Evaluation of Ground Water Quality for Irrigation Purposes: A GIS Based Study of Nankana Sahib

Arslan Afzal, Bilal Ahmad

Abstract— Sampling and analysis of groundwater of Nankana sahib tehsil, Pakistan has been made to determine and evaluate its suitability for irrigation purpose. three water samples from each twenty five villages were collected and analyzed for various physical and chemical properties like pH, sodium adsorption ratio (SAR),Residual sodium carbonate (RSC), calcium (Ca^{++}), Magnesium (Mg^{++}), sodium (Na^{+}), chloride (Cl^{-}), carbonate (CO_3^{-}),bicarbonates (HCO_3^{-}), sulfates (SO_4^{-}).According to results 6.67% samples were fit, while 80% were unfit for the irrigation purpose while 13.33% were lies in the range of marginally fit after comparison with the standard value of the irrigation water used for the agricultural crops. The values of EC, SAR, RSC and chloride were ranged from 367-5080 μscm^{-1}, 0.23-25.86, 0.1-7 and 0.5-6 $meqL^{-1}$ respectively. The classification of parameters due to which 80% samples were unfit showed that 5.33% samples were unfit due to EC, 4% samples due to RSC, 13.33% were unfit due to the EC+RSC, 2.67% were unfit due to EC+SAR and 54.67% sample were unfit due to EC+SAR+RSC. By relative frequency distribution 57 samples were unfit due to higher EC (>1250) samples were unfit due to the higher SAR(>10), 54 samples were unfit due to the higher RSC(> 2.5) and 29 samples were unfit due to the higher Chloride value. In the light of results it is evitable to treat the ground water with management practices and amendments lining of watercourse with limestone, gypsum, dilution with canal water and new private tube well should be install after resistivity survey of groundwater and the farmer should also be get aware with the smart irrigation management practices through proper training.

Index Terms— Bicarbonates, Elecreical Conducrivity, Frequency distribution, Ground Water, Irrigatiion, RSC, SAR

1 INTRODUCTION

Pakistan is known as a Agriculture based country, the Agriculture sector of Pakistan plays an important role in the economy by contributing about 18.9 percent to GDP [5]. Water is essential for agricultural and food production .The surface water is decreasing due to change in hydrological and climate change conditions. The Ground and surface-water quality is deteriorating day by day due to the indiscriminate discharge from industrial and domestic wastewater into open water-bodies and groundwater is main treat to the country's water-reserves. Surface water resources was reduced about 70 percent in 2003 as compared to the normal years [2].The use of tube well water is increasing to overcome the shortage of canal water but due to high Electrical conductivity (EC) , sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) many of the Tubewells are found unfit for Irrigation Purposes [1]. According to [4]. In 1960 there was about 20,000 private tubewells in the country but currently number of tubewells are more than 1 million tubewells used for irrigation purposes. The Agriculture success is highly dependable on the quality of water applied to the crops. Due to the application of poor and hazard quality water the agriculture Land/soil is affected and damage the crop yield in several ways. The accumulation of the salts in root zone, limited and availability of water and plant can take up lesser water which results in high plant stress and decreased crop yield [9].

In some area top layer is containing fresh water suitable for the irrigation purposes but in deep aquifer water quality is not good. The Agricultural productivity area of Province Punjab falls under semi-arid and arid zones. Study was conducted to access the water quality of the different areas of Punjab and the samples were analyzed for EC, SAR and RSC and Chloride ions [3]. Percentage of fit samples from areas of Chakwal ,Shiekhupura ,bhai pheru and Lahore were 37% ,29% ,49% and 16% respectively while 49% ,50% ,18% and 59% were unfit and rest of the samples were declared as marginally fit for irrigation [4]. [9] reported for ground water quality of Kasur District. Out of 64 water samples from various tubewells 26 samples was found fit, 8 samples was lies in the range of marginally fit while 30 samples was unfit for Irrigation Purpose.

