Case Studies

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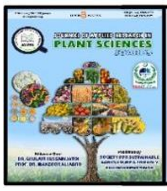

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Assessment of Groundwater Quality and Status: A Case Study of District Pakpattan

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ABSTRACT

Contaminated Ground water leads to soil degradation, reduction of plant growth, increase the risk of crop diseases, reduces water availability for irrigation, increase risk of animal poisoning, salinity and other changes in soil chemistry. In order to determine the suitability of underground water a study was carried out in soil and water testing laboratory Pakpattan which is the substation of Ayub Agriculture Research Institute Faisalabad, to determine the suitability of underground water for irrigation. The samples were collected from different areas of district Pakpattan in 500ml water bottles and subjected to find various parameters to accesses water quality. The findings reveal that significant variability in water quality across the district was found. Some samples met the criteria for safe irrigation; others exhibit high salinity, sodicity, arsenic concentration and ion concentrations that could negatively impact on soil health and crop productivity. These results indicated that 59.5% water samples were unfit, 12.5% were marginally fit and only 28% sample were fit for irrigation purpose. The findings revealed that there is a dire need for targeted water management strategies and regular monitoring to ensure the sustainability of agricultural practices in this area.

KEYWORDS: Groundwater, irrigation suitability, salinity, crop productivity.

INTRODUCTION

Pakpattan is the city of Punjab province in Pakistan having approximately 2724 square Kilometers (1052 square miles) area with population of 1.824 million according to latest report (Pakistan Bureau of Statistics 2023). This Tehsil is primarily agricultural, contributing significantly to the region's economy with crops such as wheat, rice and sugarcane. The production of wheat, rice, maize and cotton in year of 2020-21 in tons was405, 208.8, 1191.9 and 23.16 respectively and in 2021- 22 the same crop production was 323.50, 256.63, 1230.5 and 13.57 respectively (Awan, 2023). There are different factors which affect the rate of growth and production of crops and water is one of important factor among them. Groundwater is considered as a supplemental source for irrigation and is exclusively used for irrigating crops especially in arid and semi-arid areas. This affects the crop productivity and also causes many diseases to humans that use it for drinking purposes like typhoid, cholera, dysentery, diarrhea etc. While non-polar compounds suspend into water based on density, water has the innate ability to dissolve ionic substances due to hydrogen bonding and polarity (Steve *et al*., 2024). Thus, it creates a reaction matrix where large compounds break down into smaller ones that are visually indistinguishable (Shmeis, 2018).The availability of pristine water is hindered by several compelling factors. Surface water sources, for instance, are particularly vulnerable to the surrounding natural and man-made environment. Anthropogenic activities, in particular, pose significant threats to these water sources through contamination, overexploitation, and modification. These human-induced impacts make it challenging to maintain the purity and availability of surface water (Faraz *et al*., 2023). These water reservoirs are utilized by flora, fauna, and venomous insects alike and they also provide a habitat for both flora and fauna. As a result, groundwater is predominantly used for drinking, industrial, and agricultural purposes (Jamil *et al*., 2021). However, increasing population and urbanization have caused excessive water withdrawals, especially in areas with strategic deficiencies. Additionally, poor management of liquid and solid waste has further degraded groundwater quality. Pakistan experiences severe shortages of water and water contamination, just like other developing nations throughout the world. The country is regarded as water-stressed and is expected to experience a water shortage in the coming years since its existing water resources have practically depleted (Hashmi *et al*., 2009; Kumar *et al*., 2022).

In Pakistan, multiple studies have highlighted water quality problems stemming from the lack of effective enforcement of administrative laws on liquid and solid waste disposal (Batool & Shahzad, 2021; Fida *et al*., 2022). Pakistan is the fourth largest user of groundwater, following India, China, and the USA. In Pakistan, agriculture is the most water-dependent sector, with over 50% of its irrigation needs being fulfilled by groundwater sources (Qureshi *et al*., 2020).In urban areas near Lahore, Faisalabad, Multan, Peshawar, Sheikhupura, and Bahawalpur, irrigation water sources have been found to contain high quantity of heavy metals (Batool & Shahzad, 2021). The concentration of carbonates, magnesium, calcium, chlorides and other metals that change the pH of water also increasing in ground water of Pakpttan day by day. The decline in water quality is attributed to the discharge of municipal wastewater into water sources, as well as the uncontrolled use of pesticides, insecticides, and excessive fertilizers on crops in urban cities (Daud *et al*., 2017).The unregulated extraction of water intensifies the concentration of contaminants in the restricted water availability. Since 1990, there has been a notable increase in the installation of privately owned tube-wells in Pakistan (Abbas *et al*., 2022).In order to achieve agricultural production targets, the figure of privately owned tube wells has increased significantly, rising from 20,000 in 1960 to over 6 million according to recent guess (Qureshi, 2020).The data indicates that the water source recharge rate in the country is 15% less than the groundwater dismissal rate (Prathapar *et al*., 2021). River Satluj sever for irrigation purposes, it enters to the Pakpattan from the east side and passes through from its southern boundary (Sial, 2023).

