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Assessment of Inorganic Impurities of Ground Water in South Western Districts of Punjab – India

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ABSTRACT: The source of water on the Earth is precipitation as rain, snow or sleet. This natural water from rain that falls on ground either remains as surface water (as rivers, streams and lakes) or percolates down to become part of aquifer system. The present study is concentrated on present status of chemical characteristics of ground water of area of Faridkot and adjoining districts, the primary data was collected in the form of questionnaire. The collected samples were tested for pH, TDS (mg/lit), EC (µS/cm), alkalinity, total hardness and the contents of fluoride, chloride, chlorine, calcium and iron. This analysis is synchronized with the sites and the objectives of the study.

The natural as well as anthropogenic activities such as extensive agriculture, lack of proper crop rotation, water logging, excessive use of fertilizers rich in phosphate and unmanaged irrigation have resulted in contamination of groundwater thus limiting its use for personal consumption without further purification over the past few decades. The variability of chloride and fluoride contents in samples collected from different sampling sites in south-western Punjab, comprising of Faridkot and adjoining districts, is of great concern as each and every site chosen had another site in its vicinity that had fluoride and chloride contents below permissible range set by WHO standards.

I. INTRODUCTION

Out of total earth's surface, 29% is taken up by the land masses covered by the seven continents and the remaining 71% is occupied by the water. Of total water available on Earth's surface, maximum part of the planet's crust water, i.e. about 96.5%, is found in seas and oceans. About 1.7% of Earth's water is found as groundwater, another 1.7% in glaciers and the ice caps of Antarctica and Greenland, while a small fraction is found in other large water bodies, and 0.001% in the air as vapours, clouds (accumulation of water droplets and dust suspended in air), and precipitation (rain, snow or sleet).

Only 2.5% of the total Earth's water is fresh water, and 98.8% of that fresh water is in the form of ice (except ice in clouds) and groundwater. Technically, apart from groundwater consisting of water flowing through shallow aquifers, it can also contain soil moisture, permafrost or the frozen soil, and immobile water in very low permeability bedrock.

Rain that falls is the purest form of water that gets converted into either surface water or constitutes groundwater due to water that percolates down to sub surface. The water table may be deep or shallow depending on physical characteristics of the region, the meteorological conditions and the recharge and exploitation rates. Its chemical character is mainly influenced by type, depth and sub surface geological layers of soils through which surface water percolates. Also, its quality is influenced by atmospheric dust, smoke, and smog.

Groundwater is a reliable, cheap, convenient to use and an ecologically important resource and plays an indispensible role in the economy of any nation. It is withdrawn from wells or using hand pumps for various individual, agricultural and commercial purposes.

There is a growing concern about the deterioration of ground water quality due to geogenic and anthropogenic activities. Groundwater pollution most often results from improper disposal of wastes on land. It is less visible and more difficult to clean up than surface water pollution. Apart from the sources, other factors that affect contamination of the groundwater are depth of well, geological formations that determine speed of flow of contaminants.

Fluoride and nitrates are the main contaminants that are reported from various parts of our India such as states of Andhra Pradesh, Maharashtra, Assam, Manipur, Gujarat, Haryana, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Bihar, Orissa, Rajasthan, Tamil Nadu, West Bengal, Jharkhand, Chhattisgarh, and Uttar Pradesh [1,2] affecting almost more than half of the population leading to various health hazards among people across the nation. The same has also been reported from various districts of Punjab.

Broadly the ground water pollutants are classified into two types: A point source is technically defined as any discernable, confined and discrete conveyance from which pollutants are or may be discharged. E.g.: Landfills, accidental spills, leaking septic tanks and gasoline storage tanks. Non-point sources include naturally occurring inorganic pollutants such as arsenic or fluoride, VOCs, generated because of industrial processes, excessive fertilizers and pesticides used in agriculture, oil field brine pits, and leaking underground pipelines[3].

Fluoride is the simplest anion of fluorine, F^- , nearly water insoluble, occurs naturally in igneous and sedimentary rocks as cryolite and fluorspar respectively. There are various hydro-geochemical factors that affect the amount of fluoride content in groundwater such as the nature of the geological strata, climatic conditions, contact between rocks and circulating groundwater, nature and types of rock and content of bicarbonates and calcium as wells as anthropogenic factors, such as coal burning and use of phosphoric fertilizers. It has also been reported that arid and semi-arid areas are more prone to the high fluoride contents in their ground water due to evaporation as compared to humid areas which have low incidences of high fluoride contents due to high rainfall inputs and the subsequent diluting effect [4]. The ground water in these areas is usually slow that further enriches fluoride contents in water. The presence of certain ions particularly bicarbonates and calcium also effect the concentration of fluoride in ground water [5].

The occurrence of fluoride in higher concentration in groundwater is a complex phenomenon which results from interplay of multiple complex interdependent hydro-geochemical processes. These processes directly affect the quality of groundwater. The major cations and anions present in the groundwater are Na^+, $Ca^{2+,}$ K^+, Mg^{2+}, and HCO_3, Cl^-, SO_4^{2-}, NO_3. The major weathering processes occurring in the water are carbonate, gypsum, and silicate weathering [6]. The abundance of Ca2+ and Mg2+ is attributed to carbonate and gypsum weathering [6–8]. Sodium and potassium ions to the groundwater mainly results from dissolution of silicates and soda feldspar (albite) and potash feldspars (orthoclase and microcline). Feldspars are more susceptible for weathering and alteration than quartz in silicate rocks.

