Journal of Himalayan Earth Sciences, Volume 56, No. 1, 2023 pp. 01-10

Assortment of various groundwater sources through hydrochemical investigation in Rawalpindi district

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Submitted date: 16/09/2022 Accepted date: 18/01/2023 Published online: 31/03/2023

Abstract

Water plays a vital role in different physiological functions like maintenance of turgidity, nutrient uptake and metabolic processes in plants. The application of groundwater has been adopted for crop cultivation in many water-scarce areas. However, the quality of groundwater is deteriorating day by day due to urbanization and industrialization. . Therefore, a five-year (2015-2020) study was conducted to assess the fitness of groundwater being used for field application in different tehsils of Rawalpindi District. A total of 559 samples were collected in six tehsils of Rawalpindi, analyzed and categorized according to suitability criteria set by FAO (2013). Mean data showed that 70% of the total samples were fit, 9% marginally fit and 21% were found unfit for irrigation purposes. It was also recorded that a maximum (37%) of total unfit samples belonged to Gujar Khan tehsil whereas, the majority of samples of Taxila tehsil were fit compared to other Tehsils of Rawalpindi District. About 14.7% of water samples were recorded unfit due to Electrical Conductivity (EC), 5.9% due to Sodium Adsorption Ratio (SAR), 11.4% due to Residual Sodium Carbonate (RSC), 19.4% due to EC+RSC, 14% due to EC+SAR, 8% due to SAR+RSC, and 11.8% were unfit in terms of EC+RSC+SAR. Depending upon water quality, farmers were advised to use good quality water for crops. Suitable remedial measures for marginally fit/unfit water samples were suggested considering the salinity or sodicity of the samples.

Keywords: Irrigation water, salinity, Sodium Adsorption Ratio, Residual Sodium Carbonate, Electrical Conductivity

1. Introduction

Water has a pivotal role in triggering agricultural production and has key importance in food security. In the recent era of increased population, increasing trend of settlements in cities, and demand for quality products have changed the scenario of utilizing water for agricultural production. Due to high demands, it is expected that there would be great pressure on the farming community to produce more yields from limited land holdings and water resources (Hunter et al., 2017). Holopainen and Lehikoinen (2022) analyzed the physicochemical properties of water and concluded that increasing anthropogenic pressures affect the status of surface water ecosystems. The situation will become worse when the requirement for water will increase not only for the agriculture sector but also for the industries as well. To sustain the annual yield, there would be a requirement for widespread intensification of fertilizer, pesticide, and irrigation regimes (West et al., 2014).

The topography of Pakistan has been divided into seven geographic areas out of which the Potwar plateau is significant which covers the districts of Rawalpindi, Jhelum, Mianwali and Chakwal. The area under the range of the Potwar plateau is approximately more than one million hectares which are dependent upon rainfall. If we talk about the topography of the Potowar plateau, it has very uneven lands consisting of patched low lands being formed through heavy water erosion. Rawalpindi District has an important position in the Pothwar plateau. July and August are the most pouring months in this region and about 70% of annual rainfall is received in these months (Nizami et al., 2004). The major issues of the Plateau are shortage of water for domestic and livestock use, lack of irrigation facilities, loss of rainwater and erosion of topsoils, frequent droughts, dry spells and meager profitability of rain-fed agriculture. Water supply in hilly areas is time-consuming, unsafe and expensive work (Ghani et al., 2013). The erratic pattern and loss of rainfall water led farmers to use surface and groundwater sources to attain crop production goals. Fujihara et al., (2008) concluded t that less availability of water results in increased demand for field application because of the uneven distribution to the farmers. Nevertheless, water is an important component to sustaining life on the earth but due to anthropogenic activities, the quality and availability of water is decreasing day by day (Uddin et al., 2021).

