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Assessment of Ground Water Contamination by Inorganic Impurities in Ferozepur District of Punjab State, India

GURJEET KAUR[1], SANGEETA SHARMA[1,*] and UMESH KUMAR GARG[2]

[1]Department of Applied Sciences and Humanities, Shaheed Bhagat Singh State Technical Campus, Ferozepur-152001, India
[2]Guru Teg Bahudar Khalsa College of Information Technology, Chhapianwali, Malout-152107, India

*Corresponding author: E-mail: sangeetassharma70@gmail.com

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Malwa region of Punjab state, India has become the center of water borne diseases due to excessive use of pesticides, chemical fertilizers, heavy metals, industrial toxins that cause toxicity in water. The main contamination in ground water is by physico-chemical parameters and heavy metals *i.e.* pH, total dissolved solids, total alkalinity, total hardness, calcium, chlorides, fluorides, arsenic and lead. The contamination of ground water with heavy metals causes health hazards to humans and animals. Due to lack of adequate facilities and resources for the management and handling of waste, the ground water contamination has been increased. In the present study, assessment of ground water quality was carried out in the villages of Ferozepur district of Punjab state, India. With main emphasis on analyzing the groundwater parameters of Ferozepur district which are responsible for health hazard to humans and animals. Various groundwater samples were collected randomly from the villages of Ferozepur district and analyzed for pH, total dissolved solids, total alkalinity, total hardness, calcium, chlorides, fluorides, heavy metals (arsenic and lead) using standard procedures. The concentrations of calcium, chlorides, fluorides and pH were within the permissible limits, whereas, alkalinity and total hardness were observed beyond permissible limits in most of the water samples. Even among majority of the samples taken, the concentration of arsenic and lead was found within the permissible limits. Results showed that the ground water samples collected from depth ranging from 100 to 360 ft, recorded values within permissible limits for drinking purpose as prescribed by WHO. Further, ANOVA has been applied on analysis results to study the effect of pH on fluoride and chloride, depth on fluoride and chloride and depth on arsenic and lead. Also, to adjudge the overall quality of water in Ferozepur district, the water quality index (WQI) has been calculated on the basis of large number of physico-chemical characteristics of water. The water quality index of ground water in Ferozepur district has been calculated to be 107. The value is close to 100 so the quality of ground water in Ferozepur district can be categorized under 'Good Quality' water.

Keywords: Groundwater, Water quality index, Contamination, Inorganic pollutants.

INTRODUCTION

Water is a primary need for humans and crucial natural resource [1]. There is 70-80 % water in human body. The general survey reveals that 36.1 crore km^2 surface area is covered by sea out of total surface area of earth *i.e.* 51 crore km^2. Rivers, lakes and groundwater are the sources of fresh water. The availability of fresh water is getting less day by day in the world [2]. In India, 89 % of groundwater is used for irrigation purpose which is the major source of consumption of groundwater, whereas 9 % is used for domestic purpose and 2 % for industrial purpose [3].

Hydrological monitoring stations are the source of determination of quantity of water by maintaining record of water level, its discharge and velocity and water quality is determined by collecting water samples from points, fixed at these monitoring stations and analysis of various parameters is done. The analysis results revealed the quality of water, on the basis of which spatial and temporal trends of surface water and groundwater are obtained [4].

Groundwater is stored underground in aquifers and is available below the surface in rocks and soil. About 97 % of freshwater is mainly groundwater and is a vital source of drinking water all-over the world. In areas, where surface water supply is less and polluted, groundwater is the only source of drinking water [5]. Groundwater at depth is usually safe from micro-organisms and chemicals where direct contamination is not possible; whereas at shallow, contamination of groundwater occur by mixing of sewerage, industrial waste and agriculture waste, pesticides, *etc*. [6].

In Punjab state, groundwater is reducing day by day because of its misuse and mishandling and its contamination by geogenic and anthropogenic sources [7]. Contamination of groundwater also occurs due to leaching of fertilizers and manures from agriculture fields. The untreated effluents discharged by industries into sewers/drains may lead to contamination of groundwater as untreated effluents have limits more than permissible limits prescribed by the Government for discharge onto land for plantation/irrigation. The presence of heavy metals in drinking water also causes detrimental impacts on human health if present in higher side than a certain concentration [8].

For maintaining the health of ecosystems, the quality of water is a necessary parameter. The physical, chemical, biological properties and availability of water influence the health of ecosystems. Some ecosystems are sensitive and can be degraded by small changes in the physical and chemical properties of the water [4]. Punjab′s ecosystem is drastically affected from contamination of groundwater by various sources like geogenic, agricultural, industrial and urban activities which leads to reduction of groundwater resources and contaminates soil, plants, animals and humans. Keeping in view, all the above aspects, the present study involves the assessment of groundwater quality with respect to inorganic pollutants of Ferozepur district of Punjab state, India.

