropogenic pollutant intake may result in major changes in groundwater pollution, resulting in considerable changes in water quality. The chemical parameters of groundwater samples are displayed using Piper trilinear plots based on their ionic composition (Fig. 2). The results demonstrate that salt chloride sodium sulphate is found in 80% of the water samples, whereas calcium sulphate is found in 20%. The geological properties of the research area are salt rock, gypsum, and anhydrite, as indicated by these types of water (Kondor et al., 2021). As a result, the current study demonstrates that the chemical abundance of observed ions is in the following order: cl > SO4 > HCO3 > No3 > F for anions and Na > CA > mg > k for cations. This ion sequence can determine the diagenetic origin of these ions in groundwater.

Purified drinking water quality:

Table 4 and the supplemental materials provide descriptive statistics on the quality attributes of purified drinking water. The temperature of the purified water collected ranges from 20.4 to 34.40 degrees Celsius, with an average of 25.1± 4.27 degrees Celsius. Compared to the average temperature of purified water samples collected in December 2018 (21.8±1.7 °C), the average temperature of purified water samples collected in May 2016 (28.5± 3.3 °C) is relatively high. The pH of the tested filtered water samples ranged from 7.74 to 9.08, with an average of 8.55 ± 0.27. TDS concentrations ranged from 51.6 to 266 mg per liter, with an average of 119±32.9mg per liter. The concentration of EC ranged from 83.8 to 443 S/ cm. The average value of the 60 purified water samples collected is 198±54 8 S / cm, with TDS levels of 50 to 100 mg / L, 100 to 150 mg / L, 150 to 200 mg / L, and > 200 mg / L, respectively. Purified water samples have turbidity and free chlorine values of 1.10 to 1.78 NTU and 1.04 to 1.84 mg / L, respectively, with average values of 0.24± 0.13 NTU and 1.11 0.11 mg / L. All pH, TDS, turbidity, and free chlorine values in this investigation are within the allowed limits specified by who and the drinking water quality requirements in the designated localities, as shown in Table 1 (Organization et al., 2004).

Drinking water anions:

Table 4 shows the number of anions (CL, HCO3, SO4, NO3, and F) measured in the purified water samples collected. The average chloride (CL) concentration was 43.6 14.8 mg per liter, ranging from 18.4 to 131 mg per liter. The chloride value of the water samples obtained in May 2019 is low (average 41.9± 9.30 mg / L) compared to the water samples collected in December 2018 (average 45.3± 18.8 mg / L). Bicarbonate values ranged from 7.83 to 34.4 mg/L, with an average of 18.9 6.61 mg/L. The average sulphate concentration in the water is 12.8 6.70 mg/L, ranging from 3.33 to 29.6 mg/L. The sulfate content in drinking water in the selected localities ranges from 48 to 360 mg/L, with an average of 160 mg/L. (Jurzik et al., 2010). Chloride, bicarbonate, and sulphate contents in all purified water samples were within the permissible limits of 250 mg/L, 125 mg/L, and 250 mg/L, respectively.

Table 4 shows that the collected purified water samples have an average nitrate concentration of 1.88 0.43 mg-N / L, ranging from 1.17 to 1.96 mg-N / L, and a fluoride concentration of 1.04 to 1.58 mg / L, with an average of 1.18 0.12 mg / L. The nitrate value in the water samples taken in December 2018 and collected in

May 2019 did not differ significantly according to seasonal changes. Overall, the nitrate and fluoride concentrations in the purified water samples tested were less than the prescribed limits of 10 mg n / L and 1.5 mg / L, respectively. Because the recommended ideal level of fluoride in drinking water is 0.8 to 1.5 mg / L, the fluorination process should be evaluated for usage in water purification plants.