The agriculture success is highly dependable on the quality of water applied for crop production. Due to poor quality water the agriculture land soil is affected that results in damages the crop yield. The accumulation of salts in root zone, limited the availability of water and plant can take up lesser water which resulted in high plant stress and decreased crop yields [10]. The presence of metals in irrigation water also has adverse effects on crop production, high concentration of salts can change the plant nutrients balance in the soil meanwhile some salts are toxic to certain plants [4].The bio-mass production and yield of major crops of Nankana sahib i.e, wheat , rice and shugarcane are being effected by the poor quality irrigation water.

The groundwater quality assessment of district Jhang shows that out of 106 samples taken from different villages 30 samples (28.3 % of the total samples) were found unfit , while re-

- *Arslan Afzal has been graduated in Agricultural Engineering from University of Agriculture, Faisalabad, Pakistan. PH-+923231416404. E-mail: arslanafzal2021@gmail.com*
- *Bilal Ahmad is currently pursuing masters degree program in Agricultural Engineering in University of Agriculture, Faisalabad, Pakistan. PH-+923064613921. E-mail: eabilal@yahoo.com*

maining 76 samples (71.7 %) was found fit for irrigation purpose. Eighteen samples have permissible limit (≥1.50 dS/ m), 7 samples (6.6%) were found having high SAR (>10m mol/L)0.05 and 19 samples (17.92%) had high RSC (≥2.5 me/L) [6].
Similarly [7] reported that 34.37 percent sample was fit ,12.85 percent lies in the range of marginally fit while 52.78 percent samples was unfit for irrigated purposes in Tehsil Bhawalpur. The area selected for the present study was Nankana Sahib.The district is situated in North Punjab province of Pakistan. The GPS coordinates of Nankana Sahib are 31.449561°N , 73.70648°E comprising of an area about 2,960 km².The District lies in a semi - arid zone , the hottest month is June having maximum temperature of 40.8°C (105.4°F) and the coldest month is January with minimum temperature of 4.9°C (40.8°F).The most of the area is used for agricultural purpose, the main crops are Wheat, Rice and Sugarcane and main Fruits are Guava and Citrus while Potato, carrot, cabbage, tomato and cauliflower are main vegetables grown in this area. The area is facing high salinity problem which is directly effecting and impair the crop yield.

2 METHODOLOGY

The present study was conducted at Tehsil Nankana Sahib to access the irrigation water quality of the tubewells through which the crops grown are being irrigated. Twenty five different villages was selected to access the water quality and seventy five samples were collected with an average of three sample from each village in the month of May 2019. The samples was collected in the Plastic sample bottles that was rinsed three time with the same water before collecting the water sample. The quantity of water samples was about 1 liter collected from the tubewell outlets not from the reservoirs or watercourse by running the tubewells for 20 minutes. The tubewells were selected randomly having bore depth range from 80 to 170 feet. The position of every sample was recorded by GPS (Global Positioning System) .The samples was properly labelled , stored and analyze by soil and water testing laboratory District Nankana sahib. the present study area along with the sample points has been shown in figure 1.

The collected water samples was analyzed for Ph, EC , Ca+Mg , Na , HCO3 , Cl . The values of Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) was calculated by using the Equations given by [8] .

$$SAR = Na/((Ca+Mg)/2)^{1/2}$$

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

Whereas, the concentrations are expressed in milliequivalent per liter (me L^{-1}).,
The criteria for accessing the irrigation water quality parameters was followed as those of proposed by [11] given in the table 1.

In this study , ArcGIS 10.1 were used to show the study area , sample points location and also the spatial distribution of fit , marginally fit and unfit samples according to EC ,SAR ,RSC and ground water quality in the study area.