Rawalpindi is well known for the abrupt changes in its weather conditions due to its geographical position and situation near the Himalayas and Pir Panjal range. It prevails in the areas that are considered under the climates of humid subtropical having mild and wet winter seasons. Its mean annual temperature is 21.3oC. The mean precipitation per annum in the area is approximately 1250 mm which prevails mostly in July and August. But occasionally the pattern of rainfall is changed and the frontal clouds pour in January and February. Rawalpindi district is divided into seven tehsils which are Rawalpindi, Murree, Kahuta, Gujar Khan, Kotli Satyan, Kallar Saydan and Taxila. Agriculture is mostly dependent on rainfall but it can get a boost if groundwater could be made available as a supplementary irrigation source. Khan et al., (2019) evaluated the irrigation and drinking water quality of the Rawalpindi district for the presence of potentially toxic elements and found the lowest levels of potentially toxic elements. Excessive use of water and the increasing trend of migration towards cities have put a high demand for water for domestic as well as industrial use in Rawalpindi District (Haq et al., 2022)

Electrical conductivity (EC), sodium adsorption rations (SAR) and residual sodium carbonate (RSC) are considered the most important factors for the assessment of irrigation water quality (Joshi et al., 2009; Idris and Shafiq, 1999). The dissolution of salts and the formation of precipitates result in poor-quality water being applied to the fields for growing plants. The type and texture of the soil, climate and season of the region, cultural practices and amendments also play a pivotal role in affecting the quality of water in addition to the role of EC, RSC and SAR. So it is entangling to conclude that only chemical determinants are the only factors that may affect water quality (Singh et al., 1992). According to Rizwan et al. (2003), the trend for water quality samples remained as fit> unfit>marginally fit with the number of samples 68>19>9, respectively from the 96 collected ones in Rawalpindi District.

Previous studies related to water quality analysis in Rawalpindi District only emphasized the specific regions irrespective of temporal changes. However, this study aimed to the evaluation of groundwater quality that is getting deteriorated with time in Rawalpindi District.

2. Material and Methods

2.1 Area Description and agriculture

Rawalpindi features a humid subtropical climate with long and hot summers while winters are short, mild and wet. The weather has historically been known to change quickly due to its proximity to the Himalayas and Pir Panjal range. Its mean annual temperature is 21.3 oC. The average annual rainfall is abundant at 1,249 millimeters (49.2 inches), most of which falls in the monsoon season. However, frontal cloud bands also bring significant rainfall in the winter. Rawalpindi District is divided into seven tehsils which are Rawalpindi, Murree, Kahuta, Gujar Khan, Kotli Satyan, Kallar Saydan and Taxila (Fig. 1).

The principal crops being grown in the area include wheat, barley, maize, millets, and pulses. These three crops depict the agricultural productivity of the district. The agriculture system is dependent upon rainfall which can get a boost with the availability of groundwater. The quality of groundwater is pretty much important to fulfill the crop water requirement.

2.2 Sampling and quality parameters

During the years 2016 to 2021, sampling for water quality assessment was done through the labeled plastic bottles with all its traceability showing the source, place, depth, time and date of sampling. Water samples were collected in such a quantity (I litre) that the samples may be enough for all the analytical work All the standard operating procedures for the collection of water samples were adopted either from tube-well as well as from the wells. Proper running water of about 30 minutes of discharge from both sources was collected in storing bottles. However, depth was the focal point for the collection of samples from stagnant water sources like dams, ponds and mini-dams. Soon after collection, the samples were transported for further procedures of sample preparation and analytical work. The analytical work for Electrical Conductivity using a Conductivity meter and cations were determined by titrating the sample against EDTA 0.01 N and sodium (Na) by difference method i.e total dissolved salts (TDS) - (Ca + Mg), anions like carbonates (CO3-), bicarbonate (HCO3-) were determined by titration using sulphuric acid (0.1 N) as titrant and chloride (Cl-) was determined by titration of samples with 0.05 N silver nitrate, according to the procedures given by Malik et al. (1984).