Drinking water cations:

The sodium and potassium concentrations of purified composite water samples average 29.3 ± 9.99 mg/L and 4.72± 1.08 mg/L, respectively, with values ranging from 9.33 to 84.6 mg/L and 1.60 to 9.82 mg/L. The water samples collected in December 2018 show more significant sodium and potassium contents (range: 12.4±83.6 mg / L and 2.87±9.82 mg / L) (range: 8.33±43.9 mg / L and 2.60±10.8 mg / L) than the water samples collected in May 2019. The calcium and magnesium contents in filtered water samples ranged from 2.78 to 15.2 mg/L and 2.02 to 9.02 mg/L, respectively, with an average of 5.35± 2.31 mg/L (CA) and 4.46 ±1.41 mg/L (mg). Furthermore, compared to water samples taken in May 2016, the average calcium value of purified water samples collected in December 2018 is higher, at 6.41 2.54 mg / L, compared to an average of 4.29 1.44 mg / L in May 2019. As demonstrated in Table 1, the Na, K, Ca, and Mg levels of all purified water samples collected are within the acceptable limits specified for drinking water (organization et al., 2004).

Purified water samples collected had an average hardness value of 26.1 ± 8.87 mg/L, ranging from 14.6 ± 54.8 mg/L. The hardness value of the purified water samples taken in December 2018 is comparatively high (average 29.6±10.9 mg / L) compared to the water samples collected in May 2019 (average 22.6 ± 3.92 mg / L). All purified water samples have a hardness value lower than the permissible limit of 500 mg/L for drinking water, considered soft water. The iron concentration in purified water samples collected ranges from 21.5 to 188 mg / L, with an average of 76.7± 43.4 mg / L, while the manganese concentration is 28.7± 16.1 mg / L, with a range of 6.13 to 80.3 mg / L. The average iron value of purified water samples collected in May 2019 (86.3 ± 45.9 mg / L) is higher (67.2± 39 mg / L) than that of purified water samples collected in December 2018.

Overall drinking water quality:

All assessed purified water samples have TDS, pH, turbidity, total hardness, anions (CL, HCO3, SO4, NO3, and F), cations (Na, K, Ca and Mg), and Fe and Mn concentrations that are within the proper drinking water levels. According to a similar study, 95 percent of purified drinking water in one study location met WHO consumption requirements (Jurzik et al., 2010). The average amounts of TDS, EC, Cl, SO4, F, and cations (Na, K, CA) in the purified water samples collected in December 2018 are substantially high compared to the purified water samples collected in May 2019. In the water samples obtained in the study region, the analysis of variance (F ratio) revealed significant changes (P 0.001) in bicarbonate (F = 4.32, P = 0.008), sulphate (F = 5.05, P = 0.004), and magnesium (F = 4.58, P = 0.006). According to the present research, anionic CL > HCO3 > SO4 > No3 > F, cationic Na > CA > mg > k is the dominant order.

Water purification plants' efficiency:

The average removal effect of total dissolved anions, cations, and solids utilizing the tested water filtration equipment. TDS was eliminated at a rate ranging from 78.8% to 97.2%, with an average of 93.23%. Meanwhile, the average TDS level in groundwater in filtered water reduced from 1919± 806 mg/L to 118± 32.9 mg/L. Similarly, bicarbonate, chloride ion, and sulphate removal rates were 91.1 3.63 percent, 91.6± 3.84 percent, and 96.2± 2.71 percent, respectively. Meanwhile, the average fluoride and nitrate removal rates were 8 + 1.5 10.7% and 84.7 5.76%, respectively.

it demonstrates that (Fig 1) the average cation removal rate (Na, K, CA, Mg) is greater than 90%. The total hardness ratio removal range is 88.3% to 97.8%. As a result, more research is needed to determine whether the water purification plant is effective in eliminating secondary metals (Fe, Mn, Cu, and Zn) from water. In general, water purification technology is required to minimize dissolved solids, anions, and cations in groundwater and make it safe for human use (da Luz and Kumpel, 2020).