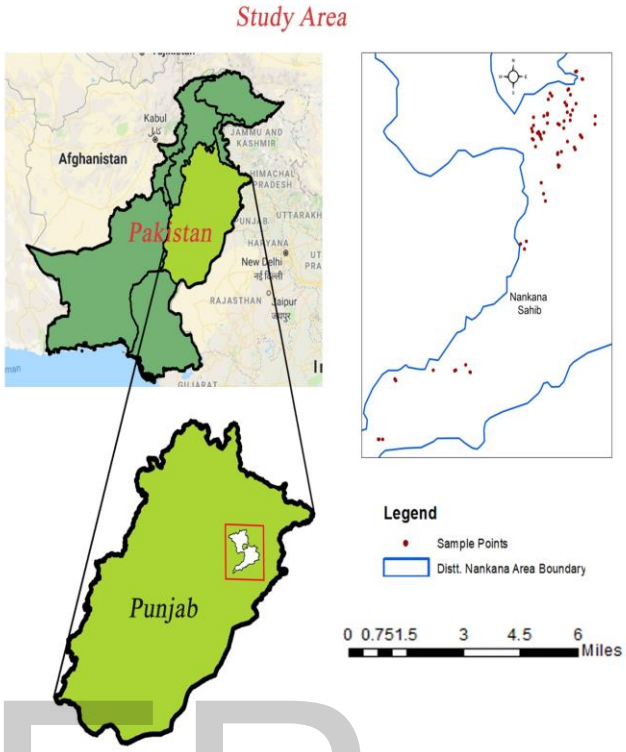

Fig 1 Study area and location of sample points.

3 RESULT AND DISCUSSION

All irrigation water contain dissolved mineral and salts , but, the concentration and composition of these salts may varies according to the source of water and time of year. Since salts can impair plant growth, it is essential for water manager to know the concentration and composition of irrigation water at various time of the year. The presence of salts in irrigation water primarily results from the chemical weathering of earth minerals (from rocks and soils). Much of the salt in geological formations has dissolved over millions of years and has been transported naturally by water.. Fresh water percolating into the ground also dissolves salts from the earth minerals it contacts.
Salts that accumulate in crop root zones, therefore, may be either from the irrigation water or from the soil and other source at the irrigated sites. Salts in irrigation water can come not just from primary sources (that is chemical weathering), but also from saline drainage water. saline water tables, fertilizers, and soil amendments (such as gypsum and lime) [10].
All the salts and minerals effect the quality of water but common practices in concentration of different salts is compared with water quality standards to decide the condition of water and management optims for irrigation and water treatments, so that soil and crop health remain sustainable for production.

The water quality parameters of different departments and scientist are given in the Table 1.In this study for assessment of irrigation water quality of 25 villages of Nankana sahib the water quality parameters given by Soil and Water testing Laboratory Punjab [9].

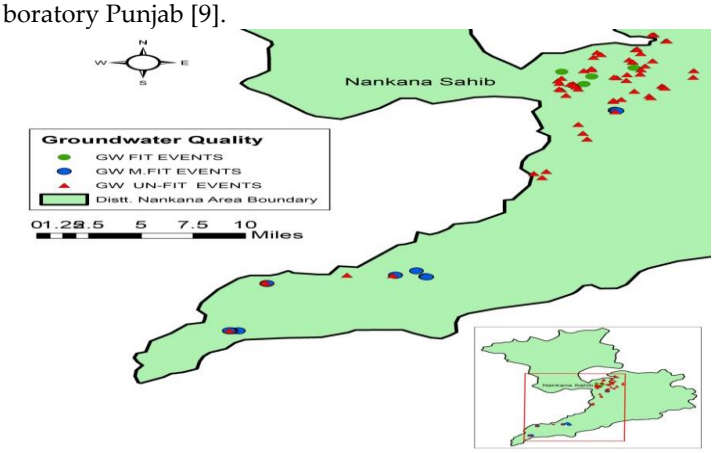

Fig 2 Groundwater quality status of Nankana sahib

From total 75 sample collected, only 5 (6.67%) samples were fit, 10 (13.33%) samples was marginally fit while rest of 60 (80%) samples were found unfit for irrigation purpose as shown in Table 4. The reason behind the unfit status of each sample relative to each parameter is also calculated and shown in Table 4. Figure 2 shows the spatial distribution of fit , marginally fit and unfit samples of groundwater.