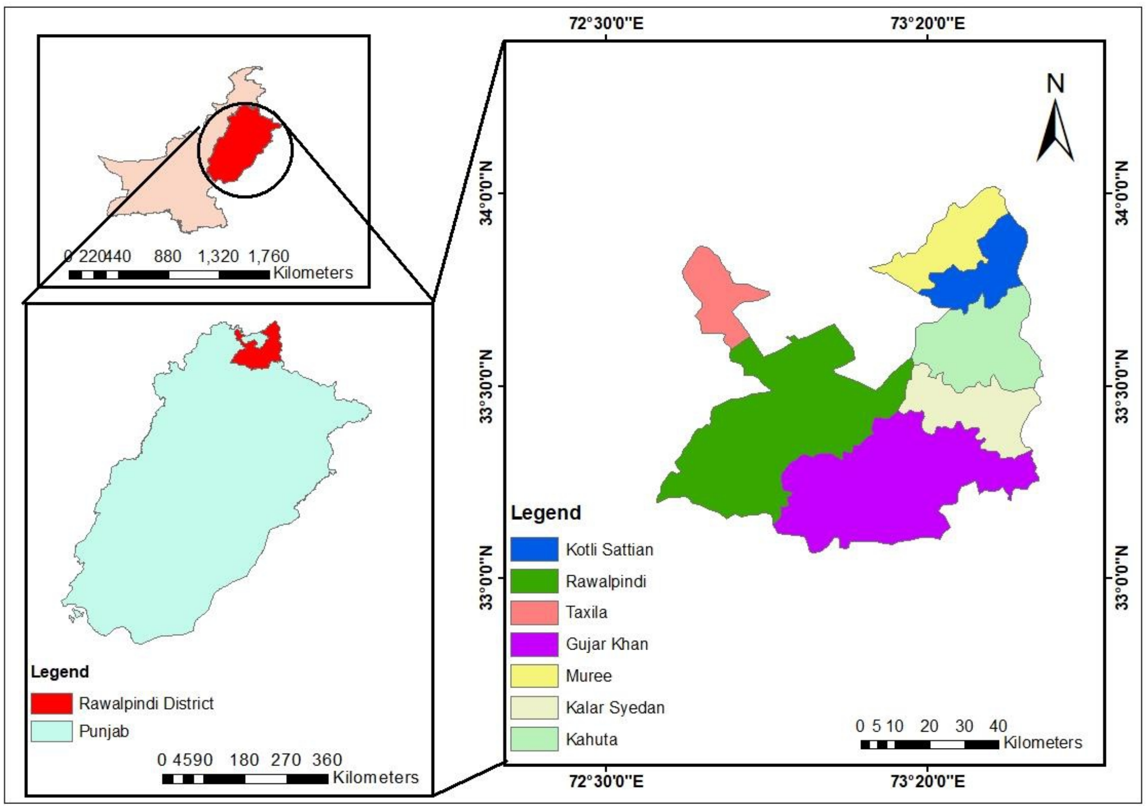

Fig. 1 Loacation map of the study area.

Table 1. Criteria for Water Quality Assessment (Malik et al., 1984).

Parameter	Fit	Marginally fit	Unfit
E C (dS m^{-1})	1.0	1.0 – 1.25	> 1.25
RSC (meq L^{-1})	<1.25	1.25 – 2.25	> 2.25
SAR	< 6.0	6- 10	> 10
Cl (meq L^{-1})	< 5.0	-	> 5.0

The calculations for the evaluation of quality parameters were done through the methods suggested by Richards (1954);

$$TDS\ in \frac{g}{m^3} = EC\ \left(\frac{\mu S}{cm}\right) \times 0.64$$

$$SAR\ in \frac{mmol}{L} = \frac{Na}{\left[\frac{1}{2(Ca+Mg)}\right]}\ 0.5$$

$$RSC\ in \frac{meq}{L} = (CO_3 +\ HCO_3) - (Ca + Mg)$$

The application of water having salt accumulation can be rectified through the addition of gypsum in the soil.

2.3 Statistical Analysis

Mean values of the analytical results were compared by performing t-test through ststistix 8.1 software.

3. Results

3.1 Water quality assessment in Rawalpindi Tehsil

Data related to the temporal assessment of water quality (Fig. 2) shows that out of the total samples, 80% of the samples were fit during 2016-17 which gradually declined to 56% during the year 2020-21 in Rawalpindi Tehsil. However, the number of unfit samples also increased from 23% to 30% during 2016-17 to 2020-21. The increasing trend in marginally fit samples was also recorded in five years (2016-21). It can be deduced from the results that the water quality of these areas is getting worse over time.