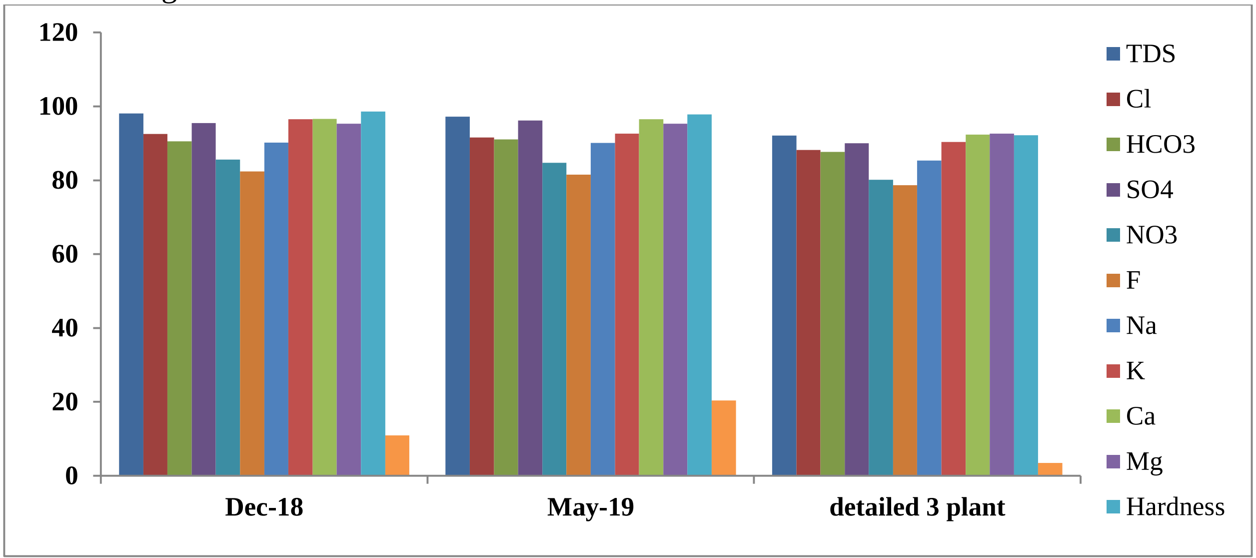

Figure 1. Purification efficiency (% average removal ±SD) of the 30 studied private water purification plants in selected study area.

The findings show that the average effect of removing contaminants from water did not differ considerably between December 2018 and May 2019. Furthermore, from December 2018 to May 2019, a detailed study of the three water purification plants revealed no significant discrepancies. The effectiveness of cleaning changes over time. For example, the average percentage of TDS elimination ranged from 87 to 95 percent between December 2018 and May 2019, with a coefficient of variation of 2.3 percent. As a result of the current research findings, the water purification plant has been investigated. The findings show that the average disposal efficiency between December 2018 and May 2019 is not considerably different. Furthermore, from December 2018 to May 2019, a detailed study of the three water purification plants revealed no significant discrepancies. With the passage of time, the purification efficiency increased.

Between December 2018 and May 2019, for example, the average percentage of TDS reduction ranged from 89 percent to 97 percent, with a coefficient of variation of 2.5 percent. As a result, the current research findings indicate that the under-examination water purification facility is functioning. High efficiency was recorded in the current experiment, with an average rate of more than 90%. The water treatment plant used reverse osmosis and filtration to remove total dissolved solids, anions (CL, HCO3, and SO4), cations (Na, K, Ca, and Mg), and total hardness before adding chlorine as a disinfectant. Furthermore, the data show that filtered water quality indicators are within acceptable drinking water standards. Drinking water in sufficient quantities and of acceptable quality is essential for public health and preventing the spread of water-borne diseases (Aly et al., 2015).

Water quality index:

The groundwater samples collected in May 2019 (range: 102± 446) show higher water quality index values than the water samples collected in December 2018 (range: 83.3± 304). All groundwater samples analyzed had an average water quality index of 157± 60.2, which is equivalent to low or very poor water quality (Table 3) and (Figure 2).