Anthropogenic activities such as use of phosphatic fertilizers, clays used in brick and ceramic industries, and coal burning also contribute to high fluoride in shallow and surface waters [9].

As per WHO water quality standards, maximum permissible limit for fluoride in drinking water is 1.5mg/L. For drinking water, the desirable fluoride concentration is 0.6 – 1.2 mg/L. At this level, the water does not promote dental carries or hinders bone development in children. However, excess concentration may result in dental & skeletal fluorosis; not only pathological changes in teeth and bones but mottling of teeth, calcification of ligaments, crippling bones deformities that may lead to cancer, decreased cognitive ability, lower intelligence quotient and development issues in children [10-13]. Recent study shows that excess fluorides than allowable limit can also effects on male productivity by disrupting the reproductive hormones [14, 15]

Chlorides are widely distributed in nature as salts such as sodium chloride or halite (NaCl), potassium chloride or sylvite (KCl), Calcium chloride ($CaCl_2$), and hydrated magnesium chloride or serum chloride ($MgCl_2$) as well as presence in oceans. In human body, Chloride ion is a structural component of some proteins, e.g. the amylase enzyme.

Chloride (Cl^-) is completely soluble and very mobile. Chloride in surface and groundwater occurs from both natural and anthropogenic sources, such as run-off containing road de-icing salts, application of inorganic fertilizers in agricultural fields, irrigation drainage, and industrial as well as septic tank effluents, and seawater intrusion in coastal areas. The common pathways for chlorine to enter into groundwater include atmospheric deposition; the dissolution, storage and handling of deicing salts; landfills; and treatment of water. Chloride is also a useful and reliable chemical indicator of river / groundwater fecal contamination, as chloride is a non-reactive solute and ubiquitous to sewage & potable water.

Chloride is not toxic to human health at low levels. However it poses taste and odour issues at concentrations exceeding 250 mg/l. It affects animals also as it produces effects such as drooling, vomiting, diarrhoea, loss of appetite, crying, excessive thirst, depression, weakness, low blood pressure, disorientation and decreased muscle functions when animals consume excess of chloride. In severe cases, it can result in cardiac abnormalities, seizure, coma, and even death. It also results in toxicosis among bird population. Salinity stress on sensitive aquatic communities can impact species diversity by changing nutrient and dissolved oxygen content in water.

Elevated chloride levels can harm vegetation by threatening the health of food sources and pose a risk to species survival, growth, and/or reproduction. Chloride salts often pose a higher risk when they associate with other ions such as magnesium or potassium as they potentially travel at different rates. Salt primarily causes dehydration which leads to foliage damage, disrupts nutrient uptake by plants and can cause injury to plant parts. Salt can have impacts on soil biota, soil welling and crusting, soil electrical conductivity, soil osmotic potential, soil dispersion, and structural stability.

Chloride can penetrate and deteriorate concrete on bridge decking, parking garage structures and reinforcing rods. Chloride content in water helps make conduction easier thereby putting an impact on railroad crossing warning equipment and power line utilities as it conducts electrical current leaks across the insulator.

II. MATERIALS AND METHODS

A. Study Area

The groundwater is the most exploited source in the agricultural state of Punjab relied upon by majority of rural population to meet their domestic and irrigation purposes. The present area under the study is has geographical coordinates between, 30-32-18 N (Site no. 22) and 31-14-32 N (Site no. 54); 74-25-28 E (Site no. 27) and 76-03-12 E (Site no. 54), determined using Global Positioning system (GPS). This area comprises of districts of Faridkot and adjoining areas in the district of Moga, which lie under the Malwa region.

B. Topography

Punjab, a part of Indo-Gangetic alluvial plain, is composed of sediments brought down by Indus river system from the Himalayas. The alluvium deposits mainly comprise of sand, silt, clay, limestone, dolomite etc. and they vary with respect to texture, depth of carbonate leaching and translocation of other mobile soil constituents. Predominantly calcareous, the pH value ranges from 7.8 to 8.5.

The south-western area of Punjab under observation is served by the Rajasthan Feeder Canal. The ground water level lies in range of 10-20 meters and is recharged through seasonal precipitation of about 433 mm per annum, surface run-off, seepage from canals and percolation from surface water bodies, and return seepage through irrigation.

C. Sampling

The primary data regarding extent of fluoride and chloride contamination was collected in the form of questionnaire drafted in the local language for the ease of people. It consisted of questions related to the water source about its type, age, and bore depth as well as queries about the use of water for drinking and domestic purposes or agricultural purposes. Number of persons surveyed for each source depended on the source of water as well as the medical history of fluoride and chloride contamination in the particular area.

The sampling sites' geographical location on the grid was determined using 'Longitude-Latitude' application on smart-phone Samsung Galaxy Grand. Field visits were carried out to collect drinking water from surface and underground water sources such as hand pumps, tube wells, taps, submersible pumps, from the selected sites based upon the analysis of the questionnaire. All the samples were stored in identical PET bottles (1-L capacity), marked numerically, and then sent for testing at Public Health Department Lab, Faridkot for pH, TDS (mg/L), EC (μS), alkalinity, total hardness, and for the content of fluoride, chloride, chlorine, and iron. The collected data was further graphically analysed.