3.2 Water quality assessment in Gujar Khan Tehsil

Percent data related to the assessment of quality parameters of irrigation water samples collected from Gujar Khan Tehsil revealed that a maximum (52%) of the collected samples were found fit for irrigation purposes in the year 2016-17. However, a declining trend (66>60%) in fit samples was recorded for the year2019-2020>2020-21 (Fig. 3). While the sample distribution in terms of unfit samples also remained consistent (40%) throughout the five-year sampling time (2016-21). Whereas, the marginally fit samples remained less than 10% throughout the five-year sampling time.

3.3 Water quality assessment in Taxila Tehsil

Analytical results of collected samples from Taxila Tehsil revealed that the quantity of fit samples ranged from 94-100% during the five years sampling time from 2016 to 2021 (Fig. 4). Whereas, whereas the maximum number of unfit samples remained at 6% and 15% during 2016-17 and 2018-19 while during the rest of the years, number of unfit samples remained negligible. Overall data revealed that the water samples of Taxila Tehsil were fit for irrigation purposes.

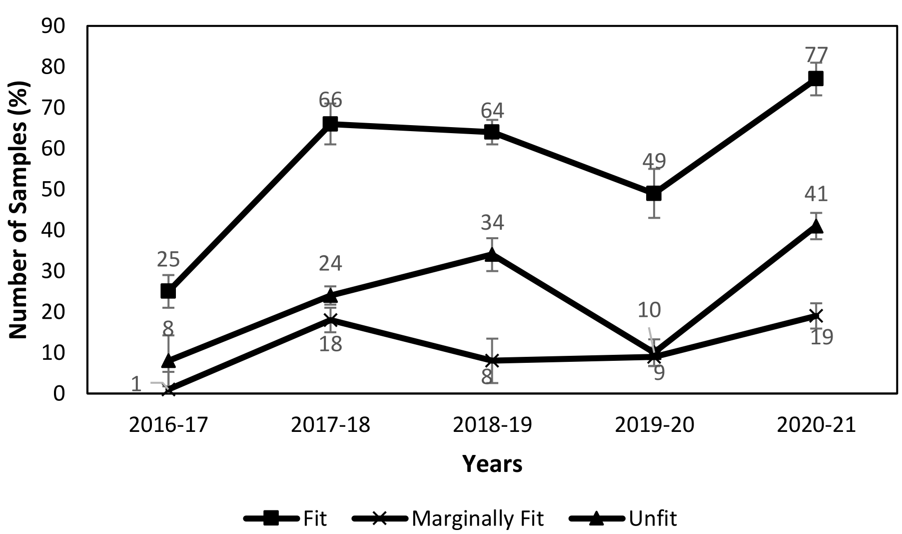

Fig. 2 Temporal variation in irrigation water quality of Rawalpindi Tehsil