The high values of TDS, EC, anions (Cl -, HCO3 -, and SO4 -) and cations (Na^+ and K^+) measured in groundwater samples collected in May 2019 are related to the high values of TDS, EC, anions (Cl -, HCO3 -, and SO4 -) and cations (Na + and K +). The research area is characterized by dry circumstances and an increase in groundwater extraction rates for agricultural and domestic reasons throughout the summer, resulting in high groundwater salinity (Fathi et al., 2006). The value of 81.7 percent, 11.7 percent, and 3.33 percent of the groundwater samples collected had WQI values that were classed as poor water (100-200), extremely poor water (200-300), and unsafe water (> 300) respectively. In the chosen study area, 47 percent of untreated groundwater is deemed improper (Class V), while 39 percent and 14 percent are deemed extremely poor, respectively, and drinking water is deemed very poor 3. Furthermore, 87 percent of groundwater samples obtained in the city Centre are deemed unsafe for human consumption.

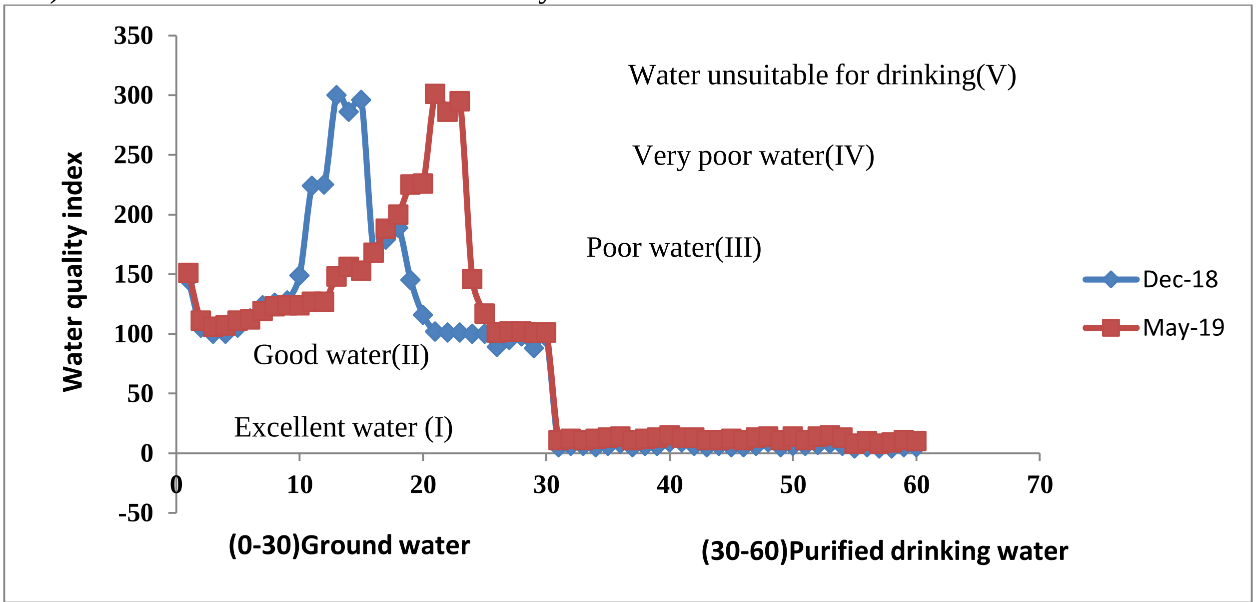

Figure 2. Values of WQI for the collected groundwater and purified drinking water from selected study areas.

On the other hand, because the ICA value spans from 13.8 to 37.9, with an average of 17.7 2.78, 100 percent of the purified water samples obtained can be classified as high-quality water (grade I) (Table 4 and Figure 2). Similar studies found that 88 percent of drinking water in the primary selected locations was extremely suitable for drinking, while 64 percent of treated groundwater in the other selected areas was of good quality (Nakada et al., 2020). Furthermore, 74 percent of drinking water in Pakistani primary schools is deemed to be of excellent drinking quality. The purification plant improves groundwater quality from grade III-V to grade I, and the drinking effect is outstanding, according to the findings of this study. As a result, it must be cleaned before using the groundwater from the current study region. As a result, WQI can be utilized as a useful management tool to aid in assessing drinking water quality and decision-making (Ahmed et al., 2020).

