# WATER QUALITY MAPPING OF DISTRICT CHINIOT, PAKISTAN BY USING GIS

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**خلاصہ**

پانی کا معیار اور قلت دنیا کا سب سے بڑا مسئلہ ہے۔ موجودہ مطالعہ ضلع چنیوٹ کے دس منتخب علاقوں میں کیا گیا تھا۔ دریائے چناب ضلع چنیوٹ سے گزرتا ہے اور اس علاقے کا اہم دریا ہے۔ دریائے چناب میں پانی کی قلت کی وجہ سے زیادہ تر زرعی ماہر آبپاشی کی خاطر اچھے زمینی پانی کا استعمال کر رہے ہیں جو زمینی آبی وسائل پر بوجھ ہے۔ کنوؤں کے پانی کے معیار کا جائزہ لینے کے لئے طبعی کیمیائی خصوصیات، پی ایچ، برقی موصلیت، ٹوٹل الکلیت، کل تحلیل شدہ ٹھوس اجزاء، آکسیڈیشن ریڈکشن پوٹینشل، ٹوٹل ہارڈنیس، کیلشیم، میگنیشیم، کلورائڈ، سلفیٹ، سوڈیم اور پوٹاشیم کو جانچا گیا۔ زرعی پیرامیٹرز کے مطابق ڈیٹا بیس قائم کیا گیا تھا اور نمونے لینے والے مقامات کے پانی کے معیار کی نشاندہی کرنے کے لئے پائپر ڈایاگرام اور جغرافیائی انفارمیشن سسٹم (GIS) کے ذریعہ نقشے بھی بنائے گئے۔ پائپر ڈایاگرام کے ڈائمنڈ کے ہائیڈروکیمیکل فیس کا موازنہ اس بات کا اشارہ کرتا ہے کہ زیادہ سے زیادہ سوڈیم کلورائڈ قسم کے مرکبات ٪47.22 پائے جاتے ہیں۔ زمینی الکلائن الکلیز سے ٪ 52.77 سے تجاوز کرتی ہیں، مضبوط ایسڈ کمزور ایسڈ سے ٪ 88.89 زیادہ ہیں۔ مثبت آئنز سوڈیم اور پوٹاشیم کی قسم 47.2% ہیں۔ منفی آئنز ٪2.22 ہیں ان کی کوئی قسم غالب نہیں۔ جس میں سلفیٹ اور بائی کاربونٹیٹ ٪ 11.11 کی مساوی تقسیم اور کلورائڈ قسم کی کم تقسیم ہے۔ ان علاقوں میں پانی میں سوڈیم کے نمکیات کی زیادہ مقدار ہے وہ گندم، چاول، گنے اور لوبیا کی سوڈیم کے نمکیات برداشت کرنے والی اقسام کے لیے موزوں ہوں گے۔ موجودہ مطالعہ زرعی مقاصد کے لئے پانی کے معیار کی نگرانی کے لئے مفید ثابت ہوگا تاکہ مستقبل میں پانی کی قلت سے نمٹنے کے لیے پانی کی کھوج کا سلسلہ بدستور جاری رہ سکے، اگر ان کنوؤں سے بغیر کسی نگرانی کے بپانی نکالا جاتا رہا تو پانی کی سطح میں کمی، پانی کی کمی اور پانی کے معیار کو گراوٹ کا سامنا کرنا پڑے گا۔ اچھے معیار کے پانی کی تلاش کرنے والے حکومتی اور پرائیویٹ اداروں کے لئے جی آئی ایس میپنگ (GIS MAPPING) مددگار ثابت ہوگی۔ مزید یہ کہ پانی کے معیار کے مطابق فصلوں کے انتخاب سے معیشت، وقت اور دیگر وسائل کی بچت ہوگی۔

## Abstract

Water quality and scarcity is the major issue of today's world. Current study was conducted in ten selected areas of district Chiniot. River Chenab flows through the district Chiniot and is the major river of the area. Due to shortage of water in river Chenab. most of the farmers are using well water for the sake of irrigation that is a burden on the ground water resources. In order to monitor water quality of the wells, physiochemical analysis (pH, Electrical conductivity, Total alkalinity, Total dissolved solids, Total hardness, Calcium, Magnesium, Chloride, Sulfate, Sodium, Potassium and oxidation reduction potential) of water was carried out. Data base was established according to the agricultural parameters and piper diagram. Geographic Information System (GIS) mapping was also carried out to point out the water quality of sampling sites. Comparison of Hydrochemical faces of diamond of piper diagram indicates that maximum sodium chloride type compounds (47.22%) are found, Alkaline earth exceeds alkalis (52.77%), strong acids exceeds weak acids (88.89%). Maximum cations are Sodium and Potassium type (47.22%). Maximum anions are no dominant type (2.22%) with equal distribution of Sulfate and Bicarbonate type (11.11%) and least distribution of Chloride type. Those areas having higher concentration of sodium salts in water will be suitable for salt tolerant varieties of wheat, rice, sugar cane and beans. Current study will be useful to monitor water quality for agricultural purposes in order to cope with the scarcity of water in future as continuous extraction of water will result in lowering of water table, depletion of water and degradation of water quality if these wells remained unmonitored. GIS mapping will be helpful to search aquifers with good quality water. Moreover, selection of crops according to the quality of water will save economy, time and other resources.