D. Intrumentation and Analysis

The samples were analyzed for physic-chemical parameters such as pH, TDS, EC, fluoride, chloride, chlorine, and iron in the lab on site using TDS meter, pH meter, test kits of Merck, as well as tested in the laboratory, and the results were cross-analyzed. The values were found to be approximately same and any errors found were within the experimental range.

III. RESEARCH AND DISCUSSION

Ground water quality in Punjab has huge variation in different zones of the state. The ground water in south-western districts of Punjab namely, Mansa, Bathinda, Muktsar, Ferozepur and Faridkot contain varying concentrations of soluble salts. As per a study conducted by Columbia university, 79% of the groundwater assessment divisions, or blocks, in Punjab are now considered 'overexploited' and 'critical' with extraction exceeding the supply. That rate of decline accelerated from 18 cm/year during 1982-87 to 42 cm per year from 1997-2002, and to a staggering 75 cm during 2002-06. Water tables are now falling over about 90 percent of the state, with Central Punjab most severely affected.

The quality of ground water is classified into the following categories:

Good Quality Ground Water- It occupies about 51% of total geographical area along the flood plains of Satluj, Beas, Ravi and Ghaggar rivers.

Marginal Quality Ground Waters- it occupies 37% area of the state in the south-western zone.

Poor Quality Ground Water: It occupies nearly 6% area of the state in Satluj-Ghaggar plain.

Table 1: Physic-chemical parameters of samples of groundwater.

S. No.	DEPTH (FEET)	SOURCE (AGE)	LATI	LONGI	TDS	EC	F	pH	ALKALINITY	TOTAL HARDNESS	Ca	Cl^-	Fe	Cl
1	40	HP 1970	30-35-06 N	74-49-21 E	850	1360	1.5	9	400	400	42	250	0	0
2	65	HP 2003	30-35-08 N	74-49-18 E	994	1590	1.5	9	400	500	42	350	0	0
3	40	HP 2002	30-35-07 N	74-49-09 E	1200	1920	2	9	410	400	46	352	0	0
4	65	HP 1995	30-35-01 N	74-49-48 E	300	480	1.5	9	180	200	40	100	0	0
5	100	MOTOR 2010	30-35-02 N	74-49-28 E	1030	1648	3	9	500	350	46	352	0	0
6	60	HP 2001	30-35-21 N	74-49-39 E	1040	1664	2	9	650	400	48	356	0	0
7	110	MOTOR 2005	30-40-19 N	74-45-08 E	992	1587	3	9	360	300	42	300	0	0
8	40	HP 1995	30-38-29 N	74-48-18 E	984	1574	1.5	9	380	400	42	304	0	0
9	45	HP 2001	30-35-06 N	74 -49-12 E	1130	1808	2	9	440	450	42	356	0	0
10	40	HP 2014	30-34-58 N	74-48-47 E	1610	2576	2	9	450	462	46	370	0	0
11	90	MOTOR 2015	30-35-29 N	74-48-16 E	1400	2240	5	9	446	456	46	350	0	0
12	90	HP 2005	30-35-22 N	74-48-58 E	1740	2784	5	9	500	460	46	370	0	0
13	50	HP 2012	30-36-05 N	74-48-11 E	1140	1824	5	9	468	450	46	342	0	0
14	50	HP 2004	30-35-39 N	74-48-51 E	1350	2160	3	9	504	448	42	354	0	0
15	55	HP 1997	30-36-24 N	74-48-01 E	2330	3728	5	9	540	500	48	400	0	0
16	125	MOTOR 2016	30-38-04 N	74-46-01 E	1550	2480	3	9	510	516	46	350	0	0
17	100	MOTOR 2005	30-36-04 N	74-48-38 E	1790	2864	2	9	516	480	42	380	0	0
18	50	HP 2010	30-36-14 N	74-48-08 E	1710	2736	2	9	460	410	42	360	0	0
19	120	MOTOR 2012	30-34-48 N	74-48-58 E	1490	2384	2	9	460	400	42	320	0	0
20	45	HP 2006	30-33-58 N	74-49-48 E	1020	1632	2	9	410	402	40	310	0	0
21	70	HP 2002	30-33-58 N	74-48-31 E	1230	1968	5	9	500	450	46	372	0	0
22	60	MOTOR 2012	30-32-18 N	74-47-13 E	1140	1824	2	9	442	360	42	304	0	0