EXPERIMENTAL

Study area: Firozpur district of Punjab state, India occupies an area of about 5,305 km^2 in southwestern Punjab (India). Total population of the district is about 10 lakhs, out of which, 5 lakhs are male and 5 lakhs are female. About 95 % rural population depends upon groundwater for execution of daily routine activities like drinking, domestic and agricultural purposes. Global positioning system is used for determining the geographical coordinates of the study area. The coordinates of total study area lie between latitudes of 30º49.218′ and 30º57.003′ north and longitudes of 74º23.078′ and 74º55.638′ east (Table-1).

Topography: The state of Punjab has been classified into five agro-climatic zones on the basis of homogeneity, rainfall pattern and distribution, temperature, soil texture and cropping pattern (Fig. 1). Out of the five agro-climatic zones, Ferozepur district fall under western plain zone, which is characterized by arid (dry) and hot zone. Average annual temperature ranges from 25 ºC to 26 ºC and mean annual rainfall varies from 200 mm to 400 mm. Depth to water level in the area ranges from 1.5 m to 31 m below ground level (mbgl). Water table is at shallow depth at several areas of Ferozepur district where it ranges from 1.5 mbgl to 7.5 mbgl causing water logging at many places. The groundwater is mainly abstracted through hand pumps (up to 25 m) and shallow and medium depth tube wells (upto 175 m) [9].

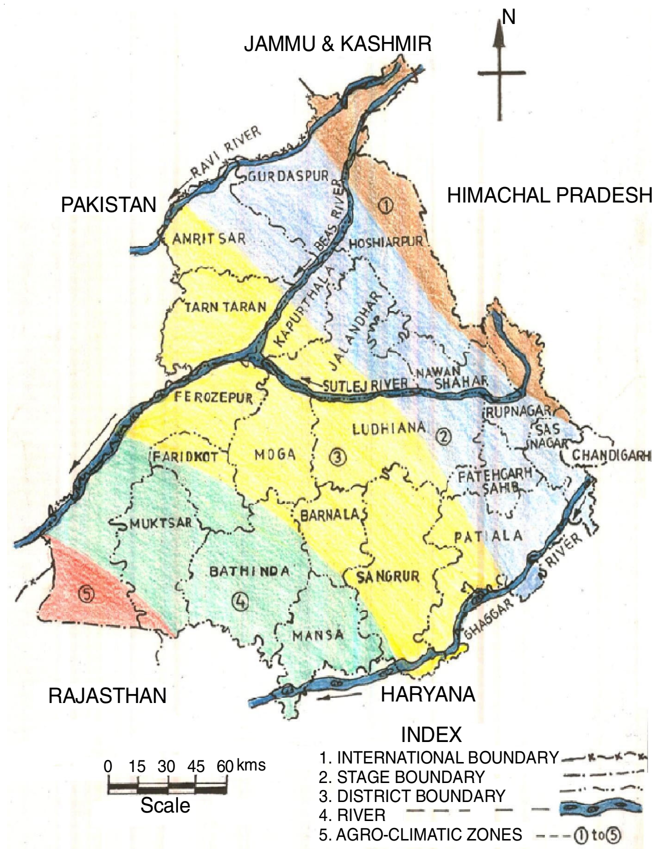

Fig. 1. Showing five agro climatic zones of Firozpur district of Punjab

Sampling: The primary data regarding extent of various inorganic impurities in the groundwater 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 (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 various inorganic impurities in the particular area. By visiting the selected areas of the district, 66 drinking water samples were collected from underground sources where hand pumps, tube wells and submersible pumps were installed. All the samples were stored in identical PET bottles (1 L capacity), marked numerically, and then various parameters were tested namely, pH, TDS, alkalinity, total hardness, and for the content of fluoride, chloride, arsenic, and lead. The analysis results were compared with acceptable limit of WHO for drinking water.

Analysis: Physico-chemical parameters such as pH, TDS, alkalinity, total hardness, fluoride, and chloride concentration were analyzed by using standard methods. pH of solution is determined by using portable handy pH meter, TDS by using TDS meter and fluoride by using field test kits of Merck. The collected samples were also tested for fluoride concentration in water in the laboratory and results were cross-checked by colorimetric determination using SPADNS method, TDS by gravimetric method, total hardness by EDTA titrimetric method, chloride by argentometric titrimetric method, arsenic by atomic absorption spectrometry using hydride vapour generation technique and lead by AAS using graphite furnace assembly (Shimadzu model AA-7000).