Given the fierce competition for scarce water resources in many countries, some water management strategies are required to protect drinking water resources from pollution and maintain public health: first, by establishing adequate drinking water distribution networks that cover both urban and rural areas of the country. Community: Second, all artificial projects must undergo an environmental impact assessment (EIA) to prevent drinking water pollution. Third, develop regular water quality monitoring and evaluation systems to assure good drinking water quality. Fourth, various types of ion exchange materials, reverse osmosis, and filtration for removing ions from water are evaluated to determine the efficiency of water purification equipment.

Conclusion

The current study was comprised to assess the water quality in nearby areas of PMAS Arid Agriculture University Rawalpindi-Pakistan with the aid of the water quality index (WQI). The water quality at twenty sampling stations was acceptable for drinking purposes with respect to physicochemical characteristics but declined total dissolved salts and excess of allied anions and cations. According to the results ground water was observed to be significantly declined due to excess of salts. The overall quality of selected samples meanwhile, 80.6% was for poor quality (class III), 10.9% for very poor quality (class IV) due to higher number of dissolved salts. It has a different approach for purification of ground water to convert poor quality to excellent quality water (class I). The WQI has provided authentic results in comparison to raw data of the surrounding areas of selected study area. It could be concluded that water stations should be properly managed due to draughts happened in surrounding of selected study area and water should need to interact further for appropriate treatment before drinking purpose for future recommendation.

Acknowledgments

The authors would like to acknowledge the help of the PGRS (220350) grant, Faculty of chemical and processing engineering Technology, University of Malaysia Pahang.

Author Contributions

Muhammad Qasim Ali (First author)-Conceptualization, Methodology, Software, Validation, Writing-Original draft, Writing-Review and editing; Supervision; Noormazlinah (corresponding author)-Resources, Methodology, Software, Validation, Writing-Original draft, Writing-Review and editing.

Data availability statement: All data generated or analyzed during this study are included in this published article.

Conflicts of Interest: The authors declare no conflict of interest.

Ethics approval: Not applicable.

Consent to participate: Not applicable.

Consent for publication: Not applicable.

Competing interests: Not applicable.

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Table 1: Relative weight (Wi) for each water quality parameter and World Health Organization (WHO 2011) standards for drinking water (maximum permissible limit).

Parameters	Weight (wi) (2009) Standards	relative weight (Wi)	WHO (2011) and SASO (2009) Standards
pH	3	0.062	6.6–8.4
TDS (mg/L)	5	0.103	490
Turbidity (NTU)	3	0.062	5
Free Cl2 (mg/L)	2	0.042	0.3-0.6
Total Hardness (mg/L)	3	0.062	500
Chloride (mg/L)	4	0.083	250
Bicarbonate (mg/L)	2	0.043	125
Sulphate (mg/L)	3	0.062	252
Nitrate (mg/L as N)	4	0.083	10
Fluoride (mg/L)	3	0.062	1.5
Sodium (mg/L)	4	0.083	200
Potassium (mg/L)	3	0.062	12
Calcium (mg/L)	3	0.062	100
Magnesium (mg/L)	3	0.063	50
Iron (_g/L)	2	0.042	300
Manganese (_g/L)	2	0.043	100

Table 2. Water quality classification based on water quality index values

Water class	Type of water	WQI Value Range
I	Excellent water	<50
II	Good water	50-100
III	Poor water	100-200
IV	Inferior water	200-300
V	Water unsuitable for drinking	>300

Table 3 shows descriptive statistics for measured parameters, WQI values in groundwater samples obtained from a study area, and the ANOVA F ratio of statistically significant variance.