S. No.	DEPTH (FEET)	SOURCE (AGE)	LATI	LONGI	TDS	EC	F	pH	ALKALINITY	TOTAL HARDNESS	Ca	Cl^-	Fe	Cl
23	40	HP 2013	30-32-31 N	74-47-01 E	804	1286	2	9	316	320	42	150	0	0
24	50	MOTOR 2010	30-33-12 N	74-45-40 E	550	880	5	9	450	360	46	302	0	0
25	100	MOTOR 2016	30-33-02 N	74-45-23 E	1430	2288	2	9	500	364	46	364	0	0
26	90	MOTOR 2016	30-40-19 N	74-45-08 E	826	1322	3	9	320	310	42	152	0	0
27	160	MOTOR 2016	31-09-41 N	74-25-28 E	1940	3104	3	9	540	442	46	368	0	0
28	125	MOTOR 2002	30-34-19 N	74-47-41 E	1380	2208	2	9	500	402	46	320	0	0
29	60	MOTOR 2007	30-34-55 N	74-46-08 E	550	880	5	9	310	260	40	250	0	0
30	60	MOTOR 2003	30-39-22 N	74-46-13 E	562	899	2	9	300	280	42	256	0	0
31	110	MOTOR 2013	30-36-25 N	74-54-12 E	680	1088	2	9	354	360	40	280	0	0
32	40	HP 2009	30-38-05 N	74-47-09 E	306	490	1	9	250	250	40	210	0	0
33	520	HP 2008	30-38-38 N	75-01-44 E	564	902	1	9	300	254	42	240	0	0
34	100	MOTOR 2015	30-34-32 N	74-50-33 E	820	1312	2	9	400	360	42	320	0	0
35	110	MOTOR 2015	30-36-49 N	74-47-53 E	526	842	1.5	9	302	300	40	220	0	0
36	45	HP 2009	30-41-51 N	74-46-56 E	415	664	2	9	356	306	40	290	0	0
37	110	MOTOR 2005	30-40-19 N	74-45-07 E	1090	1744	3	9	450	420	42	350	0	0
38	60	HP 2002	30-46-59 N	74-52-57 E	380	608	2	9	302	260	42	180	0	0
39	500	MOTOR 2005	30-40-08 N	74-47-53 E	1090	1744	3	9	500	406	46	310	0	0
40	400	MOTOR 2005	30-41-30 N	74-47-34 E	2580	4128	2	9	602	650	48	380	0	0
41	100	MOTOR 2008	30-43-01 N	74-49-41 E	1320	2112	2	9	416	382	42	300	0	0
42	105	MOTOR 2013	30-41-28 N	74-47-34 E	860	1376	2	9	322	300	42	260	0	0
43	45	HP 2005	30-41-05 N	74-46-48 E	564	902	1.5	9	300	260	40	150	0	0
44	45	HP 2010	30-35-04 N	74-48-37 E	1200	1920	3	9	448	402	42	320	0	0
45	60	MOTOR 2005	30-33-09 N	74-48-01 E	450	720	2	9	306	300	42	180	0	0
46	80	MOTOR 2005	30-50-40 N	74-29-39 E	1060	1696	5	9	502	450	46	364	0	0
47	60	MOTOR 2009	30-36-54 N	74-45-59 E	818	1309	5	9	420	326	42	300	0	0
48	350	MOTOR 2011	30-38-37 N	75-07-01 E	550	880	1	9	302	306	40	230	0	0
49	70	MOTOR 2002	30-21-30 N	75-38-51 E	380	608	1	9	216	220	38	150	0	0
50	100	MOTOR 2005	30-47-10 N	75-12-18 E	494	790	1.5	9	310	248	40	204	0	0
51	80	HP 2005	30-47-02 N	75-12-28 E	600	960	1.5	9	314	250	42	250	0	0

S. No.	DEPTH (FEET)	SOURCE (AGE)	LATI	LONGI	TDS	EC	F	pH	ALKALINITY	TOTAL HARDNESS	Ca	Cl^-	Fe	Cl
52	210	HP 2005	30-37-18 N	74-56-48 E	624	998	2	9	320	306	40	260	0	0
53	85	HP 2010	30-39-26 N	75-07-35 E	1380	2208	2	9	410	382	42	282	0	0
54	70	HP 2012	31-14-32 N	76-03-12 E	960	1536	1.5	9	360	300	42	260	0	0
55	120	MOTOR 2005	30-39-26 N	75-07-35 E	1090	1744	3	9	470	406	46	264	0	0
56	90	HP 2005	30-47-14 N	74-42-07 E	1620	2592	2.5	9	540	380	42	380	0	0
57	420	MOTOR 2005	30-43-19 N	74-52-43 E	1430	2288	2.5	9	500	420	46	302	0	0
58	440	MOTOR 2005	30-43-49 N	74-52-34 E	1300	2080	2	9	440	368	46	364	0	0
59	400	MOTOR 2005	30-42-06 N	74-49-06 E	1430	2288	2	9	480	406	44	364	0	0
60	70	HP 2012	30-4--01 N	74-45-00 E	1330	2128	1.5	9	430	260	46	307	0	0

According to the WHO standards, the permissible limit for pH is 6.5-8.5. However all the analyzed samples have pH greater than the permissible limit with mean pH=9 and are alkaline probably because of presence of carbonates and bicarbonates from carbonate weathering.