TABLE-1
PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER/ DRINKING WATER

S. No.	Village ID	Sample ID	Depth (feet)	Source (age)	Latitude	Longitude	pH	mg/L							
								TDS	F^-	Alkalinity	TH	Ca^{2+}	Cl^-	As^{3+}	Pb^{2+}
1	V1	V1A	45	HP 2000	N30°49.649'	E74°45.453'	7.8	950	1.10	436	264	30	116	0.010	0.010
2		V1B	35	HP 2010	N30°49.698'	E74°45.515'	7.7	768	0.35	294	216	28	66	0.010	0.020
3		V1C	40	HP 2010	N30°49.711'	E74°45.519'	7.3	472	0.25	236	158	24	46	0.010	0.010
4		V1D	45	HP 2013	N30°49.720'	E74°45.509'	7.9	892	0.55	426	254	30	92	0.010	0.010
5		V1E	42	HP 2008	N30°49.726'	E74°45.512'	7.7	746	0.45	314	238	32	86	0.011	0.010
6		V1F	40	HP 2010	N30°49.736'	E74°45.489'	8.0	1090	1.20	458	184	26	130	0.010	0.010
7		V1G	40	HP 2010	N30°49.716'	E74°45.476'	8.1	1160	1.00	514	278	42	156	0.010	0.010
8		V1H	30	HP 2009	N30°49.724'	E74°45.460'	8.0	1120	0.85	470	166	28	114	0.010	0.020
9		V1I	85	Motor 2013	N30°49.711'	E74°45.457'	7.9	812	0.50	398	234	40	98	0.010	0.010
10		V1J	25	HP 1997	N30°49.713'	E74°45.480'	7.7	794	0.35	360	212	34	82	0.020	0.010
11		V1K	550	Motor 2016	N30°49.745'	E74°45.477'	7.5	658	0.25	282	148	26	74	0.012	0.010
12		V1L	225	Motor 2002	N30°49.762'	E74°45.464'	8.0	1100	1.10	426	426	38	146	0.010	0.010
13		V1M	125	HP 2002	N30°49.665'	E74°45.491'	7.6	642	0.45	318	270	34	82	0.010	0.020
14		V1N	110	HP 2012	N30°49.685'	E74°45.490'	7.9	826	0.40	390	142	20	78	0.010	0.010
15		V1O	100	HP 2012	N30°49.730'	E74°45.515'	7.6	784	0.35	330	296	38	74	0.010	0.010
16	V2	V2A	120	Motor 2012	N30°55.186'	E74°35.320'	7.5	336	0.25	214	248	32	56	0.010	0.010
17		V2B	160	Motor 2006	N30°55.67'	E74°35.120'	7.1	324	0.35	178	192	26	40	0.010	0.010
18		V2C	120	Motor 2002	N30°55.837'	E74°35.855'	7.5	340	0.25	228	216	30	64	0.010	0.010
19		V2D	180	Motor 2002	N30°55.001'	E74°35.931'	7.4	376	0.40	234	250	36	78	0.010	0.010
20		V2E	140	Motor 2015	N30°55.296'	E74°35.870'	7.7	682	0.55	326	494	52	88	0.012	0.010
21		V2F	220	Motor 2011	N30°55.590'	E74°35.156'	7.6	354	0.45	260	238	30	72	0.010	0.010
22		V2G	150	Motor 2010	N30°55.208'	E74°35.081'	8.1	1380	0.65	526	850	118	142	0.011	0.010
23		V2H	60	Motor 1997	N30°55.025'	E74°35.767'	8.0	1190	0.50	468	730	94	126	0.010	0.010
24	V3	V3A	220	Motor 2004	N30°49.674'	E74°23.432'	7.8	634	0.45	352	526	72	98	0.010	0.010
25		V3B	230	Motor 2011	N30°49.772'	E74°23.198'	7.2	286	0.25	178	194	26	38	0.010	0.010
26		V3C	100	HP 2000	N30°49.236'	E74°23.638'	7.9	652	0.40	336	470	54	82	0.010	0.010
27		V3D	180	Motor 2011	N30°49.724'	E74°23.592'	7.7	534	0.35	288	446	50	78	0.010	0.010
28		V3E	70	HP 2015	N30°49.518'	E74°23.776'	7.8	560	0.45	312	480	62	96	0.011	0.010
29		V3F	225	Motor 2010	N30°49.925'	E74°23.078'	7.5	318	0.30	224	252	36	68	0.010	0.010
30		V3G	220	Motor 2015	N30°49.218'	E74°23.395'	7.0	246	0.25	162	178	24	32	0.010	0.010
31	V4	V4A	200	Motor 2007	N30°51.804'	E74°55.623'	7.9	1380	0.65	322	264	36	178	0.010	0.010
32		V4B	350	Motor 2010	N30°51.848'	E74°55.612'	8.2	1740	0.85	458	312	44	260	0.010	0.010
33		V4C	350	Motor 2009	N30°51.870'	E74°55.595'	7.9	1400	0.70	316	248	30	186	0.010	0.010
34		V4D	310	Motor 2016	N30°51.865'	E74°55.609'	8.1	1610	1.00	432	276	38	234	0.020	0.010
