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Assessment of Water Quality in Groundwater in Bist-Doab Region

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Abstract: Deterioration of groundwater quality leads to hazardous effects on human health. The unutilized fertilizers leach to aquifers thus polluting groundwater. Thus, a case study was conducted for analyzing the Electrical Conductivity (EC) in the groundwater using GIS technique, in Bist-Doab region, Punjab. The ion concentration data for various ions (Ca, Mg, K, Na, HCO_3, Cl, SO_4 and NO_3) for the year 2004 for the Bist-Doab region were analysed. $CaSO_4$, $MgHCO_3$, and NaCl were identified as major contributor (contributing > 92%) towards total EC. Thus, Critical regions were mapped in the study area where the contribution of these chemical species exceeds the arbitrary threshold value selected for the present study. Further, empirical equations were developed for determination of relationship these chemical species with total EC. The results show that major contribution of EC_{NaCl}, EC_{MgHCO3} and EC_{CaSO4} in total EC starts only after the EC value is above 372.2, 5.82 and 302.5 μS respectively.

INTRODUCTION

Water in appropriate quantity and quality is needed for all the creatures on the earth. With an increase in urbanization, industrialization, agricultural sector, sewage water discharge, industrial effluents and agro-chemicals (NO_3, Phosphorous, pesticides, insecticides, herbicides etc.) are becoming major problem for human beings. Fertilizers along with agro-chemicals have been recognized as potential source of groundwater pollution. The unutilized fertilizers and heavy metals, suspended solids, etc, from sewage and industrial effluents leach down to groundwater resulting in deterioration of groundwater quality. A part of these fertilizers and manures are consumed by the growing plants. Studies conducted world-wide have reported higher concentration of nitrates and phosphates in groundwater under cultivated land and sewage disposal sites (Murphy, 1992, Diez et al., 1994, Tashiro and Taniyama, 1994). William and Donald (1989) observed that these fertilizers have a potential to reach the groundwater along with water through soil profile. The recovery of fertilizer by a single crop rotation varies between 25-70 % of the total applied fertilizer (Allision, 1966). Benbi et al. (1991) analyzed chemical composition of groundwater of Sangrur block of the Punjab state and reported that the NO_3-N concentration ranged from 0.2 to 8.6 mg/l. They also prepared groundwater quality map and demarcated the area where groundwater is being polluted. Singh et al. (1999) conducted studies on NO_3-N concentration in groundwater of an intensively cultivated area of Punjab and reported more NO_3-N concentration (3.77 mg/l) in Post-monsoon season than pre-monsoon season (3.33 mg/l). Kumar et al. (2003) observed that N-Leaching losses of 32.2 to 29.6% of the total applied nitrogen at 60 cm and 90 cm depth below the ground surface under irrigated rice field condition.

During the last decade, significant changes in cropping pattern and fertilizer use have taken place in Punjab. Owing to the change in the cropping pattern, the consumption of fertilizers has enormously increased from 33.06 Kg/ha in 1970-71 to 174.8 Kg/ha in 2001-02 (Anonymous, 2002a). The unutilized fertilizers leached down to groundwater result in an increase in Electrical conductivity in groundwater, while the unutilized fertilizers reaches via surface runoff polluting the water quality through surface water groundwater interaction. Thus, the Bist-Doab region, which is potential agricultural zone of paddy-wheat-vegetables crop rotation, consuming high doses of agro-chemicals and fertilizers, was selected for analyzing and monitoring Electrical Conductivity (EC) in groundwater using GIS technique. Groundwater is also utilized in Bist-Doab region for irrigation purposes and drinking purpose. Thus, groundwater study in Bist-Doab region is also very important because it is an important source of irrigation and drinking water in the region, and a detrimental effect on the groundwater quality can result in a decline in the agricultural production thus leading to a hindrance in economic growth of this region.

This research was, therefore, initiated to address two important questions associated with groundwater pollution study in Bist-Doab Region:

1. Identification of chemical species which are major contributors of EC in the study area and mapping the critical regions where their EC value is above threshold.
2. Development of empirical equations of these chemical species with total EC.