3.1 Electrical Conductivity

The EC of water samples were ranged from 367 to 5080 μS cm^{-1} with mean of 2539.7 (μS cm^{-1}) and standard deviation 1385.81 μS cm^{-1} as shown in Table2 .The water samples categorized on basis of EC shows that 12 (16%) samples was in range of fit (<1000) , 6 (8%) samples was in range of marginally fit (1001-1250) while 57(76%) samples was in unfit range (>1250) for irrigation shown in table3.village Chandar kot had the minimum EC i.e, 367 μS cm^{-1} while ,village Naliwala had the highest value EC of 5080 μS cm^{-1}.Figure 3 shows the spatial distribution of fit, marginally fit and unfit samples according to the electrical conductivity.

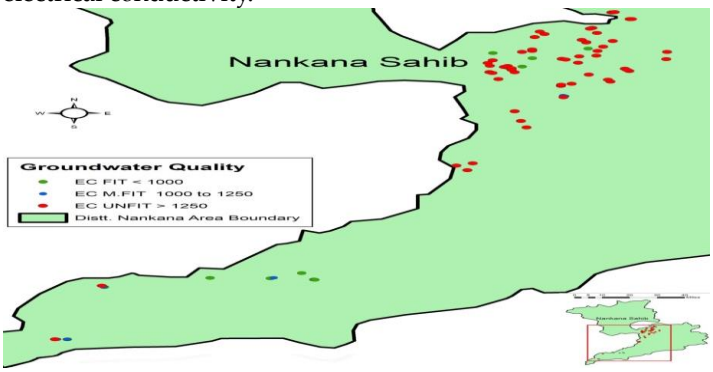

Fig 3 Quality status of Electrical conductivity of water samples in Nankana Sahib

3.2 Sodium Adsorption Ratio

The sodium adsorption Ratio (SAR) of water samples were ranged from 0.23 to 25.86 with mean of 11.96663 and standard deviation of 7.160505 as shown in Table 2. Overall, 22 (29.33%) samples was lie in fit range (<6) whereas, 9(12%) was in marginally fit range (6-10) and 44(58.67%) samples was lies in unfit range (>10) for irrigation shown in Table 3. Village Hallan syedan had the lowest SAR value of 0.23 and Naliwala had the hightest SAR i.e, 25.86. figure 4 shows the spatial distribution of fit, marginally fit and unfit data samples according to the sodium adsorption ratio.

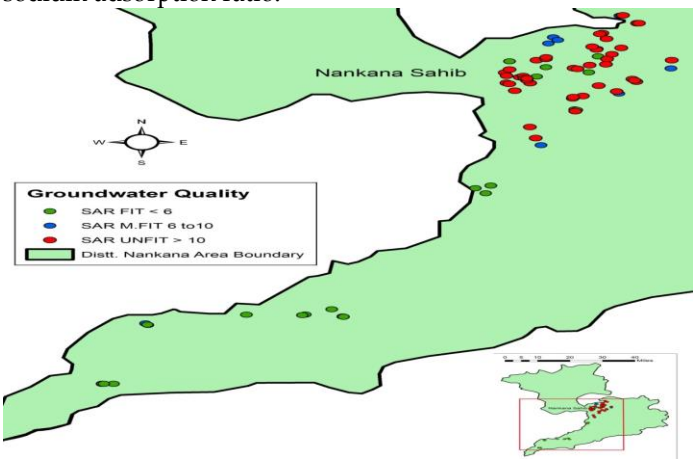

Fig 4 Quality status of SAR of water samples in Nankana Sahib.

3.3 Residual Sodium Carbonate

The residual sodium carbonate (RSC) of water samples ranged from 0.1 to7 me L^{-1} with mean of 4.017333 me L^{-1} and 1.973019 me L^{-1} standard deviation as shown in Table2 . The water samples categorized on the basis of RSC showed that 7(9.33%) water samples was in fit range (<1.25) , 14(18.67%) samples was lies in marginally fit range (1.25-2.50) while 54(72%) samples was lies in unfit range (>2.5) for irrigation shown in Table3. The water sample of village Hallan syedan have the minimum RSC value of 0.1 me L^{-1} while Adampura have the maximum RSC value of 7 me L^{-1}.Figure 5 shows the spatial distribution of of fit, marginally fit and unfit data samples according to the residual sodium carbonate.