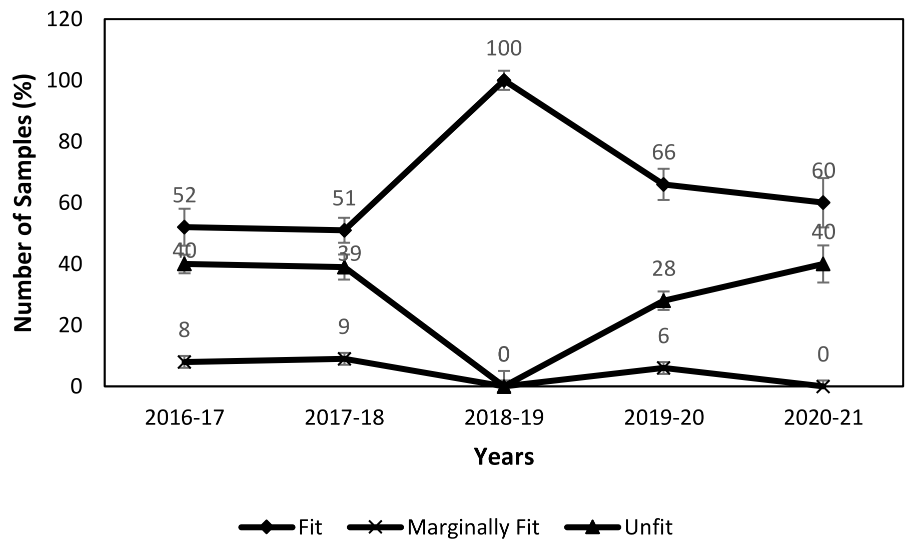

Fig. 3 Temporal variation in irrigation water quality of Gujar Khan Tehsil

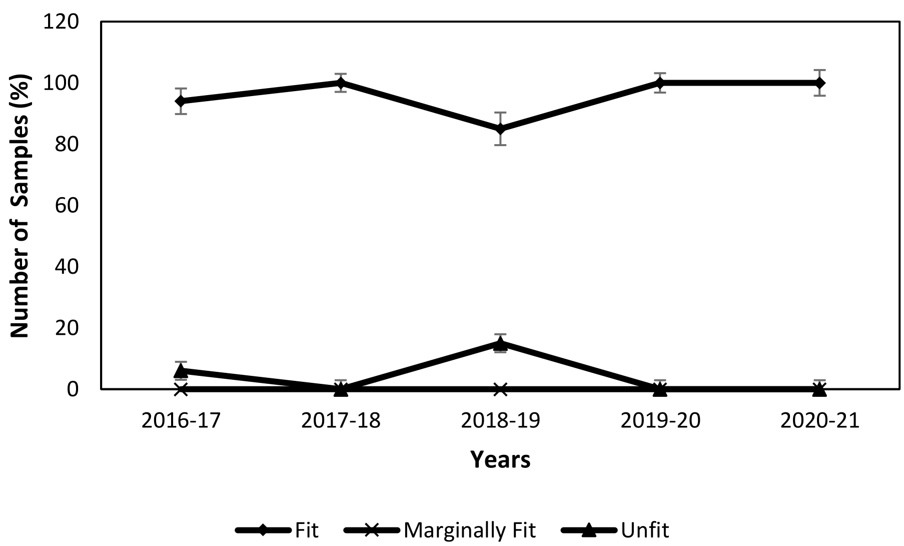

Fig. 4 Temporal variation in irrigation water quality of Taxila Tehsil

3.4 Water quality assessment in Kallar Syedan Tehsil

Data related to the suitability of irrigation water in Kallar Syedan Tehsil shows (Fig. 5) that 100% of the collected samples were fit in 2016-17 while a similar trend of suitability was recorded in 2017-18. However, 30% of the collected samples were analyzed as unfit rendering behind the 70% fit. Whereas, in 2019-20 quantity of unfit samples remained at 20% of the collected samples. From the data, it can be concluded that the water in Kallar Syedan Tehsil is of good quality and fit for irrigation purposes.

3.5 Water quality assessment in Kahuta Tehsil

Data related to the temporal assessment of water quality shows (Fig. 6) that the maximum number of samples remained fit for irrigation purposes. During 2018-19 about 80% of the samples were fit and 20% were found unfit. The quantity of marginally fit samples remained negligible throughout the sampling period of five years (2016-2021). From the results, it was recorded that the water quality of Kahuta Tehsil was good for irrigation purposes.