STUDY AREA

The Bist-Doab is a triangular region and covers an area of 9060 km^2. The word "Doab" signifies the region between two rivers namely, Satluj and Beas, in the present study. It comprises the Hoshiarpur, Kapurthala and Jalandhar districts of Punjab State, India. It is bounded by Siwalik range in the north-east, the river Beas in the north and west sides and the river Satluj in south and east-south. The area lies between 30°51'N and 30"04'N latitude and 74"57' and 76"40'E longitude (Figure 1). The study area is part of the Indo-Gangetic alluvial plain of the Holocene age. The area is drained by the Satluj and Beas rivers and their tributaries. The drainage density is high in the NE strip bordering the Siwalik hills, but it is moderate to low in the rest of the area with sub-parallel and sub-dendritic patterns. The Beas and Satluj, two perennial rivers, rise in the high Himalayas and traverse long distances in the Himalayan and Siwalik zone before entering the state of Punjab. High rainfall and poor vegetation cover are responsible for soil erosion in the Siwalik foothill zone (Sehgal et al. 1988).The climate of the study area is influenced by the Himalayas in the north (Chopra and Sharma, 1993).

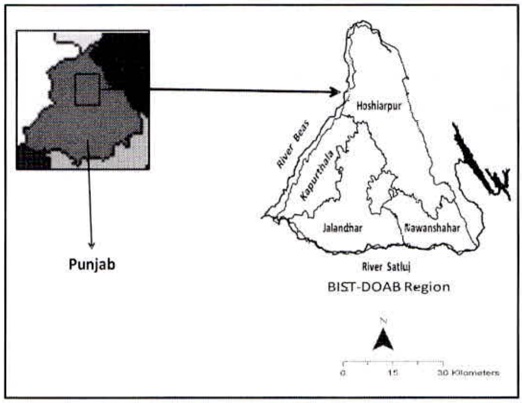

Fig. 1 : Map showing the location of study area in India

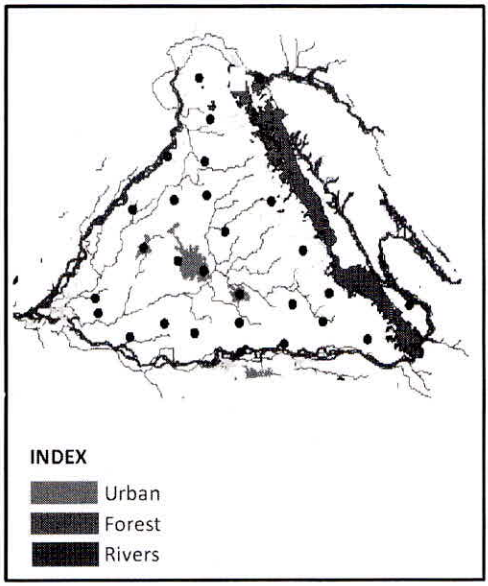

Fig. 2 : Map showing all the districts in Bist-Doab region

METHODOLOGY

The map all the districts in BIST-DOAB were scanned from Survey of India (SOI) toposheet. A GIS technique was used to carry the digital analysis. The georeference map (Figure 2), district boundary map, attribute map and contour map of various water quality constituents of the study area were prepared using Arc map, ILWIS and Surfer software. Stepwise method for preparation of various maps is presented through flowchart (Figure 3).