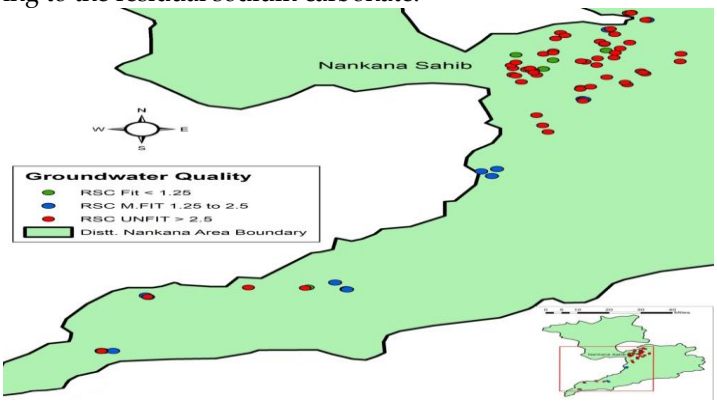

Fig 5 Quality status of RSC of water samples in Nankana Sahib.

3.4 Salts added to Soil (kg $acre^{-1}$ foot of irrigation water)

Salts added Salts added kilogram per acre foot of irrigation

water applied can be determined by total soluble salts multiply with the factor 1.23275. Salts added kg per foot of irrigation water applied ranged from 289.5-4007.9. Minimum salts i.e. 289.5kg and maximum salt 4007.9 kg with acre foot irrigation water are being added in soils of village Chandar kot and Naliwala respectively. Table 4, 5 and 6 shows the range, mean and S.D of values of amount of salts (Kg) added to soil per acre foot of irrigation.

Table 1

Table1: Irrigation water quality criteria.

9.	Status	Richards, L.A. (1954)	WAPDA (1996)	Malik et al., (1984)
EC (µS cm^{-1})	Suitable	750	<1500	<1000
	Marginal	750-2250	1500-3000	1000-1250
	Unsuitable	>2250	>3000	>1250
SAR	Suitable	10	<10	<6
	Marginal	10-18	10-18	6-10
	Unsuitable	>18	>18	>10
RSC(me L^{-1})	Suitable	<2.5	<2.5	<1.25
	Marginal	3.5-4.5	2.0-4.0	1.25-2.5
	Unsuitable	>4.5	>4.0	>2.5
Cl (meq L^{-1})	Suitable	<4.5	-	-
	Marginal	-	-	-
	Unsuitable	>4.5	-	-

Table 2

Range ,mean and standard deviation of irrigation water quality parameters.

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	367-5080	2539.693	1385.816
SAR	0.23-25.86	11.96663	7.160505
RSC (me L^{-1})	0.1-7	4.017333	1.973019
Cl (me L^{-1})	0.5-6	3.294667	1.436672

Table3

Relative frequency distribution of water samples for different irrigation quality parameters realative to their range.

Parameter	Class interval	Relative freq. distribution No. of Sample	(%)	Status
Electrical conductivity, EC (µS cm^{-1})	<1000	12	16	Fit
	1001-1250	6	8	Marginally
	>1250	57	75	Fit
Sodium Adsorption Ratio, SAR (m mol $L^{-1})^{1/2}$	<6	22	29.3	Unfit
	6-10	9	3	Fit
	>10	44	12	Marginally
	<1.25	7	58.6	Fit
	1.25-2.50	14	7	Unfit
Residual Sodium Carbonate, RSC (me L^{-1})	>2.50	54	9.33	Fit
	0-3.9	46	18.6	Marginally
	>3.9	29	7	Fit
Chloride (me L^{-1})			72	Unfit
			61.3	Fit
			3	Unfit
			38.67	

Table 4

Village wise range of water quality parameters.