35		V4E	250	Motor 2013	N30°51.861'	E74°55.584'	7.8	1490	0.80	368	250	34	192	0.010	0.010
36		V4F	200	Motor 2007	N30°51.839'	E74°55.626'	8.0	1550	1.00	394	288	40	216	0.010	0.010
37		V4G	300	Motor 2013	N30°51.922'	E74°55.601'	7.9	1420	0.75	336	254	32	198	0.020	0.010
38		V4H	700	Motor 2009	N30°51.971'	E74°55.591'	7.6	534	0.30	218	62	16	54	0.010	0.010
39		V4I	330	Motor 2014	N30°52.010'	E74°55.586'	7.8	996	0.45	280	142	20	86	0.010	0.010
40		V4J	240	Motor 2015	N30°51.988'	E74°55.608'	8.0	1390	0.75	346	170	24	168	0.011	0.010
41		V4K	250	Motor 2014	N30°51.009'	E74°55.638'	7.9	1170	0.55	221	164	26	132	0.010	0.016
42		V4L	350	Motor 2016	N30°51.036'	E74°55.637'	7.8	1120	0.65	274	138	22	116	0.010	0.010
43		V4M	750	Motor 2015	N30°52.054'	E74°55.638'	7.5	652	0.35	230	84	16	72	0.012	0.010
44		V4N	300	Motor 2008	N30°52.033'	E74°55.616'	7.9	1080	0.50	270	132	20	84	0.010	0.010
45		V4O	300	Motor 2006	N30°52.019'	E74°55.623'	7.8	1040	0.45	256	118	20	78	0.010	0.010
46	V5	V5A	200	Motor 2006	N30°56.907'	E74°37.609'	8.1	1190	0.65	348	712	126	164	0.010	0.010
47		V5B	250	Motor 2007	N30°57.003'	E74°37.624'	7.5	492	0.25	220	276	34	46	0.010	0.010
48		V5C	200	Motor 2010	N30°56.878'	E74°37.578'	7.7	532	0.30	246	218	30	58	0.010	0.010
49	V6	V6A	60	HP 2009	N30°55.001'	E74°31.193'	8.1	1300	1.10	542	716	98	324	0.010	0.010
50		V6B	500	Motor 2017	N30°55.001'	E74°31.193'	7.0	284	0.25	150	66	14	38	0.010	0.010
51		V6C	60	HP 2017	N30°55.342'	E74°31.131'	7.4	372	0.30	216	258	32	46	0.020	0.010
52		V6D	60	HP 2017	N30°55.327'	E74°31.082'	7.5	486	0.40	258	294	36	62	0.010	0.010
53		V6E	65	HP 2010	N30°55.141'	E74°31.187'	7.5	492	0.35	284	360	42	86	0.010	0.016
54		V6F	50	HP 2016	N30°55.213'	E74°31.464'	7.8	910	0.45	362	488	54	112	0.010	0.010
55		V6G	80	Motor 2002	N30°55.202'	E74°31.462'	7.9	874	0.60	330	536	72	98	0.010	0.010
56		V6H	40	HP 2001	N30°55.049'	E74°31.193'	7.7	622	0.45	318	470	52	84	0.012	0.010
57		V6I	80	Motor 2005	N30°55.049'	E74°31.193'	7.4	330	0.25	216	242	30	48	0.010	0.010
58		V6J	80	Motor 2007	N30°55.052'	E74°31.197'	7.6	548	0.40	290	432	48	76	0.010	0.010
59		V6K	60	Motor 2013	N30°55.063'	E74°31.207'	7.9	616	0.50	374	450	56	92	0.010	0.010
60		V6L	220	Motor 2012	N30°55.060'	E74°31.203'	7.3	320	0.30	166	178	26	40	0.010	0.010
61		V6M	200	Motor 2015	N30°55.038'	E74°31.203'	7.5	346	0.35	178	190	28	44	0.011	0.010
62		V6N	160	Motor 2012	N30°55.027'	E74°31.189'	7.4	358	0.25	192	236	32	68	0.010	0.010
63		V6O	255	Motor 2017	N30°55.018'	E74°31.208'	7.1	312	0.30	170	184	26	50	0.010	0.010
64		V6P	65	Motor 2007	N30°54.707'	E74°32.167'	7.9	720	0.65	438	546	70	118	0.010	0.016
65		V6Q	80	Motor 2000	N30°54.527'	E74°32.827'	7.7	600	0.45	324	458	56	80	0.010	0.010
66		V6R	70	HP 2001	N30°54.948'	E74°32.203'	8.1	1090	0.85	456		90	134	0.010	0.010

V1 = Shakoor; V2 = Naurang ke Sayal; V3 = Khunder Uttar; V4 = Talwandi Bhai; V5 = Ferozepur City; V6 = Rodewala

RESULTS AND DISCUSSION

Impurities in drinking water were detected by using improved analytical methods to ascertain the quality of drinking water. Table-1 denotes the results of physico-chemical parameters and heavy metals present in drinking water samples collected from selected sampling sites across district Ferozepur of Punjab state, India.