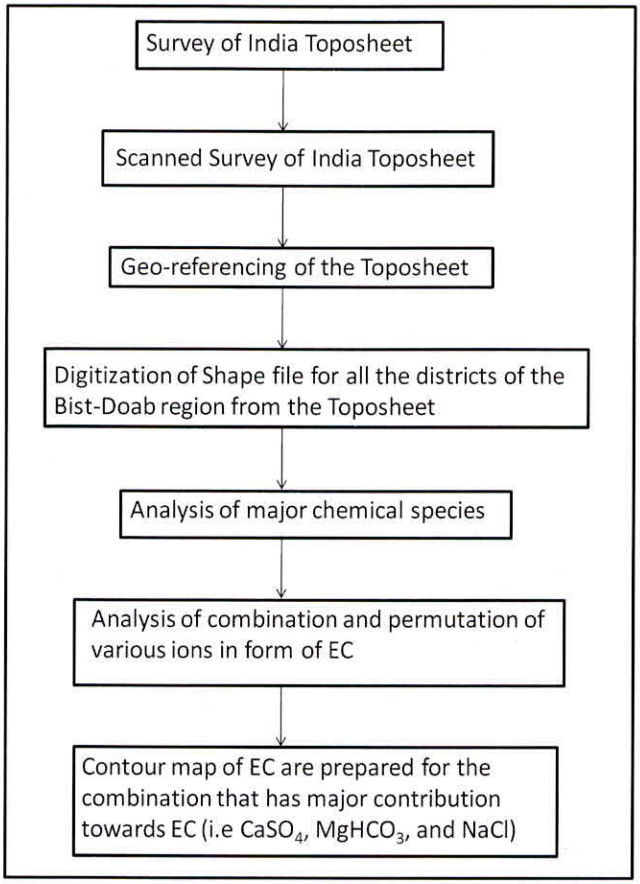

Fig. 3 : Flow chart of GIS operation for preparing EC concentration map

The water quality constituents for consideration were interpolated, and a contour map of NaCl, $MgHCO_3$, and $CaSO_4$ in terms of EC_{Lab} were prepared for 2004. The water quality contours were interpolated using Krigging technique.

RESULTS AND DISCUSSION

The ion concentration data (in ppm) for various ions (Ca, Mg, K, Na, HCO_3, Cl, SO_4 and NO_3) for the year 2004 for the Bist-Doab region has been collected from CGWB (NWR), Chandigarh. The ion concentration is then converted in ìS. From the above ion concentrations it is found that $CaSO_4$, $MgHCO_3$, and NaCl are the major contributor (contributing > 92%) towards EC_{Lab} (Table 1). Hence, $CaSO_4$, $MgHCO_3$, and NaCl are taken for analysis in the present study. For our present study we have taken an arbitrary value as threshold for EC_{NaCl}, EC_{MgHCO3}, and EC_{CaSO4}. These arbitrary values are presented in Table 1 a.

Table 1. Concentration of EC_{CaSO4}, EC_{MgHCO3}, and EC_{NaCl} in ìS for data collected for the year 2004.

Location	EC_{Lab}	EC_{NaCl}	EC_{MgHCO3}	EC_{CaSO4}	$EC_{NaCl, MgHCO3 and CaSO4}$ (µS)
Kartarpur	2070.47	1210.72	360.39	455.66	97.89
Behrampur	1271.99	597.9	353.06	244.9	94.01
Rahon	1182.34	367.08	479.15	175.8	86.44
Chohal	1113.65	375.7	372.94	219.42	86.93
Sultanpur Lodhi	1053.11	576.1	343.2	112.68	97.99
Garhshankar	1030.17	307.33	390.92	122.16	79.64
Chahdera	1007.9	206.88	393.17	328.5	92.13
Adampur	1002.52	462.93	312.17	139.1	91.19
Nawanpind	1001.52	336.95	478.21	59.4	87.32
Banga	982.46	414.11	401.62	115.44	94.78
Rampur Colony	888.87	358.66	336.84	110.8	90.71
Shahkot	878.53	375.66	273.31	172.52	93.51
Jalandhar	857.93	379.96	292.41	128.52	93.35
Allwalpur	845.71	377.73	303.59	125.06	95.35
Jallehri	695.82	200.52	275.19	157.32	90.98
Hussainpur	661.77	147.27	331.74	135.38	92.84
Nakodar	639.54	155.66	391.39	51.32	93.56
Phillaur	629.96	187.68	382.52	44.58	97.59
Talwara	606.7	145.22	202.49	168.6	85.1
Nanagal Bihala	589.9	104.67	277.89	146.16	89.63
Paddi Jagir	587.25	85.37	362.3	107.84	94.6
Gohiran	576.57	149.34	301.46	85.98	93.1
Rahlan	562.42	111.1	213.13	221.86	97.1
Durmiwal	541.96	40.54	335.74	156.48	98.3
Paddi	521.79	104.54	288.59	79.44	90.57
Thakarwala	507.55	104.47	342.26	33.22	94.56
Dasuya	487.81	121.68	219.65	124.4	95.47
Hardonamoh	483.84	121.62	216.77	127.28	96.24
Singha Katri	468.28	106.84	183.86	149.06	93.91
Nurpur Bedi	444.85	68.29	237.52	114.2	94.42
Chak Dhan	443.26	76.89	178.16	136.92	88.43
Dala	442.58	109.78	247.29	73.9	97.38
Hazipur	434.18	106.63	247.51	76.36	99.15
Karimpur Chhawal	418.65	61.9	231.58	90.9	91.81
Balachaur	412.61	57.68	210.6	105.92	90.69
Argowal	409.07	85.44	201.08	77.7	89.04
Mukerian	382.83	104.67	152.64	110.34	96.03
Khera Majra	382.13	61.84	207.25	75.78	90.25
Bhammaur	317.97	66.2	182.45	62.88	97.97