The average rainfall also has greater impact on irrigation; the average rainfall in pakpattan district is 300mm (11.46inch), Urbanization, along with population growth 1.824 million (Pakistan Bureau of Statistics 2023), has intensified pressure on limited water sources. This has resulted in water shortages, prompting the use of untreated municipal wastewater for irrigating agricultural fields to meet crop water needs. The use of poor-quality water directly affects crop biomass, fruit quality, and yields (Seleiman *et al*., 2021).Multiple studies have highlighted the bio-accumulation of metal salts in fruits and vegetables (Aziz *et al*., 2021; Atta *et al*., 2023).Currently, irrigation water content is not scanned in this area, and open irrigation practices have led to issues such as soil acidity /salinity, increased weed development, retention of metals and metalloids, and reduced crop productivity. Therefore, it is essential to analyze water quality parameters to ensure the necessary balance of nutrients and minerals in the soil. Furthermore, regulating agriculture dependent on contaminated and saline water is crucial to sustainable growth and to ensure healthy productivity. Considering the rising trend of wastewater irrigation and existing gaps in monitoring and regulation, the present research study aims to examine water quality and the associated risks to crop productivity, with a focus on proposing solution-oriented approaches. To achieve this goal, the study aims to evaluate the worthy of groundwater sources for irrigation, focusing on factors like salinity, alkalinity and mineral composition and analyze dimensional trends and disparity in irrigation water classification to propose effective irrigation management strategies that enhance water use efficiency and mitigate negative impacts.

MATERIAL AND METHOD:

Study Area: In Pakpattan, summers are extremely hot, humid, and clear, while winters are short, cool, dry, and mostly clear. Throughout the year, temperatures typically range from 42°F (5.56°C) to 105°F (40.56°C), rarely dropping below 38°F (3.33°C) or rising above 112°F (44.44°C) (Pakistan Bureau of Statistics 2023). The land of Pakpattan is agro-supportive land and the main crops that are cultivated here include cash crops (maize, cotton, wheat, rice, and sugarcane etc) and other crops such as mustard, rapeseed, sunflower, and pulses. This warmed climate is also ideal for the cultivation of fruits such as citrus, mangoes, pomegranate, date-palm, guava, strawberry, falsa, jujube, banana and grapes (Hussain *et al*., 2019).

Water sample collection: Water sampling sits were chosen based on their proximity to agricultural areas. A total of 500samples were collected from the outlets of tube wells rather than the reservoirs from the following twenty five villages Chanwant, Karam Pur, Peer Ghani, Chan Peer, Chak Shafi, Chak Tawana, Chak 9/SP, Chak 10/SP, Chak 13/SP, Chak 14/SP, Chak 15/SP, Chak 16/SP, Chak 23/SP, Chak 29/SP, Chak 36/SP, Chak 38/SP, Chak 56/SP, Chak 63/SP, Chak 6/KB, Chak 15/KB, Chak 18/KB, Chak 20/KB, Chak 19/EB, Chak 31/EB. Prior to taking the sample, the tube wells were run for approximately thirty minutes. Distilled water was used to clean the bottles and then filled manually with flowing water from the running tube wells; two to three inches were left empty of 500 ml capacity bottles. Bottles were tightly closed and labeled with the information such as farmer's name, location, date, time and depth of bore. The sample bottles were kept in boxes and brought to the Soil and Water Testing Laboratory Pakpattan for analysis purpose. Additional information such as irrigated area, pipe diameter, and farmer details CNIC area owned and address, and GPS (Geographical Positioning System) coordinates was also collected during sampling.