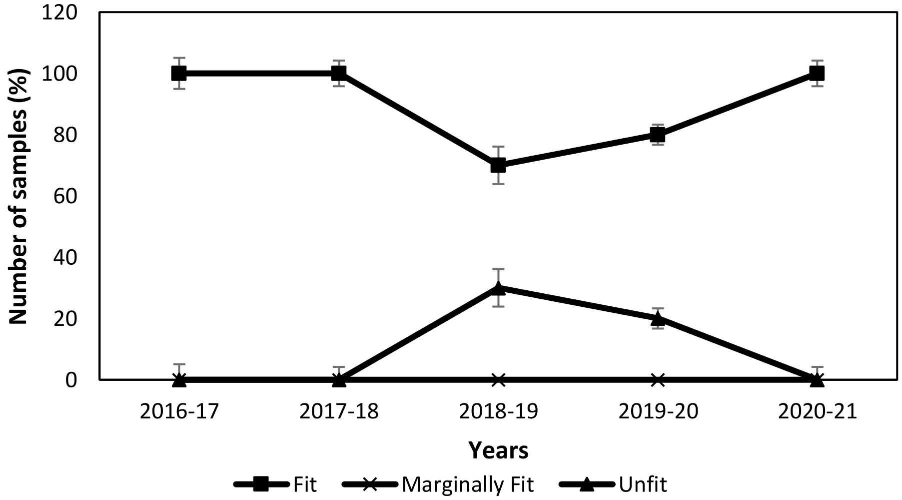

Fig. 5 Temporal variation in irrigation water quality of Kallar Syedan Tehsil

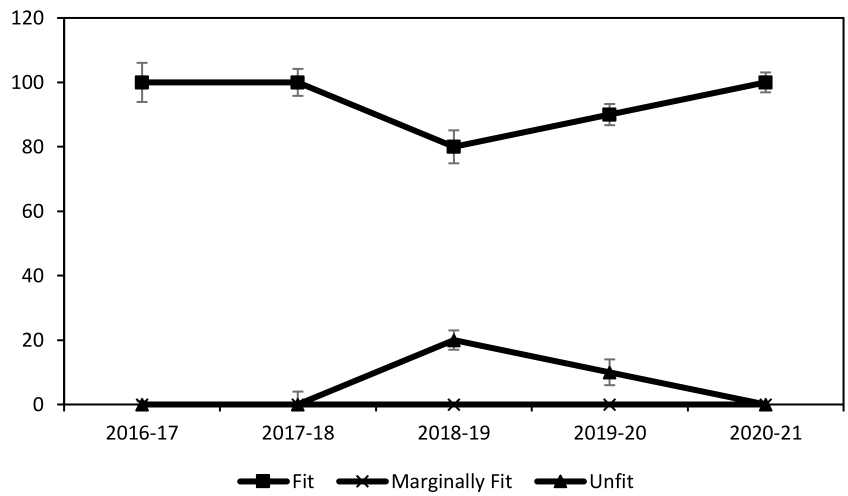

Fig. 6 Temporal variation in irrigation water quality of Kallar Syedan Tehsil.

3.6 Water quality assessment in Murree Tehsil

Analytical results of collected samples from Murree Tehsil revealed that the number of fit samples ranged from 85-100% during the five years of sampling time (Fig. 7). Whereas, the maximum number of unfit samples remained at 15% during 2016-17. However, 6% and 8% of the total number of samples were analyzed marginally fit that were collected during 2017-18 and 2020-21, respectively. Overall data revealed that the water samples were fit for irrigation purposes in Murree Tehsil of Rawalpindi District.

3.7 Classification of unfit samples based on electrical conductivity (ds m-1), Sodium Adsorption ratio and Residual sodium carbonates (me L-1)

The mean data for unfit water samples collected during 2016-2021 given in Fig. 8 shows that the number of unfit samples due to EC, SAR and RSC increased with temporal change irrespective of spatial distribution. However, the level of unfitness due to EC surpassed SAR and RSC by showing the maximum (36%) unfit samples in 2020-21, irrespective of spatial distribution. Whereas, the combined effect of EC+RSC had a significant impact in depicting the unfitness of the samples as compared to EC+SAR, SAR+RSC, EC+RSC+SAR, irrespective of the spatial and temporal distribution of collected samples. Maximum (29%) samples were recorded as unfit due to EC+RSC in 2017-18 followed by 20% in 2020-21.