The results of some physico-chemical parameters like pH, TDS, alkalinity, total hardness, fluoride, chloride and some heavy metals like arsenic and lead are shown in Table-1. As per WHO guidelines, pH of drinking water should lie in between 6.5-8.5. The pH of water samples was found to lie in between 7.0 to 8.2 with mean pH 7.71 which was slightly alkaline. The minimum and maximum pH value of 7.0 and 8.2 was observed in the sample ID V3G and ID V4B, respectively.

High TDS values were observed at many locations. The acceptable limit of TDS in water is 1000 mg/L as per WHO standards. Twenty one samples (32 %) were found to have TDS more than 1000 mg/L with maximum TDS of 1740 mg/L in sample no. 32 (sub-tehsil Talwandi Bhai). The broad agricultural practices and large extraction of groundwater leads to high concentrations of dissolved materials which further increase value of TDS. High TDS is due to Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^{2-}, Cl^-, *etc.* ions present in water.

The maximum permissible limit of total hardness in water is 600 mg/L as per WHO guidelines. About 88% of samples were found to have total hardness less than the maximum permissible limit. The total hardness of sample ID V2G was more than the permissible limit with maximum value of 850 mg/L.

The permissible limit for calcium is 75 mg/L as per WHO guidelines. Presence of calcium in sample ID V5A was more than the permissible limit with maximum value of 126 mg/L. As per WHO guidelines, the permissible limit of arsenic content is 0.010 mg/L and there are 19 % samples found to have arsenic content more than permissible limit. Around 0.09 % samples found to have lead content beyond permissible limit that is 0.010 mg/L. Table-2 denotes the summary of water quality parameters of studied area.

Statistical analysis

Fluoride analysis: Groundwater samples contained fluoride concentration ranges from 0.25 to 1.20 mg/L with mean value and SD of 0.52 mg/L and 0.08575, respectively. As per analysis results, it was noted that no sample exceeded the acceptable limit (Table-3). The minimum fluoride concentration (0.6 mg/L) which prevents dental caries and encourages the development of bones and is unfit for drinking purpose. About 69.9 % of total samples found to have fluoride concentration below minimum fluoride concentration required. Talwandi Bhai is the location where most of the samples having fluoride concentration within permissible limits. Table-3 and Fig. 2 denotes the frequency distribution of fluoride against sampling area.

The study also revealed that the fluoride dissolution increases with respect to depth as there could be an increase in the geo-