**Key words:** GIS mapping, water quality, Piper diagram

## Introduction

Agriculture is the main source of provision of food in of Pakistan. Since surface water is not sufficient for irrigation, farmers have to rely on the subsurface groundwater for irrigation. As the groundwater is not unlimited source of water, therefore it has to tap cautiously. However, unfortunately, there is no systematic monitoring of extraction of groundwater by the concerned authorities. Every agriculturist and land owner extract the water by coring whenever his need arises of water. As a result of this haphazard extraction, groundwater is being depleted and deteriorating quality of water. In order to preserve the water resources for present and future generation, groundwater quality parameters needs to be evaluated for efficient crop production. As crop productivity depends on quality of water, therefore, irrigation with poor quality of water decreases its yield.

This study is conducted to evaluate the current situation of groundwater quality in District Chiniot, by analyzing the dissolved concentration and level of Ca, Mg and Na, Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). These chemicals are the main constituents that affect the quality of water for irrigation. The increased concentration of these elements from their permissible limits in irrigation water affects the quality of surficial soil. In high salt irrigation water, Sodium replaces the Ca and Mg (Ali *et al.,* 2011; Anant, 2012).

**Study area**

The subsurface groundwater samples were collected from one of the Tehsil of district Chiniot of Punjab, Pakistan. It is located on both sides of River Chenab (Bashir *et al*., 2019). For the current study, ten towns and villages (Rabwah, Ahmad Nagar, Burji, Dawar, Kot Wasawa, Chanian, Kot Ameer Shah, Khichian, Wahab di Jhalar and Chowk Madad Ali) of district Chiniot, Tesil Lalian, located on the right bank of River Chenab were selected for the analysis of subsurface water. The location of the sampling sites is shown in figure 1.

## Methodology

Subsurface water samples were collected from wells being used for irrigation purposes and their locations determined by hand held GPS (Garmin, etrex 10). Physiochemical analysis including pH, Electrical conductivity and Total dissolved solids were conducted by pH/ EC/ TDS meter (HANNA, HI 9813-5), Total alkalinity, Total hardness, Calcium, Magnesium were conducted by titrimetric method while Sodium and Potassium by microprocessor flame photometer(model 935) whereas, Sulfate was determined by spectrophotometer (HACH, DR 1900). Later sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were calculated. Oxidation reduction potential (ROP) was measured to understand oxidation reduction conversions of elements. Hydro chemical facies were determined by Piper diagram. The results of the analysis were plotted as contour maps using ArcGIS 10.2.

## Results and Discussion

### 4.1 Physiochemical analysis

Pakistan belongs to that region where rainfall is untimely. To fulfill deficiency of water, farmers rely on surface water and ground water. To meet the demand of water for irrigation, ground water is one of the main exploited resource (Ashfaq *et al*., 2009). The results of the physiochemical analysis as shown in table 1, indicate that all parameters except Sulfate (94%) are within FAO's established guidelines.

**Table 1 Physiochemical parameters**

| Parameters | Average mg/L | Average meq/L | Max | Min | FAO Guidelines | % Fit samples |
|---|---|---|---|---|---|---|
| pH | 7.269 | 7.269 | 7.9 | 6.7 | 6- 8.5 | 100% |
| EC | 904.444uS/cm | 0.090 dS/m | 0.282 dS/m | 0.037 dS/m | 0-3 dS/m | 100% |
| TDS | 652.75 mg/L | 652.750mg/L | 1974 mg/L | 268 mg/L | 0-2000 mg/L | 100% |
| Total Hardness | 283.055mg/L | 283.055mg/L | 770 mg/L | 180 mg/L | ------ | 100% |
| Calcium | 127.555 mg/L | 6.377meq/L | 18.4 meq/L | 1.6 meq/L | 0-20 meq/L | 100% |
| Magnesium | 54.305 mg/L | 4.525 meq/L | 4.525 meq/L | 0.208 meq/L | 0-5 meq/L | 100% |
| Chloride | 112.0833 mg/L | 3.157277 meq/L | 14.64789 meq/L | 0.704225 meq/L | 0-30 meq/L | 100% |
| Sulfate | 214.4722 mg/L | 4.468171 meq/L | 28.02083 meq/L | 0.125 meq/L | 0-20 meq/L | 94% |
| Total Alkalinity | 250.6944 mg/L | 4.109745 meq/L | 8.196721 meq/L | 1.229508 meq/L | 0- 10 meq/L | 100% |
| Sodium | 139.8989 mg/L | 6.08256 meq/L | 22.62174 meq/L | 0.73913 meq/L | 0 – 40 meq/L | 100% |
| Potassium | 28.07 mg/L | 0.71974359 meq/L | 0.817949 meq/L | 0.511795 meq/L | 0-2 meq/L meq/L | 100% |

Regular monitoring of pH is necessary as pH is an Important indicator for the determination of bio available elements e.g., at lower pH Aluminum (Al) dissolves in water as $Al^{+3}$ in acidic conditions that react with phosphorous and form insoluble Aluminum phosphate cause deficiency of phosphorous to plants resulting in low yield (Matsumoto *et al*., 2017).The table 1indicates that pH ranges from 6.7 to 7.9. pH of 100% samples was according to the FAO guidelines. Average pH was 7.2. Geographical distribution of pH shows that lower limit of pH is near the Kirana Hills and increases on west side with increasing distance from Hills (Fig 2).