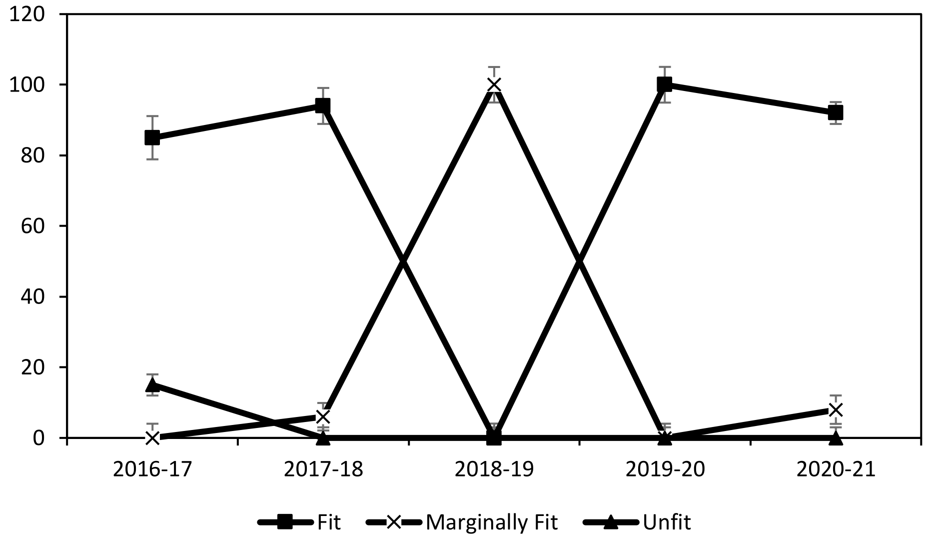

Fig. 7 Temporal variation in irrigation water quality of Murree Tehsil

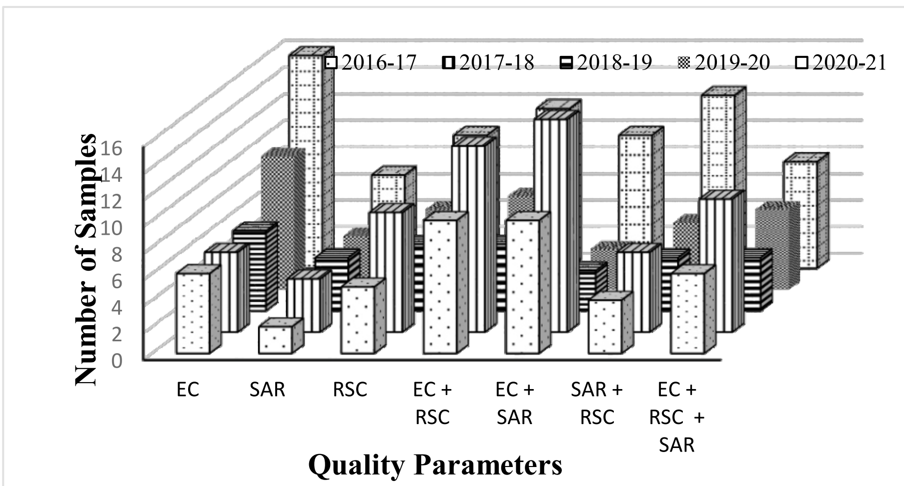

Fig. 8. Classification of unfit samples based on electrical conductivity, Sodium Adsorption ratio and Residual sodium carbonates

4. Discussion

It was observed from the results that the water quality of Rawalpindi Tehsil was declining with temporal changes. The majority of the samples were unfit due to higher EC rendering no indication of sodic issues in the waters. Our results for the samples collected during 2016-17 are following the findings of Rizwan et al., 2003 who reported that a maximum number of water samples of Rawalpindi Tehsil were fit for irrigation purposes. Whereas, our results of samples collected in 2020-21 are in disagreement with the findings of previous studies. The main reason for unfit samples would be due to urbanization, industrialization and anthropogenic activities over time. Nouri et al., (2008) reported that the water quality deteriorated due to many reasons including natural processes (soil erosion, rainfall pattern and weathering), and anthropogenic (urbanization, industrialization, agricultural interventions as well as disturbance of non-renewable resources). It has been reported that the water quality of major cities of Pakistan, such as Sialkot, Gujarat, Faisalabad, Karachi, Kasur, Peshawer, Lahore, Rawalpindi and Sheikhupura is deteriorating because of unchecked disposal of untreated municipal and industrial wastewater and unscrupulous use of fertilizers, pesticides and insecticides (Bhutta et al., 2002).