Physical and chemical parameters analysis: The following parameters were analysed.

a) Electrical conductivity (EC)
b) Magnesium+ Calcium (Ca^{2+}+(Mg^{2+})
c) Carbonates (CO_3^{2-})
d) Bicarbonates (HCO^{3-})
e) Sodium (Na^+)
f) Chloride (Cl^-)

Standard operating procedures were followed to measure these parameters at Soil and Water Testing Laboratory Pakpattan. EC was used to determine the salt concentration in water, which is a indicator of dissolved salts/ions such as Ca^{2+}+Mg^{2+}, Na^+, SO_4^{2-} and Cl^- in the water.EC was measured with the help of EC meter ORION ATAR 212 made by the rmo Scientific. The remaining parameters were determined by titration methods. SAR (Sodium Adsorption Ratio) was calculated to determine the sodicity and it was calculated by comparing the relative abundance of sodium (Na^+) to calcium + magnesium (Ca^{2+} + Mg^{2+}) ions, all the ions expressed in milliequivalents per liter (meq/L).

To calculate the SAR (with cation concentration in milliequivalents per liter (meq/L), the following formula was used:

$$SAR\ (\text{m.mol/L})^{1/2} = Na^+/\sqrt{(Ca^{++} + Mg^{++})/2}$$

(Malik *et al*., 1984)

Additionally, the RSC (Residual Sodium Carbonate) parameter was used to evaluate the fitness of water for irrigation purpose, indicating potential sodium-related issues in soil due to polluted water irrigation. RSC was calculated on the bases of high concentrations of carbonate ($CO_3^{2-)}$ and bicarbonate (HCO_3^-) as compared to calcium + magnesium (Ca^{2+} + Mg^{2+}) ions in water. High levels of HCO_3^- and CO_3^{2-} ions can precipitate with Na^+ions, leading to excess $NaHCO_3$ and $NaCO_3$, as a results soil structure is disturbed and pores in soil are clogged. RSC was calculated using Richard's (1954) formulas.

To calculate the RSC (with cations /anions concentration in milli equivalents per liter (meq/L)), the following formula was applied:

$$RSC(meL^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

(Malik *et al*., 1984)

Based on the values of RSC, SAR, and EC, and in accordance with international standards, the water samples were classified accordingly.

Table 1: Criteria for Fitness of Irrigation Water.

Parameters	Fit	Marginally fit	Unfit
EC (µScm^{-1})	<1000	1000 – 1250	> 1250
RSC (meq L^{-1})	<1.25	1.25– 2.25	> 2.25
SAR (m.mol L^{-1})$^{1/2}$	<6	6 – 10	>10

(Malik *et al*., 1984)

Statistical Analysis: Statistical analysis was carried out on the data gained from analysis to obtain realistic values. In order to obtain realistic values (standard deviation, mean and percentage calculations) the methodology described by Steel *et al*. (1997) was followed.by using the SPSS-2016

RESULTS AND DISCUSSION

Results of analysed water samples are presented in Fig. 1, which indicated that 39% samples were fit with respect of ECe, 12.5% samples were marginally fit and 48.5% samples were unfit. These results are very alarming that approximately 50% samples are unfit for irrigation purpose. Results revealed that concentration of soluble salts have a significant amount in ground water of this area. This amount of soluble salts is a major hindrance in good out puts and better quality production of agricultural products, which ultimately creates a negative impact on farmer's economy. Prices of inputs including seed, fertilizers, pesticides and labors are increasing day by day and canal water availability is decreasing with a greater rate. The farming community has to cope with critical situations as they face a dual problem: canal water is decreasing, and underground water is unfit for irrigation purposes. The question is, how do they fulfill their required amount of irrigation water? The deep study; of results of Figure. 2 revealed that village chanwat has 75% underground water fit and 20% marginally fit with respect of EC, chak14/SP 70 % while chak 15/SP 65 % and chakShafi 60%unfit samples and they all have 15% marginally fit. On the other hand chak karampur has zero percent fit underground water and only 5% is marginally fit.Most of the villages have 15% to 25 % marginally fit water samples.Fig.2also revealed that chak13/SP and chak 63/SP have 70% unfit underground water, chak 6/KB and chak 36/SP have 65% unfit underground water, chak peer ghani, chann peer, chak 15/SP, chak 20/KB and chak 31/EB have 60% unfit underground water. While from the remaining villages many have 50% or more unfit underground water. These findings are very astonishing for the famers of this area, which are totally dependent of agricultural products