Average $EC_{NaCl, MgHCO3, and CaSO4}$ is 92.82 ìS

Table 1 (a) : Threshold values of salinity (EC_{NaCl}, EC_{MgHCO3}, and EC_{CaSO4}) considered for groundwater analysis in the present study.

Chemical species	Threshold EC values
NaCl	400 µS
$MgHCO_3$	300 µS
$CaSO_4$	200 µS

Figure 4 shows the relationship between EC_{Field} and EC_{lab} in ìS. Since, there could be errors in field measurement of EC_{Field}, we calculated EC_{lab} in lab by adding up the EC concentration of all the measured constituents (Mg, K, Na, HCO_3, Cl, SO_4 and NO_3). Since, the correlation between EC_{Field} and EC_{lab} is very close ($R^2 = 0.9$) all the analysis is done with respect to EC_{lab}.

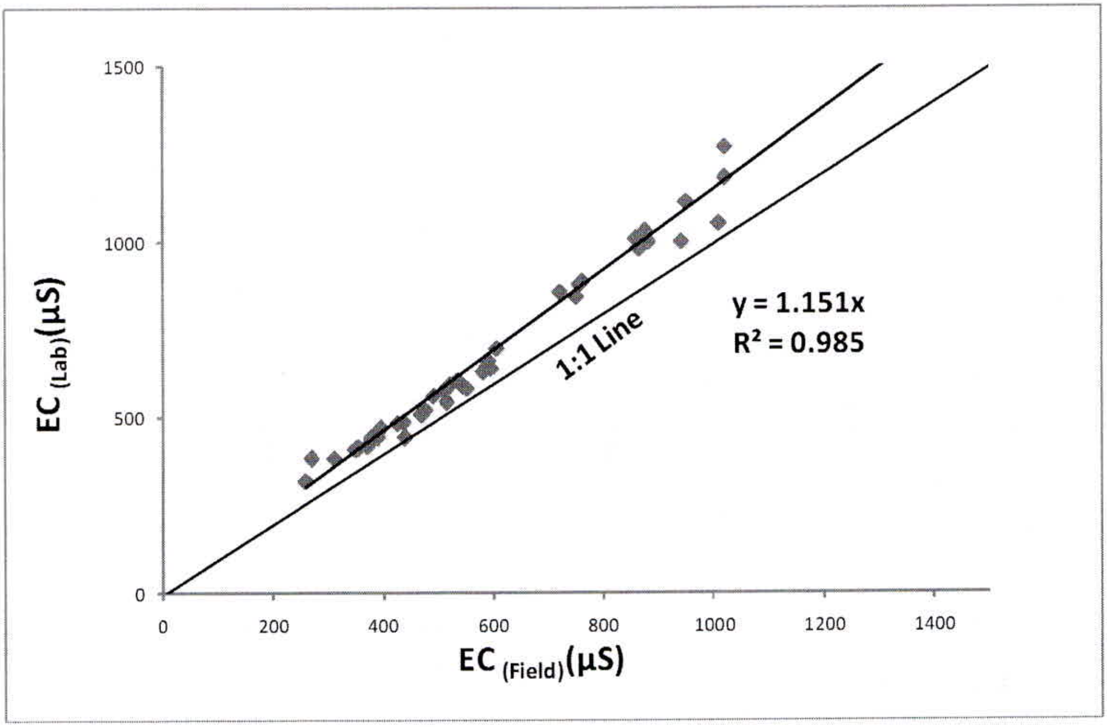

Fig. 4: Relationship between EC_{Field} and EC_{lab}

The concentration of EC_{CaSO4}, EC_{MgHCO3}, and EC_{NaCl} were then interpolated for the entire Bist-Doab region using GIS technique and their contour maps were prepared for the year 2004.