Village Name	EC µS cm^{-1}	SAR $(mmolL^{-1})^{1/2}$	RSC me L^{-1}	Salts Added Kg/acre
Kot Santram	1060-3940	4.42-18.45	2.1-6.1	836.3-3108.5
Tailan	2330-3380	10.28-15.86	2.8-5.3	1838.28-2666.68
Sagianwala	1857-2740	8.44-13.21	3.1-4.6	1465.1-2161.75
Budha	1630-3300	8.18-15.59	2.7-6	1286-2603.57
Wakeel Wala	865-3030	3.29-1628	1.1-6	682.45-2453.67
Adam Pur	4130-4450	20.17-21.08	6.2-7	3258.4-3510.87
Dolat Pur	3250-5040	16.28-23.42	1.6-5	2564.12-3976.36

Daria	3900-4190	18.22-20.19	6.1-6.5	3076.94-3384.64
Dhoor Kot	2350-3740	10.85-18.13	4.5-6	1854.06-2950.71
Nali Wala	4550-5080	21.63-25.87	5.5-8	3589.77-4007.92
Dhoop Sari	3950-4770	18.31-23.61	6-6.3	3116.39-3763.34
Lab Kot	3140-3870	15.82-19.1	4-5	2477.33-3053.28
Dairay Da Wara	3130-4220	15.97-20.9	5-6.2	2469.44-3329.41
Koru	2170-2410	9.34-11.22	4.5-5.2	1712.04-1901.39
Bhagoor	1590-1850	6.89-9	3-3.1	1254.45-1459.58
Bhawal Kot	2050-2230	10.07-10.77	2.4-3.5	1617.37-1759.38
Ilawal Kot	1600-2650	8.49-15.91	2.8-4.5	1262.34-2090.74
Chandar Kot	367-630	2.14-3.73	0.5-1.1	289.55-497.05
Ladoana	2070-4950	13.64-23.85	4.8-8	2145.98-3905.35
Attari Chak	1390-1430	4.28-5.2	2-2.5	1096.65-1128.21
Thatha Khokran	875-1450	2.83-4.75	2.7-4.9	690.34-1143.99
Hallan Syedan	485-1235	0.233-7.05	0.1-1.4	382.65-974.37
Thatha Fateh Chand	895-1420	4.12-4.57	0.9-3.8	706.12-1120.32
Banian	850-1570	2.39-9.65	1.3-3.9	670.62-1238.67
Tahli Wala	630-765	1.12-1.92	1.5-1.8	497.05-603.55

Table 5

Village wise mean values of water quality parameters.

Village Name	EC $\mu S\ cm^{-1}$	SAR $(mmolL^{-1})^{1/2}$	RSC $me\ L^{-1}$	Salts Added Kg/acre
Kot Santram	1280	9.09	3.43	1972.4
Tailan	2683.33	12.31	4.4	1842.22
Sagianwala	2255.67	10.73	3.93	1936.9
Budha	2476.67	11.84	4.73	1629.2
Wakeel Wala	2335	11.64	4.27	2422.11
Adam Pur	4263.33	20.54	6.73	3384.64
Dolat Pur	4036.67	19.5	3.5	3495.09
Daria	4126.67	19.35	6.37	3230.79
Dhoor Kot	3066.67	15.09	5.2	2702.19
Nali Wala	4776.67	23.25	6.5	3648.94
Dhoop Sari	4470	21.44	6.1	3439.87
Lab Kot	3556.67	17.82	4.63	2765.3
Dairay Da Wara	3820	19.05	5.73	2856.04
Koru	2310	10.47	4.76	1806.72
Bhagoor	1726.67	7.91	3.07	1313.62
Bhawal Kot	2150	10.5	2.93	1735.71
Ilawal Kot	2200	12.35	3.83	1972.4
Chandar Kot	439.333	2.84	0.9	335.31
Ladoana	4176.67	20.21	6.4	3869.85
Attari Chak	1416.67	4.69	2.33	1112.43
Thatha Khokran	1088.33	3.89	3.7	917.16
Hallan Syedan	980	3.11	0.73	678.51
Thatha Fateh Chand	1126.67	4.41	2.33	980.28
Banian	1216.67	5.52	2.2	820.52
Tahli Wala	720	1.6	1.7	568.05

Table 6

Village wise standard deviation of water quality parameters.