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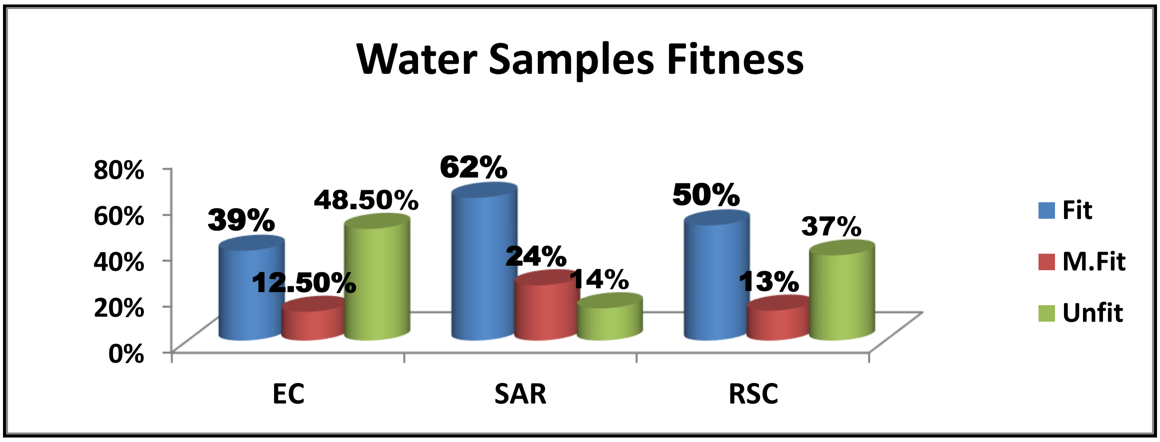

Figure. 1 Data of analysed water samples with respect to EC of Pakpattan

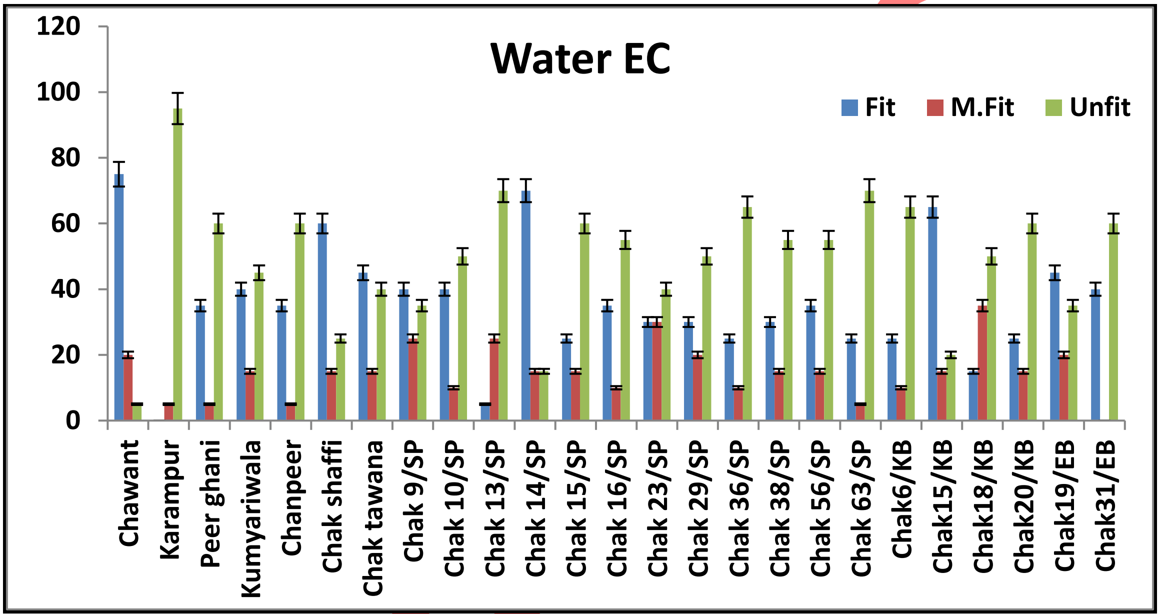

Figure. 2 Data of fit and marginally fit and unfit water samples village wise with respect to EC.