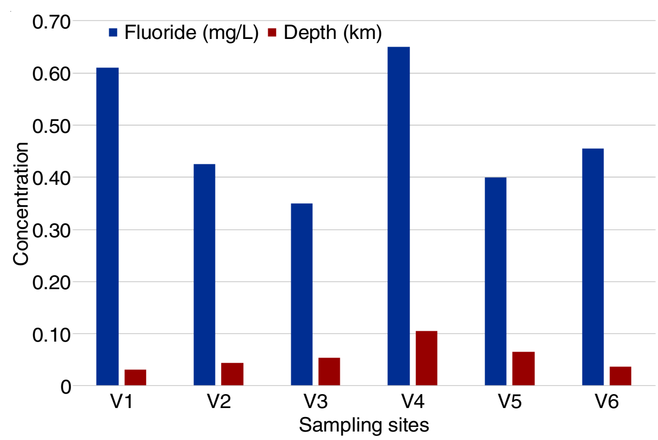

Fig. 2. Concentration of fluoride and depth at various sampling sites

TABLE-2
SUMMARY OF WATER QUALITY PARAMETERS OF STUDIED AREA

Name of village	No. of sample	TDS (mg/L)	F^- (mg/L)	pH	Alkalinity (mg/L)	Total hardness (mg/L)	Ca^{2+} (mg/L)	Cl^- (mg/L)	As^{3+} (mg/L)	Pb^{2+} (mg/L)
V1	15	472-1160	0.25-1.20	7.3-8.1	236-514	142-426	20-42	46-156	0.010-0.020	0.010-0.010
V2	8	324-1380	0.25-0.65	7.1-8.1	178-526	192-850	26-118	40-142	0.010-0.012	0.010-0.010
V3	7	246-652	0.25-0.45	7.0-7.9	162-352	178-526	24-72	32-98	0.010-0.011	0.010-0.010
V4	15	534-1740	0.30-1.00	7.5-8.2	221-458	62-312	16-44	54-260	0.010-0.020	0.010-0.010
V5	3	492-1190	0.25-0.65	7.5-8.1	220-348	218-712	30-126	58-164	0.010-0.010	0.010-0.010
V6	18	312-1300	0.25-1.10	7.0-8.1	150-542	66-716	14-98	38-324	0.010-0.020	0.010-0.016
Total	66	246-1740	0.25-1.20	7.0-8.2	150-542	62-850	14-126	32-324	0.010-0.020	0.010-0.010
Mean		793.82	0.52	7.71	314.20	305.06	40.64	101.82	0.0108	0.0107

TABLE-3
FREQUENCY DISTRIBUTION OF WATER QUALITY PARAMETERS OF STUDIED AREA

S. No.	Name of village	No. of sample	F^- (mg/L)			Cl^- (mg/L)			As^{3+} (mg/L)			Pb^{2+} (mg/L)		
			<1.0	1.0-1.5	>1.5	<250	250-1000	>1000	<0.010	Equal to 0.010	>0.010	<0.010	Equal to 0.010	>0.010
1	V1	15	11	4	Nil	15	Nil	Nil	Nil	12	3	Nil	12	3
2	V2	8	8	Nil	Nil	8	Nil	Nil	Nil	6	2	Nil	8	Nil
3	V3	7	7	Nil	Nil	7	Nil	Nil	Nil	6	1	Nil	7	Nil
4	V4	15	13	2	Nil	15	Nil	Nil	Nil	11	4	Nil	14	1
5	V5	3	3	Nil	Nil	3	Nil	Nil	Nil	3	Nil	Nil	3	Nil
6	V6	18	17	1	Nil	18	Nil	Nil	Nil	15	3	Nil	16	2

thermal gradient. Although the observation on the interdependency between depth and fluoride concentration was positively correlated (Fig. 3), the lower fluoride concentration in groundwater may be associated with the mixing of water with different chemical compositions. The enrichment of fluoride is in shallow groundwater sources because of evapotranspiration and thus, the concentration of fluoride at deep groundwater sources is less.

The study showed that chloride concentration increases with increase in depth (Table-4). The relation between depth and chloride concentration is shown in Fig. 4. Due to weather conditions, the process of leaching of chloride from rocks into soil and water is done. Due to mobility characteristic of chloride ion, it is transported to closed oceans, hence, the concentration of chloride is high at deep groundwater sources.

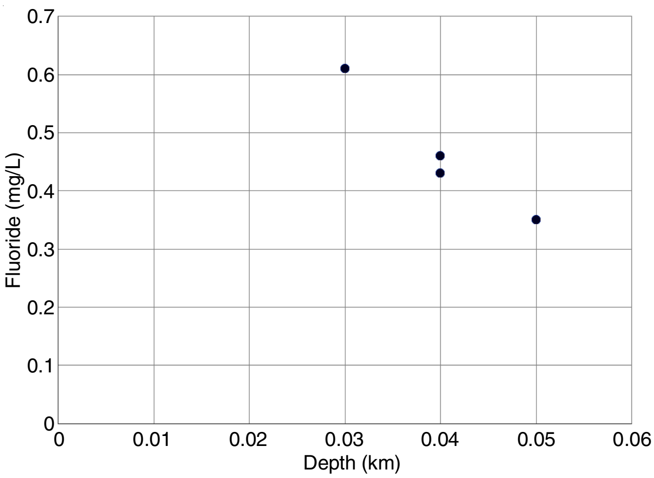

Fig. 3. Relation b/w depth and fluoride at various sampling sites

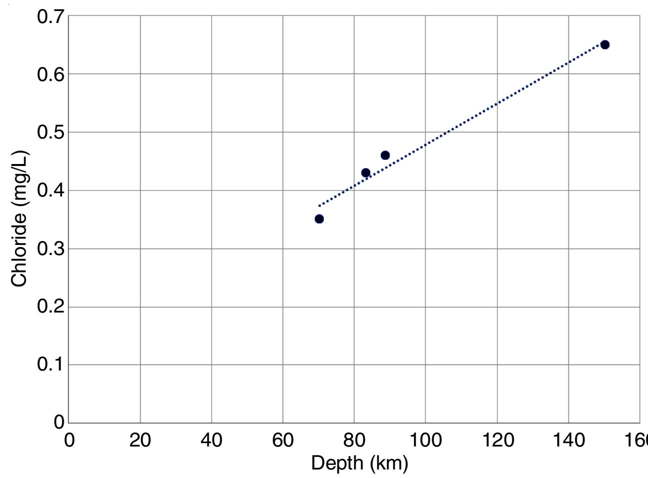

Fig. 4. Relation b/w concentration of chloride and depth

Chloride analysis: Groundwater samples contained 32 to 324 mg/L of chloride concentration with mean and SD value of 101.82 mg/L and 26.266, respectively. The analysis data showed that no sample exceeded the acceptable limit (Table-3). 250 mg/L is the minimum chloride concentration which is needed to stop the harmful effects on metal pipes and agricultural implements and 96.97% of total samples found to have chloride concentration below minimum concentration.