Village Name	EC $\mu S\ cm^{-1}$	SAR $(mmolL^{-1})^{1/2}$	RSC $me\ L^{-1}$	Salts Added Kg/acre
Kot Santram	1662.77	8.1	2.31	1311.86
Tailan	603.352	3.09	1.39	476.02
Sagianwala	447.69	2.39	0.76	353.21
Budha	835.244	3.7	1.78	658.97
Wakeel Wala	1273.69	7.25	2.75	1004.89
Adam Pur	166.533	0.48	0.46	131.388
Dolat Pur	914.458	3.62	1.73	721.471
Daria	202.567	1.01	0.23	159.82

Dhoor Kot	696.012	3.78	0.75	549.13
Nali Wala	273.191	2.29	1.32	215.54
Dhoop Sari	452.106	2.78	0.17	356.69
Lab Kot	375.81	1.75	0.55	296.50
Dairay Da Wara	600.083	2.68	0.64	473.44
Koru	124.9	1	0.38	98.54
Bhagoor	130.512	1.06	0.06	102.97
Bhawal Kot	91.6515	0.38	0.55	72.31
Ilawal Kot	540.833	3.72	0.91	426.7
Chandar Kot	131.804	0.81	0.35	103.99
Ladoana	1262.31	5.69	1.6	995.91
Attari Chak	23.094	0.47	2.29	18.22
Thatha Khokran	314.894	0.97	1.11	248.44
Hallan Syedan	428.748	3.53	0.65	338.27
Thatha Fateh Chand	267.877	0.25	1.45	211.35
Banian	360.185	3.74	1.47	284.17
Tahli Wala	77.9423	0.42	0.17	61.49

Table 7
Village wise water quality status of samples and the classification of parameters due to which samples are unfit for irrigation.

Sr.No	Fit	M.Fit	UnFit	Unfit Due To				
				EC	RSC	EC+RSC	EC+SAR	EC+SAR+RSC
1	-	2	1	-	-	-	-	1
2	-	-	3	-	-	-	-	3
3	-	-	3	-	-	1	-	2
4	-	-	3	-	-	1	-	2
5	1	-	2	-	-	-	-	2
6	-	-	3	-	-	-	-	3
7	-	-	3	-	-	-	1	2
8	-	-	3	-	-	-	-	3
9	-	-	3	-	-	-	-	3
10	-	-	3	-	-	-	-	3
11	-	-	3	-	-	-	-	3
12	-	-	3	-	-	-	-	3
13	-	-	3	-	-	-	-	3
14	-	-	3	-	-	1	-	2
15	-	-	3	-	-	3	-	-
16	-	-	3	-	-	1	1	1
17	-	-	3	-	-	1	-	2
18	3	-	-	-	-	-	-	-
19	-	-	3	-	-	-	-	3
20	-	-	3	3	-	-	-	-
21	-	-	3	-	2	1	-	-
22	1	2	-	-	-	-	-	-
23	-	2	1	-	-	1	-	-
24	-	1	2	1	1	-	-	-
25	-	3	-	-	-	-	-	-
Total	5	10	60	4	3	10	2	41
(%)	6.67	13.33	80	5.33	4	13.33	2.67	54.67

4 Conclusions

The present study showed that the ground water of tehsil Nankana sahib is highly saline in most of the area as 5(6.67%) samples were fit , 10(13.33%) samples lies in the marginally fit range and rest of the 60(80%) samples were unfit for the irrigation purposes .which is the main cause of less yield and if farmers keep on using this saline water infuture for irrigation purposes of their lands without any amendments or other chemical solution then there will be more increase in salinity and there will be a more reduction in crop yield. The classification of parameters due to which 80% samples were unfit showed that 5.33% samples were unfit due to EC, 4% samples due to RSC, 13.33% were unfit due to the EC+RSC, 2.67% were unfit due to EC +SAR and 54.67 % sample were unfit due to EC+SAR+RSC.

5 Recommendations

There are several different approaches and practices to control salinity over irrigated lands.salt tolerant crops can be grown to combat the impact of unfit irrigation water.gypsum,manure and press mud can also be used as a amendments to reduce the salinity effects on land soil also the lining of watercourse with limestones can be done canal water along with the tube well water can also be used to dilute its level of SAR. Washing of clothes by detergent should also be avoided in the field because it contains heavy metals and also the farmer should be get familiar with smart irrigation management practices

through proper training.

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