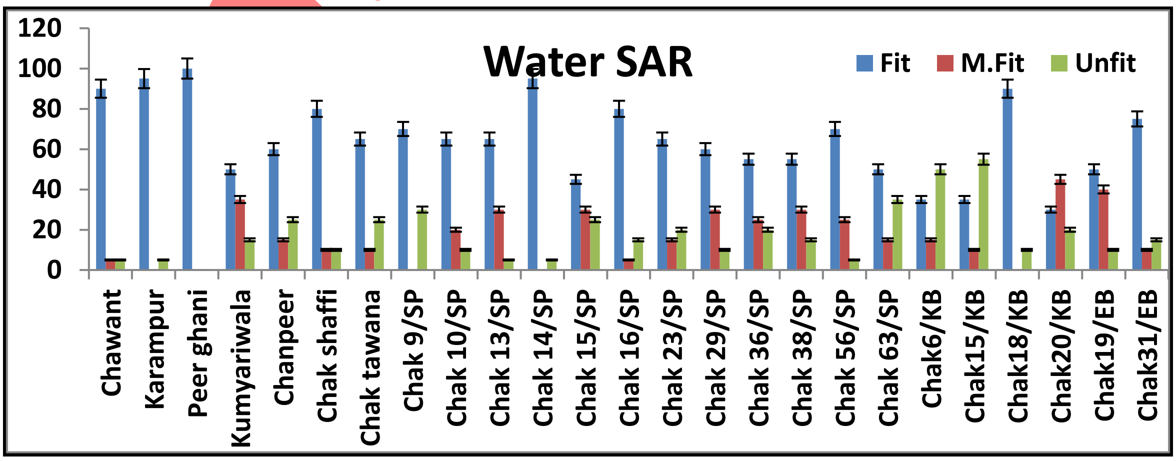

Figure.3 Data of fit and marginally fit and unfit water samples village wise with respect to SAR.

Figure 3 showed that village peer ghani has 100% fit samples with respect to SAR, while karampur and chak 14/SP has 95% fit samples and chanwat and 18/SP have 90 % fit samples. Other side ofthe picture showed that chak 20/SP has minimum (30%) fit samples while chak 15/SP and 16/SP has 80% fit samples regarding SAR. Highest marginally fit samples were found in chak 20/KB and chak 19/EB which were 45% and 40% respectively. Elevated figure of unfit samples relating to SAR was found in chak 15/KB and chak 6/KB which were 55% and 50% respectively. Village peer ghani has zero percent unfit water and chanwat, karampur, chak13/SP, chak 14/SP and chak 56/SP have 5% unfit water samples relating to SAR. Fig. 4 represents the results of underground water village wise with respect to RSC. This parameter basically indicates the excess amount of sodium carbonates and bicarbonate in water samples, which is the main sources of sodicity of soils and makes the underground water brackish.

Figure 4 very clearly revealed that village peer ghani has 100% fit samples, chak 15/KB and karampur have 95% fit underground water with respect to RSC. Chak 36/SP has 85% fit samples followed by chakshafi having 80% fit samples relating to this parameter. Highest marginally fit samples (20%) were found in chak 14/SP, 29/SP, 63/SP and 31/EB while the minimum marginally fit samples (0%) were observed in village karampur, peer ghani, chaktawana, 13/SP, 23/SP, 56/SP and 15/KB. Most unfit samples relating to RSC were observed in chaktawana, 15/SP and 6/KB having 50%, while chak 9/SP, 13/SP, 23/SP, 56/SP and 18/KB has 45% unfit water samples.