Correlation analysis: The fluoride and chloride concentrations in groundwater showed significant relationship with pH and depth.

Effect of pH on fluoride and chloride: Fluoride concentration has showed a positive correlation with pH whereas chloride showed slightly negative trend with pH ($R^2 = 0.9975$ and 0.6804, respectively) (Table-5). The positive correlation between pH & fluoride and pH & chloride levels might be

TABLE-4
STATISTICAL ANALYSIS OF WATER SAMPLES

Name of village	No. of samples	F^- (mg/L)	Range	Mean	SD	Cl^- (mg/L)	Range	Mean	SD
V1	15	0.25-1.20	0.95	0.61	0.33922	46-156	110	96.0000	30.6874
V2	8	0.25-0.65	0.40	0.425	0.14142	40-142	102	83.2500	34.7224
V3	7	0.25-0.45	0.20	0.35	0.08660	32-98	66	70.2857	26.266
V4	15	0.30-1.00	0.70	0.65	0.21630	54-260	206	150.267	65.6826
V5	3	0.25-0.65	0.40	0.4	0.21794	58-164	106	89.3333	64.9410
V6	18	0.25-1.10	0.85	0.456	0.22485	38-324	286	88.8889	65.1883
Name of village	No. of samples	As^{3+} (mg/L)	Range	Mean	SD	Pb^{2+} (mg/L)	Range	Mean	SD
V1	15	0.010-0.020	0.010	0.010	0.002499	0.010-0.010	0.000	0.012	0.00414
V2	8	0.010-0.012	0.002	0.010	0.000744	0.010-0.010	0.000	0.010	0.00000
V3	7	0.010-0.011	0.001	0.010	0.000377	0.010-0.010	0.000	0.010	0.00000
V4	15	0.010-0.020	0.010	0.011	0.003481	0.010-0.010	0.000	0.010	0.00154
V5	3	0.010-0.010	0.000	0.010	0.000000	0.010-0.010	0.000	0.010	0.00000
V6	18	0.010-0.020	0.010	0.010	0.002371	0.010-0.016	0.006	0.010	0.00194

TABLE-5
ANOVA: SHOWING EFFECT OF pH ON FLUORIDE & CHLORIDE IN GROUNDWATER

		DF	Sum of squares	Adjusted R^2	Mean square	F-value	$F_{critical}$
Fluoride	Model	1	156.2206	0.997561	156.2206	10309.96	4.9646
Fluoride	Error	10	0.151524		0.0151524		
Fluoride	Total	11	156.372124				
Chloride	Model	1	23570.8296	0.6804	23570.8296	61.01527	4.9646
Chloride	Error	10	3863.1029		386.31029		
Chloride	Total	11	27433.9325				

due to the release of hydroxyl and bicarbonate ions simultaneously during the leaching and dissolution process of fluoride-bearing minerals in the groundwater. The solubility of fluoride is lowest in the pH range of 5.0 to 5.6 due to its absorption on the surface of minerals present in clay in sub-surface rocks.

Effect of depth on fluoride and chloride: Fluoride and chloride have showed a negative and positive correlation with depth having $R^2 = 0.715517$ and 0.720376, respectively) (Table-6). High fluoride and low chloride concentrations have been found in the shallow surface waters, whereas fluoride concentration reduces with increase in depth, on the other hand, chloride concentration increases with increase in depth. Fluoride occurrence is due to geogenic as well as anthropogenic reasons but chloride occurrence is because of its build up during evaporation process in the soil because chloride is not taken up by plants and non-volatile. Chloride moves conservatively in liquid water throughout the hydrologic cycle.

Effect of depth on arsenic and lead: Arsenic and lead showed a negative correlation with depth having $R^2 = 0.04036$ and 0.215407, respectively) (Table-7). Arsenic concentration remains constant in majority of the samples and was found within permissible limit in 81 % samples as prescribed by WHO *i.e.* 0.010 mg/L, whereas the concentration of lead reduces with increase in depth and was found within permissible limit as prescribed by WHO *i.e.* in this case is 0.010 mg/L.