The maximum permissible limit of alkalinity, as per WHO standards, is 600 mg/L. The mean alkalinity of the samples was found to be 413 mg/L with only 3% samples above this maximum permissible limit. There is no proven harm but it has been found that drinking alkaline water may benefit people who have high blood pressure or diabetes. The WHO standards permit 750µS as maximum permissible limit for electrical conductivity. The range of EC values of samples is from 480µS – 4128µS, with mean EC of 1706 µS. Only about 7% samples, i.e. 4 samples out of the total 60, were found to have electrical conductivity less than the prescribed WHO standards. 3 samples (5%) were found to have electrical conductivity beyond BIS's standard of 3000µS and thus unfit for human consumption. The highest EC value of 4128 was found at site no. 40 (Vill Chahal to Vill Sandhwan Road) at 30-41-30 N; 74-47-34 E while the sample of site no. 4 (Jaganath Bhatha Road, Kotkapura) at 30-35-01 N; 74-49-48 E was found to have the lowest EC value of 418 µS. The permissible limit of TDS in water is 500 mg/L while the maximum permissible limit is 2000 mg/L. 7 samples (12%) were found to have TDS less than 500 mg/L, while 2 samples (3%) had TDS higher than 2000 mg/L with maximum TDS at 2580 mg/L in sample at site no. 40 (Vill. Chahal to Vill. Sandhwan Road). The higher TDS and EC values are likely due to the extensive agricultural practice and over-extraction of groundwater, that results in high concentrations of dissolved ions such as Na^+, Ca^{2+}, K^+, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^- and HCO_3^-.

The WHO standard for maximum permissible limit of total hardness of water is 600 mg/L. 98% of the samples were found to have total hardness less than the maximum permissible limit with an average of 369.5 mg/L. The only sample found to have total hardness more than the permissible limit (650 mg/L) was at site no. 40 (Vill Chahal to Vill Sandhwan road). The WHO standard for permissible limit for calcium is 75 mg/L. All the samples were found to have Calcium below the permissible limit with an average of 43.1 mg/L. As per WHO standards, the permissible iron content is 0.3 mg/L while the maximum permissible limit is 1.0 mg/L. The permissible chlorine content is 0.2 mg/L. All the samples collected from sites had both ion and chlorine content below the permissible limit.

A. Statistical Analysis

Fluoride Analysis. WHO specifies the permissible limit of chlorine as 1.0 mg/L while the maximum permissible limit as 1.5 mg/L, with mean concentration as 2.48 mg/L of samples collected from 60 sites. The data revealed that 4 places had chloride concentration as low as 1 mg/L while 9 sites had fluoride concentration as high as 5 mg/L. About 80% sites were found to have fluoride concentration above 1.5 mg/L while none had fluoride concentration below 0.6 mg/L, the minimum concentration required to prevent dental caries; and promoting bone development.

The major cause of fluoride occurrence in the area is the release of fluoride from fluoride bearing minerals such as topaz, quartz, mica, fluorite etc in the bed rock. Alkaline conditions with pH ranging between 7.6 and 8.6 are favorable for dissolution of fluorite mineral from the host rocks. Fluoride has a negative correlation with depth as most of the fluoride occurrence is observed in shallow surface waters that may be due to water logging and high saline conditions, atmospheric deposition of fluoride and using phosphate-rich fertilizers.

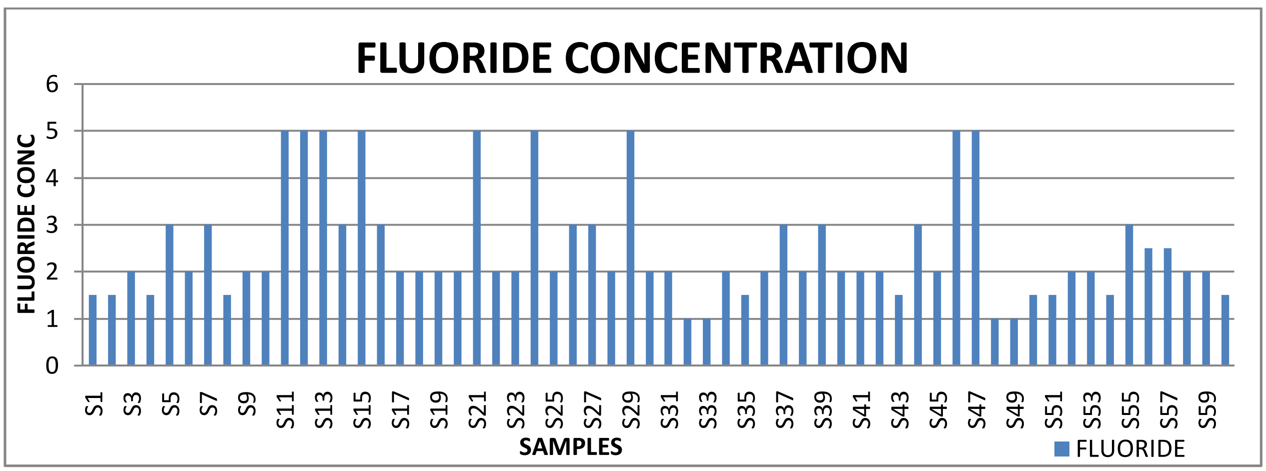


Fig. 1. Concentration of fluoride at various sampling sites.