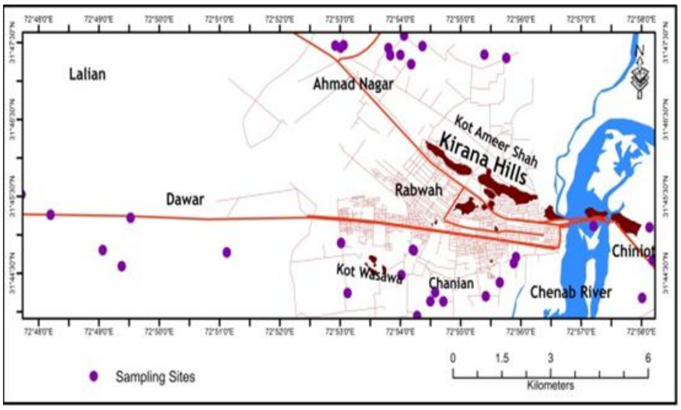


**Fig. 1. Study Area**

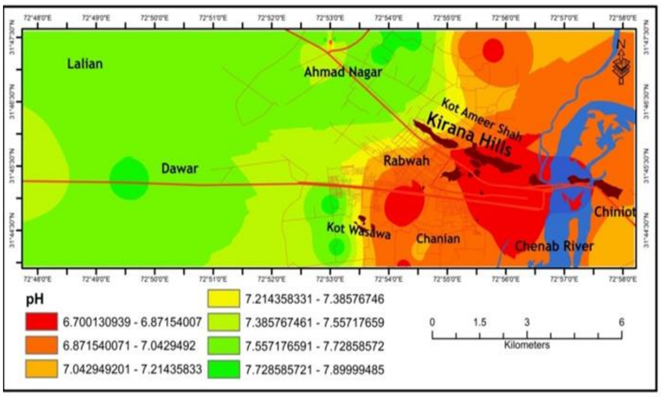


**Fig. 2. IDW map of pH**

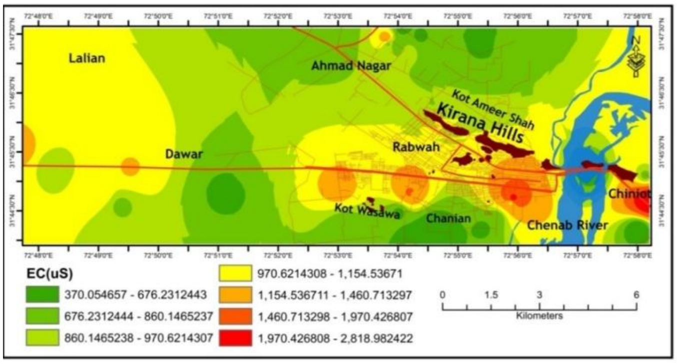


**Fig. 3. IDW map of EC**

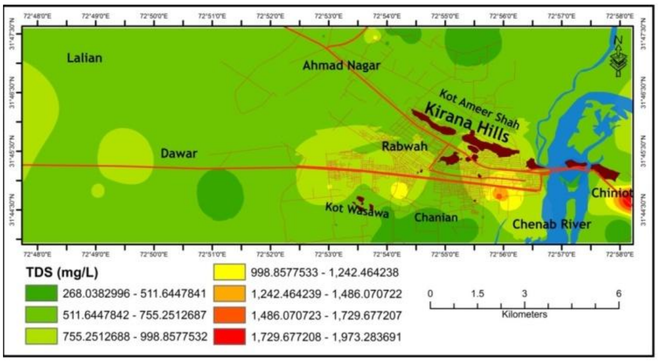


**Fig 4. IDW map of TDS**

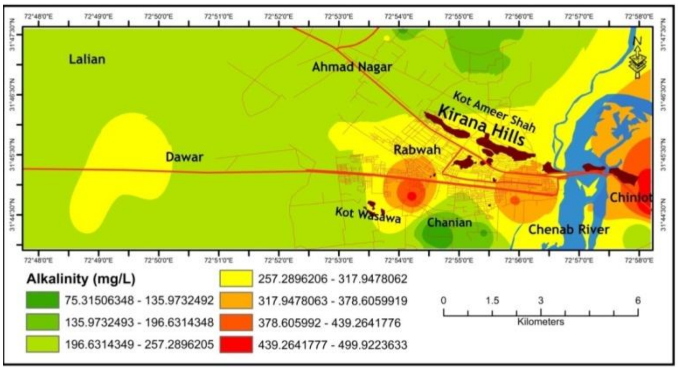


**Fig. 5. IDW map of Total Alkalinity**

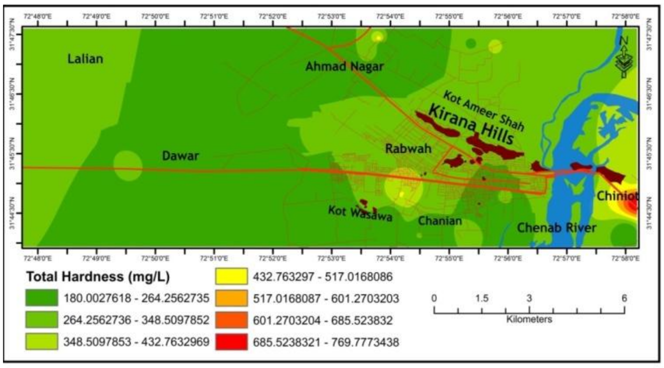


**Fig. 6. IDW map of total hardness**

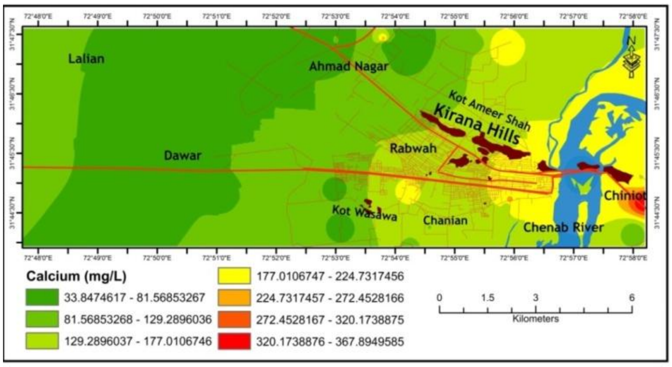


**Fig. 7. IDW map of Calcium**

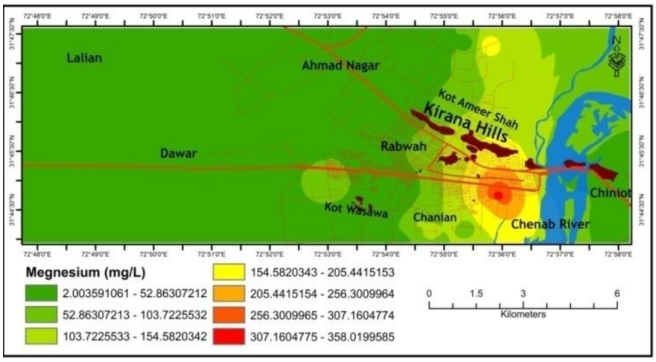


**Fig. 8. IDW map of Magnesium**

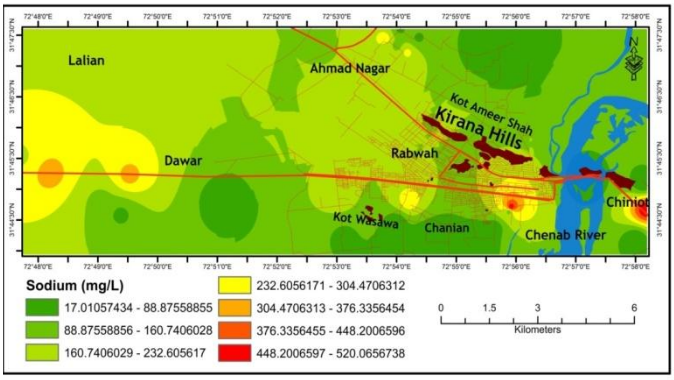


**Fig. 9. IDW map of Sodium**

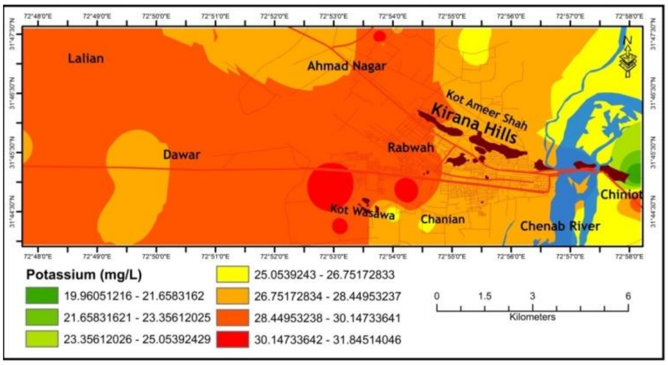


**Fig. 10. IDW map of Potassium**

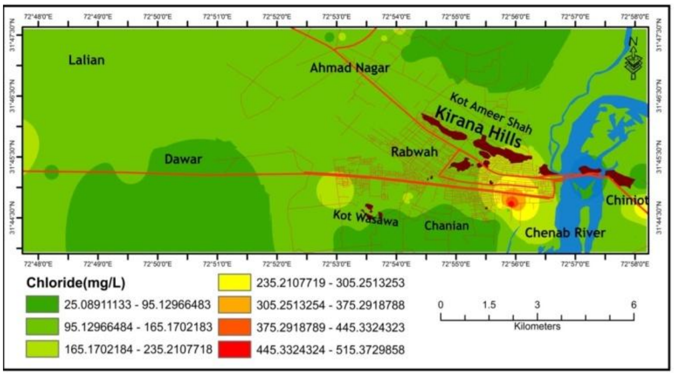


**Fig. 11. IDW map of Chloride**

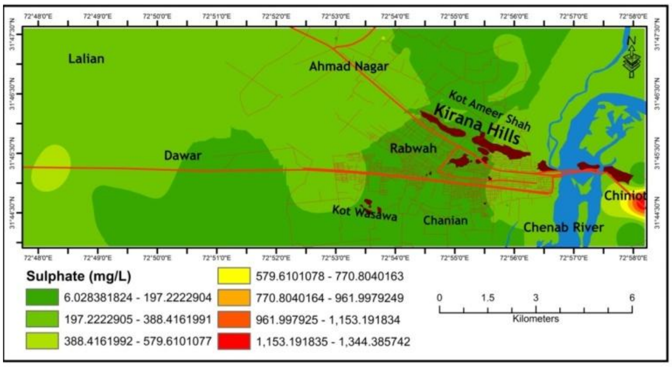


**Fig. 12. IDW map of Sulfates**

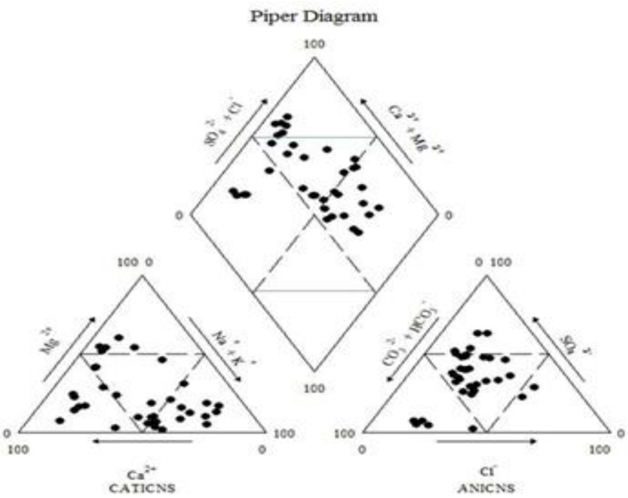


**Fig. 13. Piper Diagram**

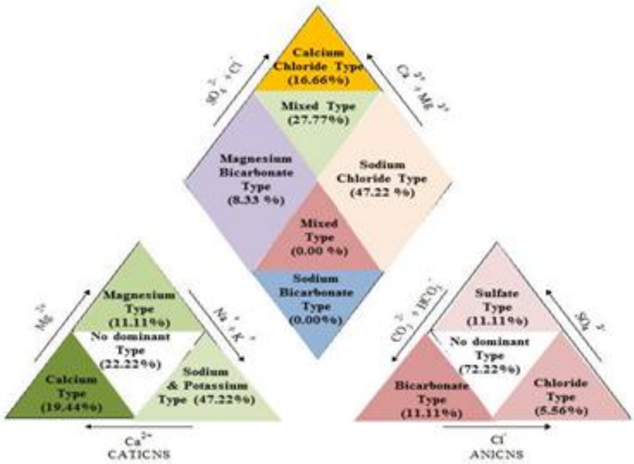


**Fig.14. Hydro Chemical Facies according to Diamond, Cation and Anion Triangle**

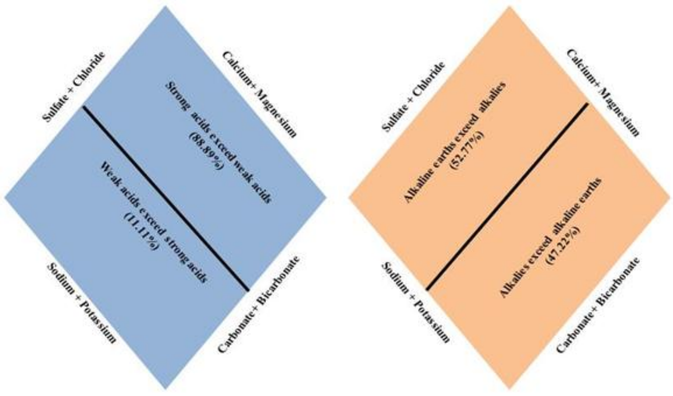


**Fig.15. Hydro Chemical Facies according to Alkaline Earth Metals and Acids**

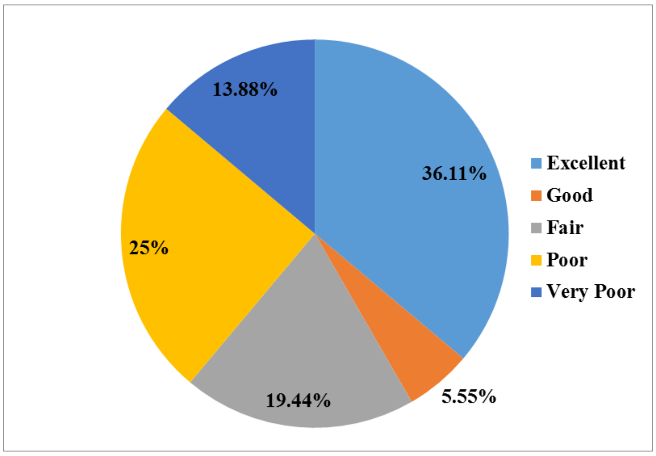


**Fig.16. Percentage samples vs Sodium Adsorption Ratio (SAR) Classification**

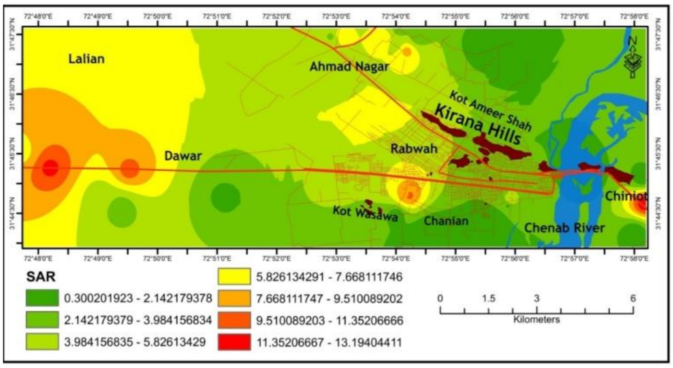