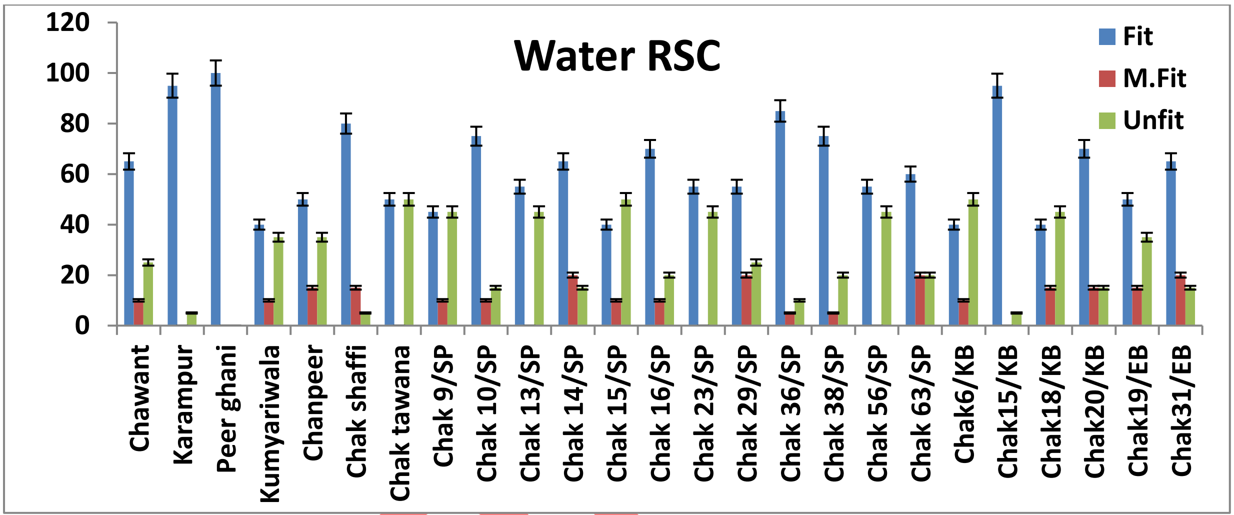

Figure.4 Data of fit and marginally fit and unfit water samples village wise with respect to RSC.

Pakpattan is very important city in agriculture point of view; it is at peak in Punjab province with the highest production of maize and potato. Potato is exported and has a significant contribution in GDP of this country. With respect to this research a field study revealed that crop yield reduced to 17.3 % when saline water is used as compared to good quality water (Cheng *et al*., 2021).Cifuentes *et al*., (2023) evaluated that when tomato and pumpkin crops were irrigated with a water having EC ≥2400 µS cm^{-1} it extenuate the biomass as compared to drip irrigated crops with fit water. Physiochemical stress is being created when crops are irrigated with sodic or saline water is applied because it plays a key role in nutrients and water uptake. Salty water disturbs the osmotic balance and ions uptake ultimately reduces the photosynthetic process (Malik *et al*., 2021). Furthermore Tekile (2023) concluded that application of sodic water plays an adverse affect on soil properties like soil permeability and soil texture. Application of this type of water damaged the soil pores as a result soil becomes hard due to which infiltration reduces and runoff increases. It also imposes negative effects on soil management practices. As the value of carbonates and bicarbonates increases with respect to calcium and magnesium it produces high RSC (Sarah *et al*., 2014).

When soil is irrigated with high value of SAR it produces high irreversible damages in soil due to high value of sodium in water (Fallatah &Khattab, 2023).A specific study was carried out in Multan, which resulted that 38% samples were found unfit and 61% samples were found marginally fit for irrigation purpose which is very critical value (Asif *et al*., 2021)these results are similar to this study. Ahmed *et al*. (2015) also carried out a study and concluded that 32% samples from Multan, 12 % from shujaabad and 27 % from Jalalpur were found marginally fit and a significant value was found unfit for irrigation purpose. Many factors including anthropogenic and natural contribute a vital role in worsening water quality. These factors include rock weathering, runoff effluent, input of decaying organic matter, and reduced infiltration rates (Mahmood *et al*., 2021). The untreated municipal waste mixes with surface water, and during the monsoon, the land area near the Satluj River becomes flooded. Satluj River, at specific points, has been reported to exceed permissible mineral content levels (Earnest & Hamid, 2021).Wu*et al*. (2016) mentioned that water table is decreasing with the rate 0.3 m/year in Punjab as pumping of ground water for irrigation purpose varies from 20% to 50% in different areas as it is a major source of irrigation in many areas.

Rehabilitation of salt affected soils can be carried out by using the amendments like organic matter, gypsum or sulfuric acid in irrigated areas (Hifza *et al*., 2021) like pakpattan. Scientists also revealed that fine textured soils affect badly as compared course textured soils when irrigated with water having high values of EC, SAR and RSC (Asif*et al*., 2021).

CONCLUSION

From the results it is concluded that approximately 80% samples were found unfit for irrigation purpose in this area, only 20% underground water is fit or marginally fit for irrigation purpose. It is very alarming situation for the farming community. It is essential that before installing a tube well or turbine water analysis must be carried out of the site so that economical loss of farmers may be minimized. Turbine or tube well should be installed in those areas where underground water is fit for irrigation purpose.

CONFLICT OF INTEREST:

There is no conflict of interest among scientist related to this study.

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