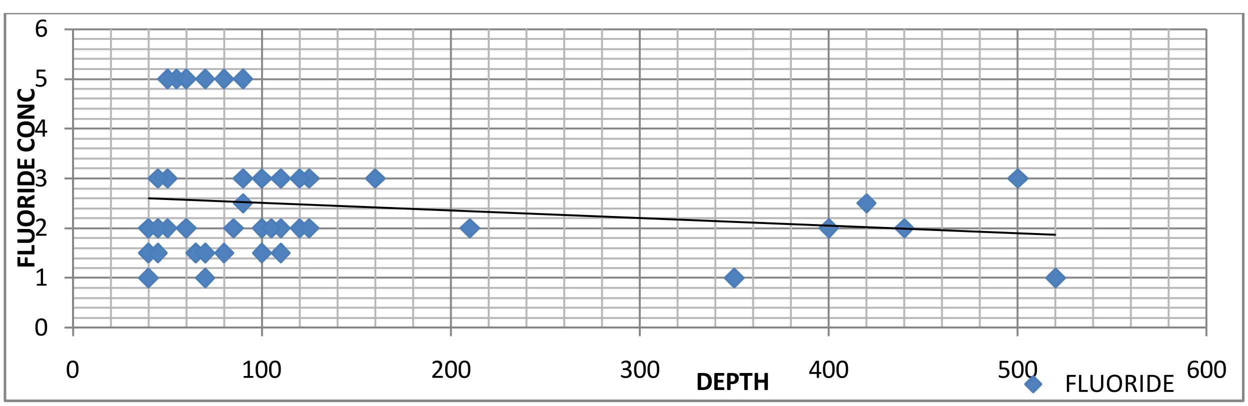


Fig. 2. Fluoride concentration relationship with depth of source.

Chloride Analysis. Samples analyzed for chloride vary from 100 mg/L to 400 mg/L with a mean value of 294.45 mg/L. The WHO standard for the permissible limit is 250 mg/L while the maximum permissible limit of chloride concentration is 1000 mg/L. Out of the 60 samples analyzed, 15 samples (25%) were found to have chloride concentration less than the permissible limit specified by WHO standards.

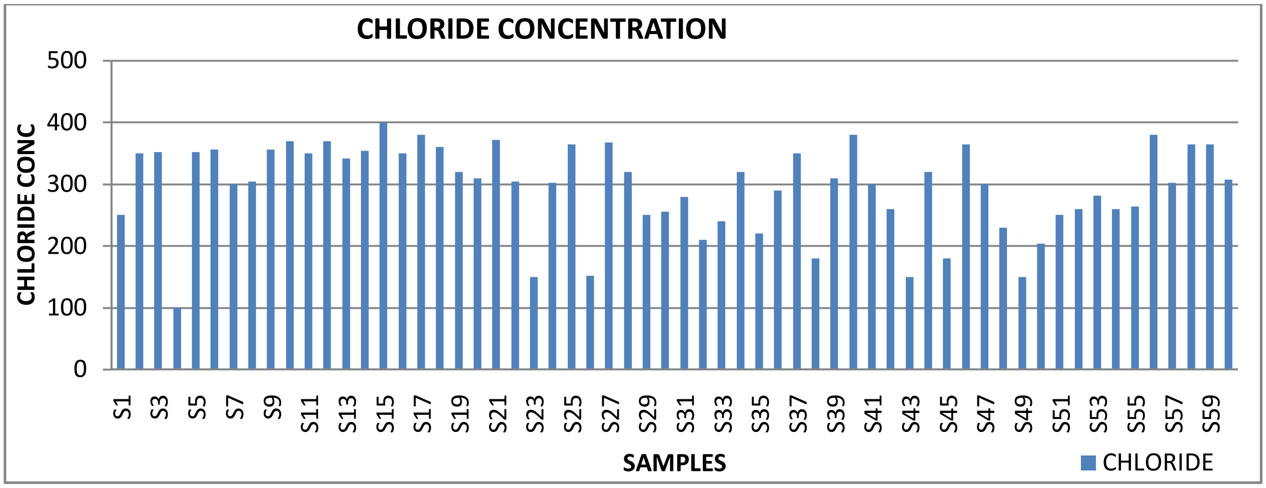


Fig. 3. Concentration of chloride at various sampling sites.

The concentration of chloride has a positive correlation coefficient with depth of source of groundwater. Non-uniform irrigation and preferential flow allows the percolation water to reach the groundwater faster and reduces the amount of salt removal that could occur during slow water passage through the soil, especially for the chloride ion, which is not readily absorbed.