Parameters	Groundwater Quality, All Data (n = 60)				December 2018 (n = 30)	May 2019 (n = 30)
	Average _SD	Min	Max	ANOVA F	Average ±SD	Average± SD
Temperature	25.3±4.39	20.5	33.5	5.06	21.1±217	28.7±3.35
pH	8.15±0.17	7.77	8.70	1.91	7.23±0.19	7.09±0.11
TDS (mg/L)	1919±806	850	5514	7.63	1869±706	1966±905
EC (µS/cm)	3191±1341	1417	9174	7.74	3111±1170	3274±1508
Turbidity	1.28910.14	1.110	1.746	1.94	0.264±0.16	0.313±0.11
Free Cl_2 (mg/L)	1.084±0.03	1.030	1.161	1.45	0.079±0.03	0.090±0.02
Chloride (mg/L)	676±370	254	2358	7.55	645±317	708±419
Bicarbonate (mg/L)	192±20.0	131	229	5.98	186±229	199±14.6
Sulphate (mg/L)	277±70.4	168	597	5.00	277±57.8	277±82.2
Nitrate (mg/L as N)	6.31±2.27	0.636	15.6	2.10	6.25±317	7.35±2.33
Fluoride (mg/L)	1.999±0.28	0.539	1.94	2.10	1.04±0.26	1.973±0.29
Sodium (mg/L)	324±132	118	989	2.06	292±101	357±151
Potassium (mg/L)	51.0±30.7	17.1	218	5.30	40.8±16.1	61.1±38.0
Calcium (mg/L)	159±68.9	83.5	460	3.67	173±74.9	144±60.0
Magnesium (mg/L)	53.7±24.9	20.3	142	11.33	60.9±19.0	46.5±28.2
Hardness (mg/L)	612±254	345	1504	4.77	678±232	546±261
Iron (_g/L)	115±92.2	27.2	312	9.83	83.3 68.0	147±103
Manganese (g/L)	36.9±18.9	7.49	90.9	3.78	35.0 18.3	38.8±19.6
WQI	**157±60.2**	**82.3**	**446**	**7.01**	**149±46.8**	**162±69.7**

Table 4 shows descriptive statistics for measured parameters and WQI values in purified drinking water samples obtained from a study location and the ANOVA F ratio of statistically significant variance.

Parameters	Groundwater Quality, All Data (n = 60)				December 2018 (n =30)	May 2019 (n = 30)
	Average ±SD	Min	Max	ANOVA F	Average ±SD	Average ±SD
Temperature	25.1±4.27	20.4	34.4	4.13	21.8±1.75	28.5±3.26
pH	8.55±0.27	7.74	9.08	2.14	8.46±0.30	8.61±0.21
TDS (mg/L)	119±32.9	51.6	266	2.43	123±40.8	116±22.7
EC (µS/cm)	198±54.8	83.8	443	2.41	204±68.1	192±37.4
Turbidity	0.240±0.13	1.100	1.783	1.31	0.248±0.16	1.230±0.08
Free Cl_2 (mg/L)	1.107±0.11	1.040	1.840	2.73	1.090±0.08	1.122±0.14
Chloride (mg/L)	43.6±14.8	18.4	131	3.30	45.4±18.8	41.9±9.30
Bicarbonate (mg/L)	18.9±6.61	7.83	34.4	5.32	17.9±7.56	19.9±5.46
Sulphate (mg/L)	12.8±6.70	3.33	30.6	6.05	14.2±7.28	11.5±5.88
Nitrate (mg/L as N)	1.882±0.43	1.173	3.96	2.70	1.848±0.42	1.914±0.45
Fluoride (mg/L)	1.178±0.12	1.036	1.579	2.85	1.197±0.08	1.156±0.14
Sodium (mg/L)	29.3±9.99	9.33	84.6	3.81	29.1 ±12.5	29.6±6.84
Potassium (mg/L)	4.72±1.08	2.60	10.8	3.42	3.99±1.23	4.45±0.84
Calcium (mg/L)	5.35±2.31	2.60	16.1	1.84	6.41±2.54	4.29±1.44
Magnesium (mg/L)	4.46±1.41	2.78	10.02	5.58	4.67±1.84	4.25±0.75
Hardness (mg/L)	26.1±8.87	14.6	55.8	4.16	29.6±10.9	22.6±3.92
Iron (µg/L)	76.7±43.3	21.5	188	2.19	67.2±39.0	86.3±45.9
Mn (_g/l)	28.7±16.1	6.13	80.3	1.33	28.5±13.7	28.9±18.5
WQI	**19.9±2.78**	**13.7**	**31.9**	**1.63**	**20.1±3.06**	**19.8±251**