**Fig. 17. Geographical Sodium adsorption ratio(SAR)**

Electrical conductivity is another major parameter that effect yield of plants as it provides osmotic pressure that facilitates the absorption process of roots. The Electrical Conductivity (EC)within the study area ranges from 0.03 dS/m to 0.28dS/m. Maximum value was 0.282dS/m and minimum was 0.037dS/m(Table 1). Electrical conductivity of all samples were within FAO guidelines. Spatial distribution of EC indicates that it increases near Kirana Hills and decreases with increasing distance from Kirana Hills (Fig 3). Moreover, different plants give highest yield at different EC values e.g., Lettuce prefers lowers values for maximum yield and tomatoes gave good yield at higher limits of EC (Abou-Hadid *et al*., 1995). On this base crop require less than 2dS/m EC can be cultivated in study area in order to get maximum yield. Crops mostly cultivated in this area are wheat, rice, maize and sugarcane. According to EC of current area Beans (according to USDA classification declared sensitive, require EC 0-2 dS/m) can also be cultivated besides other crops.

Total dissolved solids are directly related to total salinity. The yield and growth are directly proportional to solids in soil solution in rhizosphere. The TDS in the subsurface groundwater from study area ranges from 268 mg/L to 19 mg/L with average value of 652.75mg/L. All the water samples were found within FAO guidelines. The tendency of increase in TDS from west to east was observed

Total alkalinity in the area ranges from 1.22meq/L to 8.19meq/L which indicates that all water samples are within FAO acceptable range (1 – 10meq/L). The spatial distribution surface show that low alkalinity values were observed away from hills (Fig 5).

Total hardness ranges from 180 mgL to 770 mg/L with average value of 283.0556 mg/L. Relatively less total hardness was observed on western side (Fig. 6).

Calcium requirements of plants are fulfilled by absorption through roots. It depends on the availability of calcium in rhizosphere. Calcium is an essential plant nutrient. As the divalent cation ($Ca^{2+}$), it plays structural roles in the cell wall and membranes and as an intracellular messenger in the cytosol (Philip *et al*., 2003). The results of the analysis indicate that maximum value of Calcium is 18.4 meq/L and minimum value is 1.6 meq/L while average value is 6.377 meq/L. According to FAO guidelines, all samples are within the permissible limit. The spatial distribution of the calcium shows that there is less Calcium towards western areas as compared to eastern areas (Fig. 7).

The results of the analysis of magnesium as given in Table 1 indicates that maximum magnesium value in study area is 4.52 meq/L and minimum value is 0.208 and average value was 4.52. All the water samples show that, Mg is within range as described by FAO. Maximum magnesium was observed on eastern side. Decrease in Mg was observed towards western side (Fig. 8).

The presence of Na in the environment and its uptake by plants can reduce the amount of K required to meet the plants basic metabolic requirements. Thus, in the presence of Na, the critical level of K can be reduced (the lowest tissue K level at which 95% of the maximum yield can be achieved). Sodium salts occur as carbonates, bicarbonates, chlorides, and sulfates, and the proportions of each in different parts of the field are extremely variable. The excess of sodium results decrease in growth rate, germination, and productivity (Gunter *et al*., 2003). Analysis of sodium within the groundwater samples represent that sodium ranges between 22.6 meq/L and 0.73 meq/L with average value 6.08 meq/L. The result shows that all water samples are within the acceptable range. The spatial distribution of the sodium shows that maximum values of sodium extends towards eastern ends near hills while minimum values found towards western ends (Fig 9).