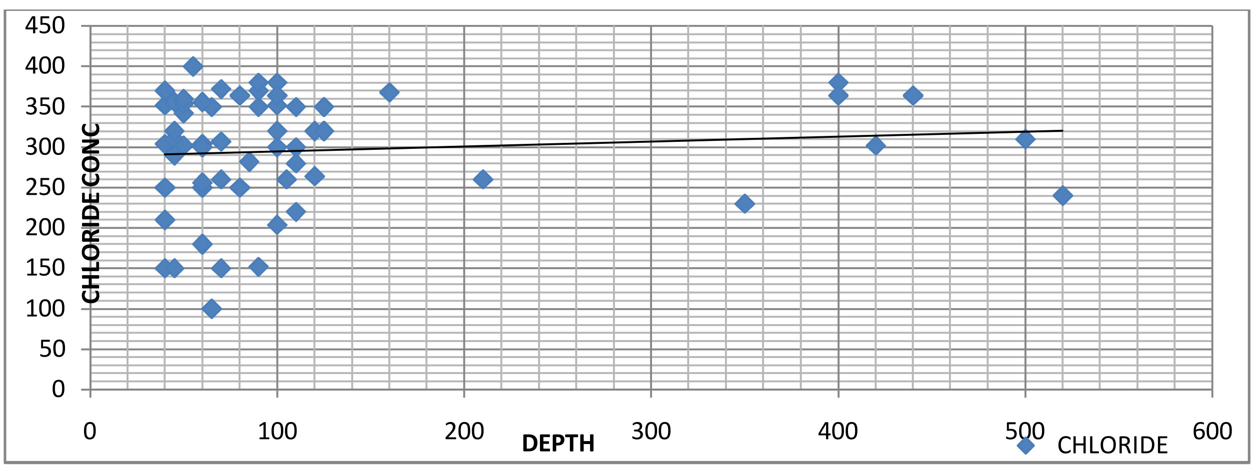


Fig. 4. Chloride concentration relationship with depth of source.

B. Correlation Analysis

The fluoride and chloride concentrations in ground water have showed significant relationship with electrical conductivity, alkalinity and TDS.

Effect of EC and TDS on Fluoride and Chloride. Electrical conductivity has shown positive trend with fluoride concentration as well as the chloride concentration in the groundwater. The higher concentration of electrolytes in water increases electrical conductance as well as pH. The site having the lowest value of electrical conductivity of the groundwater sample was found to have lowest chloride concentration too. However the trend does not tend to a smooth curve on the graph because of presence and effect of other anions and cations in the groundwater, their presence naturally or as a result of anthropogenic factors.

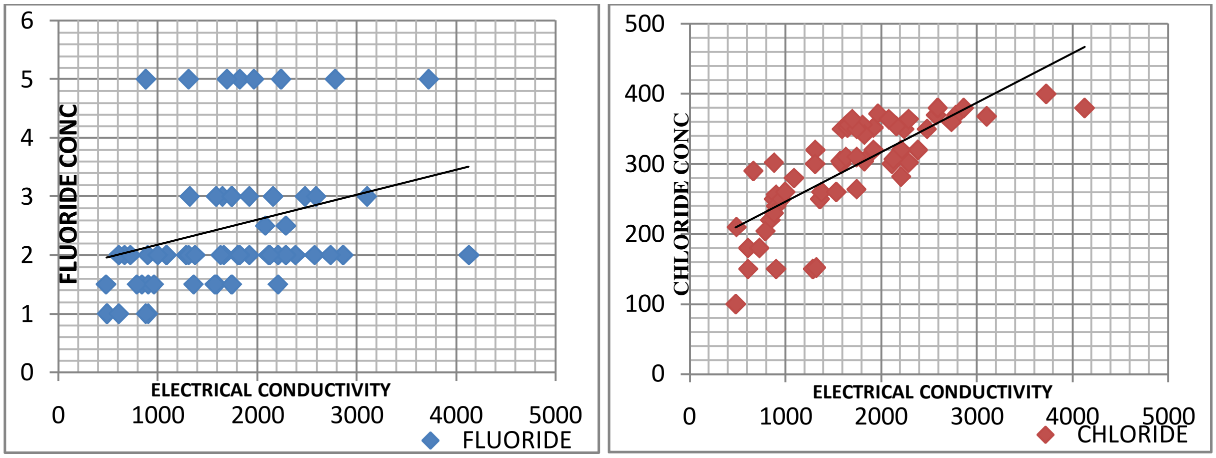


Fig. 5. Fluoride and chloride concentration relationship with electrical conductivity.

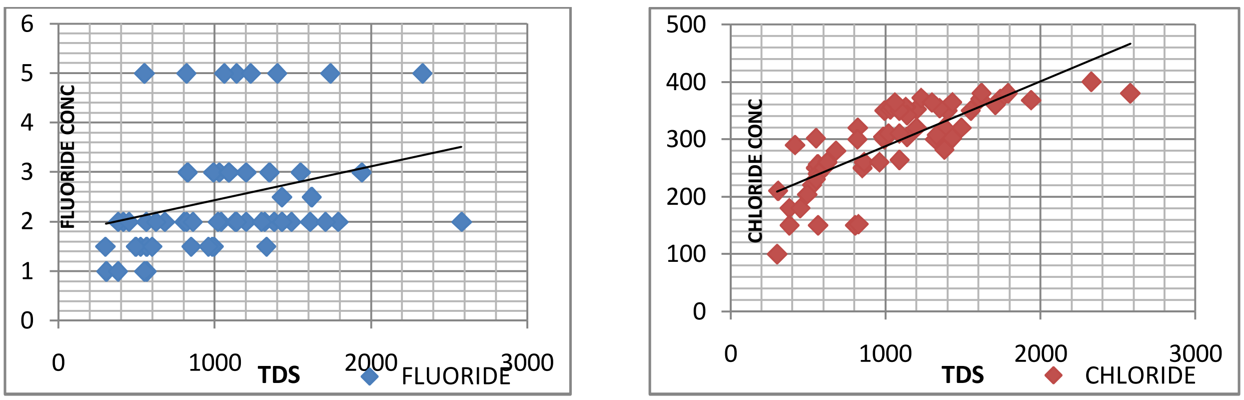


Fig. 6. Fluoride and chloride concentration relationship with TDS.