From the data, it was found that the water samples of Gujar Khan Tehsil were fit for irrigation purposes that need some amendments to improve water quality before irrigation to crops. Younas et al., (2015) suggested that proper amendments coupled with proper crop-growing techniques may be adopted while using the low quality or marginally fit water as an irrigation source. Tahir and Rasheed, (2013) analyzed the physicochemical properties of water samples collected from Gujar Khan and Murree Tehsils of Rawalpindi and found that the water quality of these tehsils was useful for irrigation purposes but with some limitations of contaminations in terms of excessive nitrate accumulation.

The analytical results of water samples collected from Taxila Tehsil of Rawalpindi District show that there is no issue of water quality deterioration but some samples were unfit during the year 2018-19. Waheed et al., (2010) worked on water samples from Taxila Tehsil and reported that 66% of water samples were fit, 21 % were marginally fit and 13 % were found unfit for irrigation purposes. This could be due to the presence of salts in the parent material of the soils in that area as well as less infiltration due to low rainfall in specific years.

Results related to water quality standards for irrigation purposes show that the water of Kallar Syedan tehsil is fit for irrigation purposes. Our results confirm Sehar et al., (2011) who analyzed physicochemical and microbiological parameters of the waters from open wells and bores of Kallar Syedan Tehsil, and concluded that maximum samples of the area were fit and were within the permissible water quality standards.

The results of Kahuta and Murree tehsils of Rawalpindi district showed that the quality of water in these areas was fit for irrigation purposes. The results conform with the findings of Tahir and Rasheed, (2013) who analyzed the physicochemical properties of water samples collected from Gujar Khan and Murree Tehsils of Rawalpindi and found that there was no significant problem of chemical contamination.

From the results of five-year analytical data related to the classification of unfit samples was inferred that an increase in EC was the main reason for the unfitness of the samples, irrespective of specific Tehsils in Rawalpindi District. The variation in EC is governed by the presence of salts in the water (Chang., 2008). Yoshino and Katsura., (2013) elaborated on the role of water in major EC anomalies in the upper mantle and transition zone. There could be various reasons for the unfitness of water which may be due to the lime present in the soil, shallow water table and the least infiltration of river flow to groundwater (Waheed et al., 2010). Our results are in agreement with Dawood et al., (2020) who analyzed the water quality of Khanewal Tehsil of Punjab province and evaluated the hazardous impact of EC, SAR & RSC, and their combinations. It was elaborated that EC had the leading role in showing 33.83 % of the total 742 water samples unfit.

5. Conclusion

Five-year data was taken for an assortment of various groundwater sources through hydro-chemical investigation in different tehsils of Rawalpindi District and it is concluded that the water quality of Rawalpindi Tehsil is deteriorating with increments each year. The probable reasons are increased population and urbanization. Unplanned and irrational usage of chemicals in Agriculture may be affecting the suitability of groundwater for irrigation. Moreover, wastes of different types may also have caused water quality deterioration. For quality management of the studied areas suitable management practices may be adopted that include the application of gypsum, green manuring, growing salt tolerant crops in the areas with high values of SAR and RSC, etc. However, more research and data collection are required regarding groundwater quality to authenticate the said conclusion.

Authors' Contribution

Asia Munir proposed the main concept and involved in write up. Obaid Ur Rehaman assisted in supervision of the research work. Kouser Majeed Malik, did provision of relevant literature, and review and proof read of the manuscript. Muhammad Waleej Arslan collected the field data.. Muhammad Akram Qazi Khan, did technical review before submission and proof read of the manuscript.

Fariha Amin helped in statistical analysis and data management through technical assistance of field data. Abdul Waheed was involved in preparation and illustration of the figures as well as graphs. Bashir Ahmad helped in methodology and provision of resources to conduct the research work.

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