Potassium supply to plants is very necessary as potassium plays an important role in enzyme activation, stomatal activity, photosynthesis, transport of sugars, water and nutrient transport, protein and starch synthesis and crop quality. Potassium deficient crops grow slowly and have poorly developed root systems. Stalks remain weak and lodging of cereal crops takes place such as corn and small grain results. Legumes are not strong competitors for soil potassium and are crowded out by grasses in a grass-legume pasture. When potassium is not sufficient, winter-killing of perennial crops such as alfalfa and grasses can occur. Seeds from potassium deficient plants are small, shriveled and are more susceptible to diseases. Fruit is often lacking in normal coloration and is low in sugar content. Vegetables and fruits deteriorate rapidly when shipped and have a short shelf life in the market (Kalavatiprajapati, 2012).

Table 1 indicates that the minimum concentration of potassium within the water is 0.51meq/L, whereas, the maximum is 0.81meq/L and average value is 0.71meq/L. The results of the water samples shows that the concentration of potassium with in the sampling area is as per FAO guidelines.

The spatial distribution of potassium as shown in figure 10 indicates no significant variation in the area, with little difference of greater potassium towards western ends and smaller values towards western ends.

Among anions maximum chloride value is 14.64meq/L, minimum value is 0.70meq/L with average value 3.15meq/L. Spatial distribution indicates greater chloride values near hills and minimum values away from hills(Fig 11).

Sulfur is very important and one of the components of sulfur amino acids methionine and cysteine and many other compounds ferredoxin and glutathione Uptake of sulfate depends on pH, temperature and availability of sulfur. Although toxic effects of sulfates have not clear yet but excess sulfate content in some plants decrease leaf area (Ivona, 2005).

Continuous assessment of these well water is necessary as continuous extraction of water may deplete water quality. Maximum value of sulfates remained 28.02 meq/L, minimum value 0.125meq/L and average value 4.46 meq/L. 94% samples were found within FAO guidelines. According to spatial distribution, greater values were observed towards eastern area near hills and minimum values towards western areas away from hills (Fig.12)

**Distribution of samples in Piper Diagram**

Most of the samples lie in sodium chloride type and mixed type region in diamond (Fig. 13). While according to anion distribution most samples were found in no dominant type region. In case of cation type most of the samples were in sodium and potassium type region (Fig. 13).

**Hydro chemical Facies according to diamond, cation and anion triangle**

Hydrochemical facies of diamond indicates that 47.22% samples are sodium chloride type, 16.66% calcium chloride type, 8.33% magnesium bicarbonate type. While no sample was found sodium bicarbonate type.According to cation triangle 11.11% type samples were magnesium type, 19.44% samples have calcium type cations. Major cations were found sodium and potassium type(47.22%) while 22.22% samples have no dominant type cations (Fig. 14)

**Hydro chemical Facies according to alkaline earth metals and acids**

According to figure 15 in 88.89% strong acids exceeds weak acids and in 11.11% samples weak acids exceeds strong acids. In case of distribution of alkalies and alkalines in 52.7% samples alkaline earths exceeds alkalies while in 47.22% samples alkalies exceeds alkaline earths.