NaCl concentration

The maximum NaCl contribution to the EC in groundwater is observed to be 1210.72 at Kartarpur Block in Jalandhar (Figure 5a). The NaCl concentrations of all the locations for the

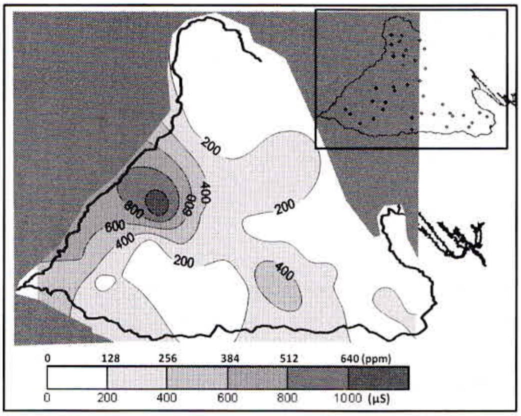

Fig. 5 a. : Contour of EC_{NaCl} in ìS

year 2004 are interpolated and a contour map of EC_{NaCl} to EC_{Lab} was prepared. The mid-western and south-east region of the study area namely, Kapurthala and Jallandhar are approaching towards the upper limit of NaCl contributed EC where there value exceeds 400 ìS. In the rest of the study area, EC_{NaCl} is low. Therefore, immediate precautions and measures are required to check the EC_{NaCl} in the groundwater in this region.

Figure 5 b represents the empirical relationship between EC_{NaCl} and calculated EC_{Lab} in ìS. Table 2 represents the percent contribution of EC_{NaCl} in total EC_{Lab}. The model indicates that

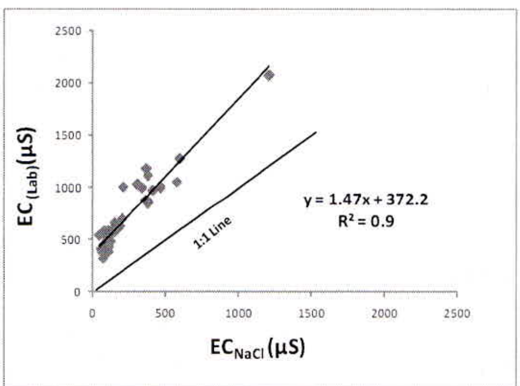

Fig. 5 b. : Relationship between EC_{NaCl} and EC_{lab} in 2004.

Table 2 : Percentage contribution of EC_{NaCl} in EC_{lab} in 2004.

Location	EC_{lab}	EC_{NaCl}(%)
Kartarpur	2070.47	58.48
Behrampur	1271.99	47.01
Rahon	1182.34	31.05
Chohal	1113.65	33.74
Sultanpur Lodhi	1053.11	54.7
Chahdera	1007.9	20.53
Adampur	1002.52	46.18
Nawanpind	1001.52	33.64
Banga	982.46	42.15
Rampur Colony	888.87	40.35
Shahkot	878.53	42.76
Jalandhar	857.93	44.29
Allwalpur	845.71	44.66
Jallehri	695.82	28.82
Hussainpur	661.77	22.25
Nakodar	639.54	24.34
Phillaur	629.96	29.79
Talwara	606.7	23.94
Nanagal Bihala	589.9	17.74
Paddi Jagir	587.25	14.54
Samundra	583.21	26.7
Gohiran	576.57	25.9
Rahlan	562.42	19.75
Durmiwal	541.96	7.48
Paddi	521.79	20.03
Thakarwala	507.55	20.58
Dasuya	487.81	24.94
Hardonamoh	483.84	25.14
Singha Katri	468.28	22.82
Nurpur Bedi	444.85	15.35
Chak Dlian	443.26	17.35
Dala	442.58	24.8
Hazipur	434.18	24.56
Karimpur Chhawal	418.65	14.79
Balachaur	412.61	13.98
Argowal	409.07	20.89
Mukerian	382.83	27.34
Khera Majra	382.13	16.18
Bhamnaur	317.97	20.82

EC_{NaCl} concentration in the region is positively correlated with calculated EC_{lab}. The coefficient of determination of 0.898.Such a higher value of R^2, indicates that their relationship is very good. Further, it can be noticed that the regression line of NaCl is very close to the 1:1 line of calculated EC ($EC_{lab} = 1.42*EC_{NaCl} + 372.2$). The slope of 1.42 between the two shows that NaCl is a potential contributor of EC in the study area.