The chloride and fluoride concentration was also observed to have found positive trend with TDS.

Effect of Alkalinity on Fluoride and Chloride. It was observed that an increase in the alkalinity value made a similar increase in the amount of fluoride but not a very smooth increase with increasing chloride concentration. In alkaline environment, the fluoride ion can be easily liberated because OH^- and F^- ions have similar radii promoting easy exchange.

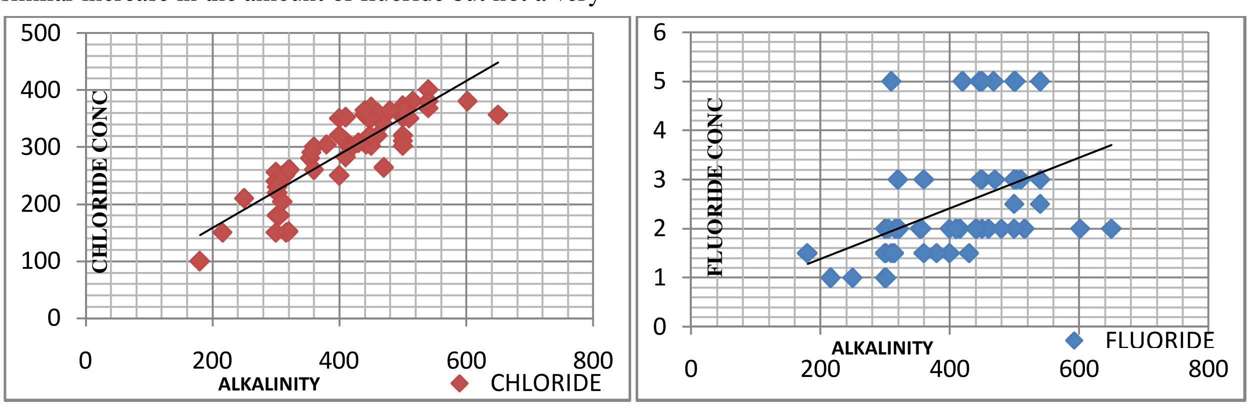
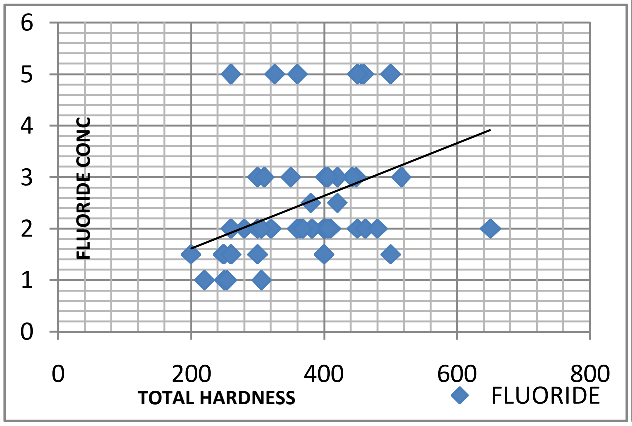


Fig. 7. Fluoride and chloride concentration relationship with alkalinity.

The majority of values were below the maximum permissible limits set by WHO standards. The trends are based on local geology and nature of other ions present in the groundwater.

Effect of Total Hardness of Fluroide and Chloride. The hardness of water does not depend upon by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cation. A positive trend was observed between the total hardness and fluoride as well as chloride concentration. However most of the samples had total hardness less than 600 ppm.



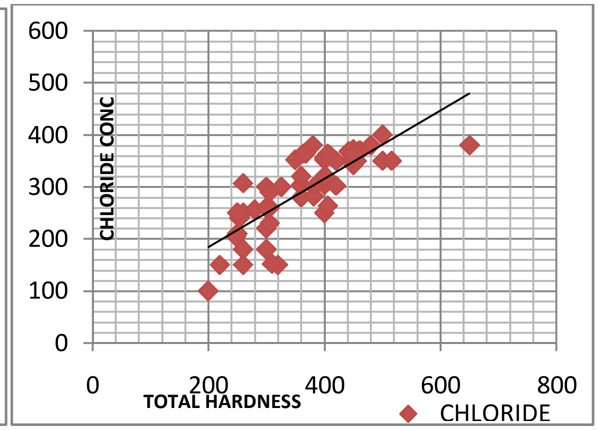


Fig. 8. Fluoride and chloride concentration relationship with total hardness.

IV. CONCLUSION

The outcomes of study have revealed that some of the rural parts of south-western districts of Indian Punjab are suffering from fluoride contamination, with maximum content at lesser depths, and are at risk of chloride contamination that increases with depth due to leaching of non-soluble salts. The contamination of groundwater has resulted from natural as well as anthropogenic activities such as persisting agricultural practices, which has limited the use of groundwater for personal consumption without further purification, thereby leading people use the technology of reverse osmosis systems to purify water for drinking purposes. The geospatial distribution of fluoride and chloride is also very non uniform and the variability is of great concern due to difference in the compounds' concentration in different areas that lie in each other's vicinity.

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