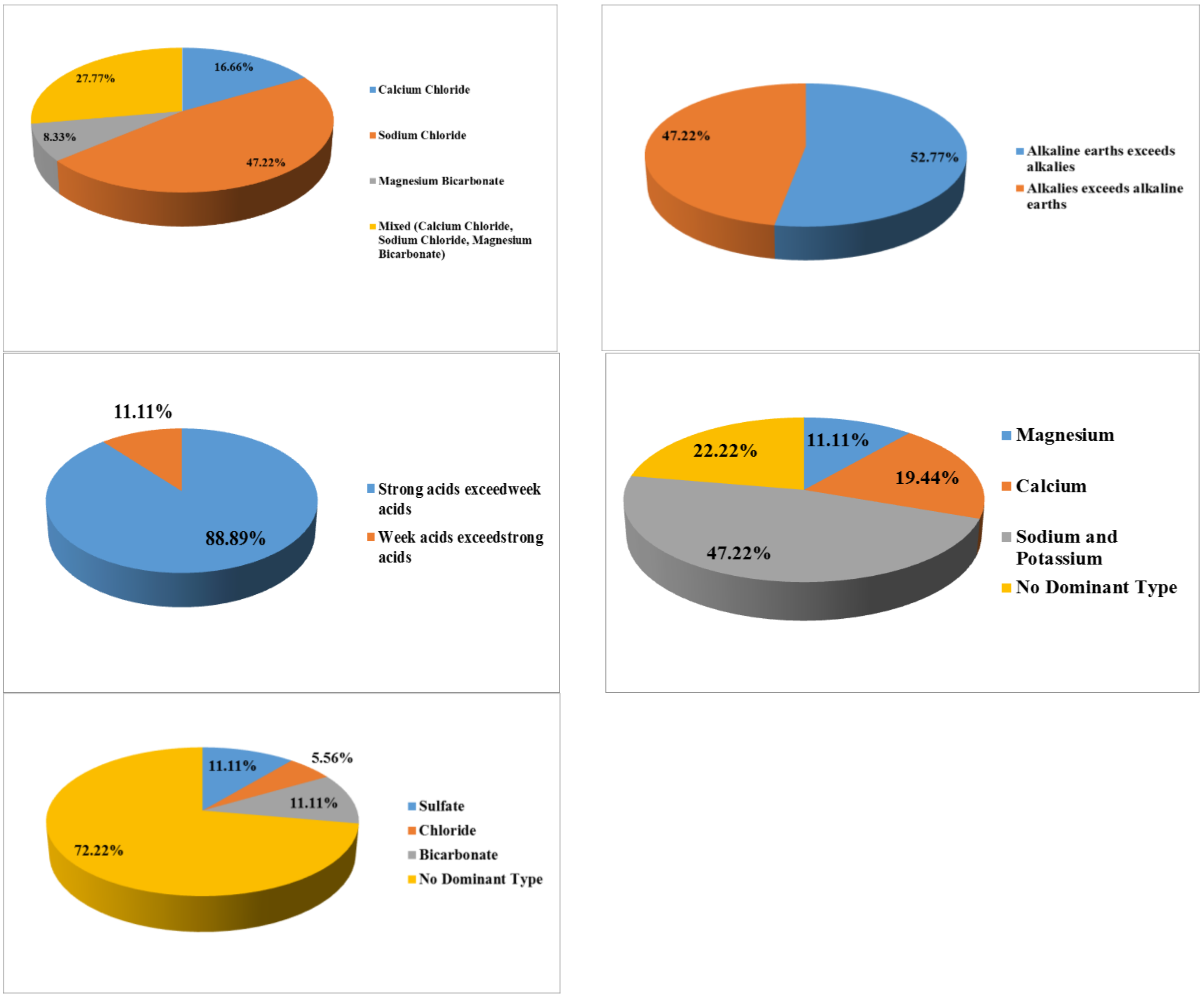


**Fig.18. Comparison of Hydro Chemical Facies of Diamond**

**Percentage samples vs Sodium adsorption ratio (SAR) Classification**

Water with higher SAR value is less suitable for irrigation as it decreases infiltration rate (Abdul waheed *et al.*, 2018). According to SAR classification (Table 2) 36.11% samples were in excellent range, 5.55% in good range and 19.44% in fair range. While 25% samples belong to poor range and 13.88% samples in very poor range (Fig. 16).

**Table 2 SAR Classification**

| SAR | Classification | Management Considerations |
|---|---|---|
| < 1 | Excellent | None |
| 1-2 | Good | Little concern, add pelletized gypsum periodically |
| 2-4 | Fair | Aerify soil, sand top dress, apply pelletized gypsum, monitor soil salinity |
| 4-8 | Poor | Aerify soil, sand top dress, apply pelletized gypsum, leach soil regularly, monitor soil salinity closely |
| 8-15 | Very Poor | Requires special attention; consult water quality specialist |
| > 15 | Unacceptable | Do not use |

Spatial distribution of SAR indicates that samples from western side have more SAR as compared to eastern side (Fig. 17).

SAR is of significant importance for the selection of irrigation water as it influence plant growth. The reduction in plant growth is due to increase in solute potential that takes place by salts due to irrigation water. As 70-90% uptake of water takes place in upper root zone where irrigation water reached (Hussain *et al.*, 2010). High alkalinity values have more drastic effect than salinity on plants. As alkaline salts increase pH also increases. The alkali salts such as $NaHCO_3$, $NaCO_3$ create more damage as compared to neutral salts such as NaCl and $Na_2SO_4$ (Zhanwu *et al.*, 2014).

Comparison of Hydrochemical facies of diamond of piper diagram indicates that maximum sodium chloride type compounds (47.22%) are found, Alkaline earths exceeds alkalis (52.77%), strong acids exceeds weak acids (88.89%). Maximum cations are sodium and potassium type (47.22%). Maximum anions are no dominant type (2.22%) with equal distribution of sulfate and bicarbonate type (11.11%) and least distribution of chloride type (5.56%) (Fig 18).

**Conclusion**

The shortage of water in river Chenab is causing more extraction of ground water through tube wells to meet the irrigation purposes. More extraction is causing an increase in salts contamination. Almost are samples were within the range defined by FAO. Except sulfate all samples are 100% fit within FAO guidelines while sulfate is 94% fit within described range. Some samples were bordering the upper limits of few parameters which can cause danger in future. That's why the continuous monitoring and further surveys are required to get proper information for further processes GIS maps are clearly indicating the deficiency and excess of different physiochemical elements. This study will help the farmers to decide about the cultivation in their next crop seasons. The results of this study will also be helpful for local administration as well as government in finding solutions of agriculturist's problems and to find appropriate solutions for water shortage in the area.

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