The major contribution of EC_{NaCl} in EC_{lab} starts only after the EC_{lab} value is above 372.2.This implies that till EC_{lab} attains a value of 372.2 the major contributors towards EC_{Lab} are other chemical species ($MgHCO_3$ and $CaSO_4$).

$MgHCO_3$ concentration

The maximum contribution of EC_{MgHCO3} in EC_{lab} for the year 2004 was 478.205ìS. The EC_{MgHCO3} contour map for the year 2004 was prepared by interpolating the data (Figure 6a). This figure shows that the EC_{MgHCO3} contribution to EC_{lab} in the districts Jallandhar and Hoshiarpur are above 300 ìS, which is on higher side for drinking and irrigation purposes. The EC_{MgHCO3} concentration in other districts in the study area is diluted in comparison to that of Jallandhar and Hoshiarpur.

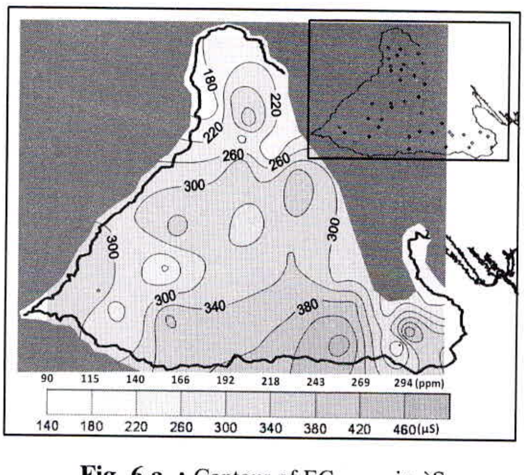

Fig. 6 a. : Contour of EC_{MgHCO3} in ìS

Figure 6 b represents the empirical relationship between EC_{MgHCO3} and EC_{lab} in ìS. The empirical equation indicates that EC_{MgHCO3} concentration in the region is positively correlated with calculated EC_{lab} and their relationship is fairly strong. The coefficient of determination of 0.581. Further, it can be noticed that the regression line of EC_{MgHCO3} is not very close to the 1:1 line of calculated EC_{lab} ($EC_{lab} = 2.226*EC_{MgHCO3} + 5.815$). The slope of 2.226 between the two shows that EC_{MgHCO3} is a potential contributor towards EC_{lab} in the study area. Table 3 represents the percentage contribution of EC_{MgHCO3} in EC_{lab}.

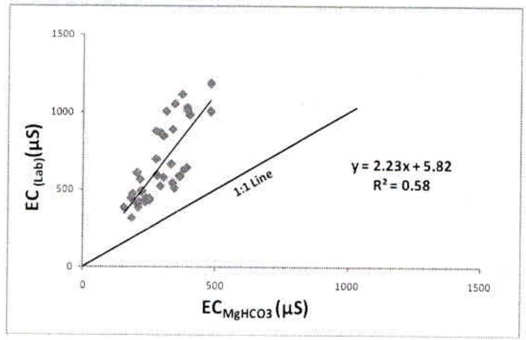

Fig. 6 b. : Relationship between EC_{MgHCO3} and EC_{lab} in 2004.

Significant contribution of EC_{MgHCO3} in EC_{Lab} starts when EC_{Lab} value attains a threshold of 5.82 ìS. This implies that the EC_{lab} starts building with the onset of EC_{MgHCO3}.

$CaSO_4$ concentration

The map of EC_{CaSO4} (Figure 7 a) in groundwater for the year 2004 clearly indicates that EC_{CaSO4} contribution towards EC_{lab} is highest at Kapurthala district near river Satluj where EC_{CaSO4} value exceeds 200 ìS. The EC_{CaSO4} concentration in rest of the region is diluted and hence is considered safe for drinking water and irrigation purposes.

Table 3. : Percentage contribution of EC_{MgHCO3} in EC_{lab} in 2004.

Location	EC_{lab}	EC_{MgHCO3} (%)
Kartarpur	2070.47	17.41
Behrampur	1271.99	27.76
Rahon	1182.34	40.53
Chohal	1113.65	33.49
Sultanpur Lodhi	1053.11	32.59
Garhshankar	1030.17	37.95
Chahdera	1007.90	39.01
Adampur	1002.52	31.14
Nawanpind	1001.52	47.75
Banga	982.46	40.88
Rampur Colony	888.87	37.90
Shahkot	878.53	31.11
Jalandhar	857.93	34.08
Allwalpur	845.71	35.90
Jallehri	695.82	39.55
Hussainpur	661.77	50.13
Nakodar	639.54	61.20
Phillaur	629.96	60.72
Talwara	606.70	33.38
Nanagal Bihala	589.90	47.11
Paddi Jagir	587.25	61.69
Samundra	583.21	62.73
Gohiran	576.57	52.29
Rahlan	562.42	37.90
Durmiwal	541.96	61.95
Paddi	521.79	55.31
Thakarwala	507.55	67.43
Dasuya	487.81	45.03
Hardonamoh	483.84	44.80
Singha Katri	468.28	39.26
Nurpur Bedi	444.85	53.39
Chak Dlian	443.26	40.19
Dala	442.58	55.87
Hazipur	434.18	57.01
Karimpur Chhawal	418.65	55.32
Balachaur	412.61	51.04
Argowal	409.07	49.15
Mukerian	382.83	39.87
Khera Majra	382.13	54.23
Bhamnaur	317.97	57.38
Average	710.49	45.53

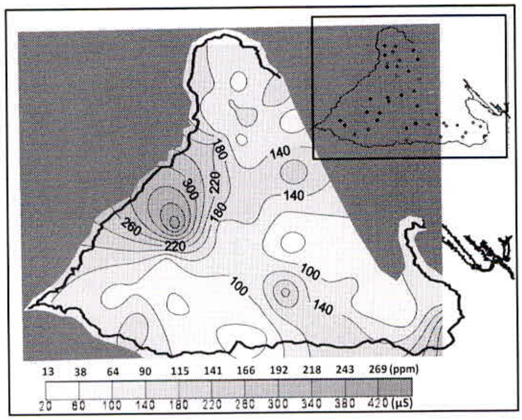

Fig. 7 a. : Contour of $CaSO_4$ contributed EC

Figure 7 b represents the empirical relationship between EC_{CaSO4} and calculated EC_{lab} in ìS. The empirical equation indicates that EC_{CaSO4} concentration in the region is positively correlated with calculated EC_{lab}. The coefficient of determination of 0.51. Further, the regression line of EC_{CaSO4} is not very close to the 1:1 line of calculated EC ($EC_{lab} = 3.092 * EC_{CaSO4} + 302.5$). The slope of 3.092 between the two shows that the contribution of EC_{CaSO4} in EC_{lab} is very strong. Table 4 represents the percentage contribution of EC_{CaSO4} in EC_{lab}, which on an average is about 19.42%.Major contribution of EC_{CaSO4} in EC_{lab} starts when EC_{lab} value reaches a threshold of 302.5ìS.

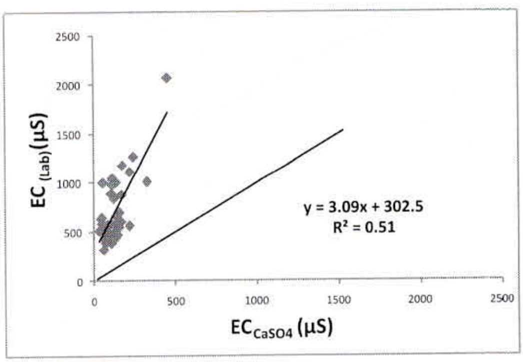

Fig. 7 b. : Relationship between EC_{CaSO4} and EC_{lab} in 2004.

Table 4. Percentage contribution of EC_{CaSO4} in EC_{lab} in 2004.

EC_{lab}	EC_{CaSO4} (%)
2070.47	22.01
1271.99	19.25
1182.34	14.87
1113.65	19.7
1053.11	10.7
1030.17	11.86
1007.9	32.59
1002.52	13.88
1001.52	5.93
982.46	11.75
888.87	12.47
878.53	19.64
857.93	14.98
845.71	14.79
695.82	22.61
661.77	20.46
639.54	8.02
629.96	7.08
606.7	27.79
589.9	24.78
587.25	18.36
583.21	9.00
576.57	14.91
562.42	39.45
541.96	28.87
521.79	15.22
507.55	6.55
487.81	25.5
483.84	26.31
468.28	31.83
444.85	25.67
443.26	30.89
442.58	16.7
434.18	17.59
418.65	21.71
412.61	25.67
409.07	18.99
382.83	28.82
382.13	19.83
317.97	19.78
Average	19.42

SUMMARY AND CONCLUSIONS

The Bist-Doab region of Punjab has been selected for assessment of water quality concentration in groundwater. The study area is one of potential fertilizers and pesticides consuming region the Punjab. In order to study the status of various groundwater constituents which contribute EC in the study area the concentration of EC_{NaCl}, EC_{MgHCO3}, and EC_{CaSO4} were analysed for the year 2004(Figure 8). The major contribution of EC_{NaCl} in EC_{lab} starts only after the EC_{lab} value is above 372.2.This implies that till EC_{lab} attains a value of 372.2 the major contributors towards EC_{Lab} are other chemical species ($MgHCO_3$ and $CaSO_4$). A similar trend is observed for $CaSO_4$, where major contribution of EC_{CaSO4} in EC_{lab} starts when EC_{lab} value reaches a threshold of 302.5ìS. EC_{MgHCO3} contribution in EC_{lab} starts after when its value reaches 5.82. This implies that the EC_{lab} starts building with the onset of EC_{MgHCO3}.

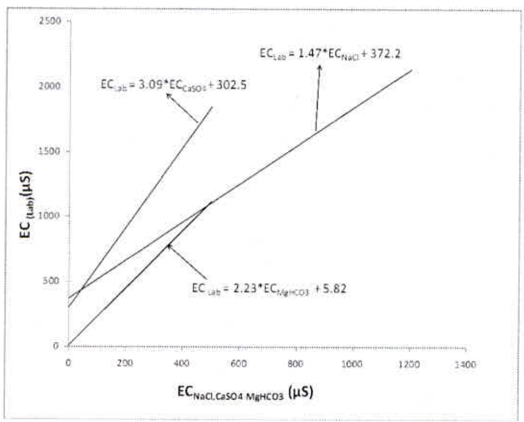

Fig. 8. : Relationship between EC $_{NaCl, MgHCO3, and CaSO4}$ and EC_{lab}

The following are the conclusions of the present study:

- EC of groundwater in the study area is observed from 317.97 to 2070.47μS/cm. At lower values of EC, salinity is mainly due to dissolution MgHCO3, at EC > 300 μS, salinity increases due to contribution from NaCl and $CaSO_4$.

- Empirical equations were developed for determination of relationship EC_{NaCl}, EC_{MgHCO3}, and EC_{CaSO4} with $EC_{Lab.}$ With the development of these empirical equations, it is now possible to calculate concentration of the remaining constituents if the concentration of one of the constituents is known. This is an important finding because this will result in the reduction of time and cost required for calculation of concentration of water quality constituents for groundwater assessment.
- Critical regions were identified in the study area using the EC corresponding to concentrations of Nacl (EC_{Nacl}), $MgHCO_3$ (EC_{mgHCO3}), and $CaSO_4$ (EC_{CaSO4}) exceeds the arbitrary threshold value (Table la) selected for the present study. The high concentrations of these chemical species found for NaCl and $CaSo_4$ at Kartarpur in district Jalandhar and for $MgHCO_3$ in Nawapind in Jalandhar district and Banga in Sardar Bhagat Singh Nagar district.

In the present study, empirical relations were developed for total EC and chemical species using the chemical analysis of groundwater for the year 2004. Further research may be conducted to develop these empirical relationship taking into consideration a longer time period. The trend of variation of these relations can be used for modeling to understand the chemical evolution of groundwater in the study region. The empirical model thus developed would be much more reliable because they would incorporate temporal variation in the analysis.

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