Water quality index: The quality of groundwater at certain places in Ferozepur district can also be ascertained by calculating water quality index. The methodology for computation of water quality index (WQI) includes following steps:

$$WQI = \frac{\Sigma W_n Q_n}{\Sigma W_n}$$

The quality rating index (Q_n) is calculated by using this expression:

$$Q_n = \left(\frac{V_n - V_i}{S_n - V_i}\right) \times 100$$

where, V_n is estimated value of the parameters of groundwater in Ferozpur district; V_i is the ideal value of parameter in pure water; $V_i = 0$ (except pH = 7.0 for all other parameters); S_n is standard permissible value of parameter of groundwater. The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_n = \frac{K}{S_n}$$

where, K is proportionality constant and can also be calculated by using the following equation:

$$\frac{1}{\Sigma\left(1/S_n \right)}$$

The water quality index of groundwater in Ferozepur district is equal to 107 (Table-8). The value is close to 100 so

TABLE-6
ANOVA: SHOWING EFFECT OF DEPTH ON FLUORIDE & CHLORIDE IN GROUNDWATER

		DF	Sum of squares	Adjusted R^2	Mean square	F-value	$F_{critical}$
Fluoride	Model	1	0.542384	0.715517	0.542384	70.4389	4.9646
Fluoride	Error	10	0.077		0.0077		
Fluoride	Total	11	0.619384				
Chloride	Model	1	27809.976	0.720376	27809.976	71.99	4.9646
Chloride	Error	10	3863.0284		386.3028		
Chloride	Total	11	31673.004				

TABLE-7
ANOVA: SHOWING EFFECT OF DEPTH ON ARSENIC & LEAD IN GROUNDWATER

		DF	Sum of squares	Adjusted R^2	Mean square	F-value	$F_{critical}$
Arsenic	Model	1	0.006486	0.04036	0.006486	8.59	4.9646
Arsenic	Error	10	0.007554		0.0007554		
Arsenic	Total	11	0.01404				
Lead	Model	1	0.00643107	0.215407	0.006431	14.8387	4.9646
Lead	Error	10	0.00433396		0.000433396		
Lead	Total	11	0.011				

TABLE-8
WATER QUALITY INDEX OF GROUND WATER IN FEROZEPUR DISTRICT

Parameters	V_i	S_n	$1/S_n$	K	W_n	Q_n	$W_n \times Q_n$
TDS (mg/L)	793.82	1000	0.001	0.00498	0.00000498	79.3818182	0.000395321
F^- (mg/L)	0.52	1.5	0.666666667	0.00498	0.00332	34.66666667	0.115093333
pH	7.71	8.5	0.117647059	0.00498	0.000585882	47.172	0.027637242
Alkalinity (mg/L)	314.20	120	0.008333333	0.00498	0.0000415	261.8308081	0.010865979
Total hardness (mg/L)	305.06	600	0.001666667	0.00498	0.0000083	50.84343435	0.000422001
Ca^{2+} (mg/L)	40.64	75	0.013333333	0.00498	0.0000664	54.18181333	0.003597672
Cl^- (mg/L)	101.82	250	0.004	0.00498	0.00001992	40.727248	0.000811287
As^{3+} (mg/L)	0.0108	0.010	100	0.00498	0.498	108	53.784
Pb^{2+} (mg/L)	0.0107	0.010	100	0.00498	0.498	107	53.286
			$\Sigma 1/S_i = 200.8$		$\Sigma W_n = 1.00005$		$\Sigma W_n \times Q_n = 107.229$

the quality of groundwater in Ferozepur district can be categorized under 'Good Quality' water.

Conclusion

The results of the study revealed that groundwater quality in north-west district of Punjab *i.e*. Ferozepur is having a small amount of fluoride and chloride contents in groundwater but majority of the samples are within the acceptable limits when the water samples were collected from depth ranging from 100 ft to 360 ft. The maximum fluoride concentration has been observed at shallow depths upto 100 ft. with decreasing trend afterwards suggesting that fluoride contamination decreases with increase in depth of groundwater beyond 100 ft. The studies showed that the chloride serves as a tracer of water movement. Evapotranspiration causes chloride to build up in the soil because chloride is not taken up by plants and is non-volatile. The concentration of chloride was found to be within limits at shallow depths and as well as depth upto 360 ft. The value of TDS in 32 % samples was found more than 1000 mg/L with maximum TDS of 1740 mg/L in sample at site no. 32 (sub-tehsil Talwandi Bhai). The concentration of arsenic was also found to be within permissible limits of WHO at any depth in 81 % samples while 19 % samples contain arsenic beyond permissible limit, whereas, the concentration of lead decreases with increase in depth. As the depth increases beyond 100 ft, concentration of lead lies within permissible limits in most of the samples. ANOVA has been applied on analysis results to study the effect of pH on fluoride and chloride, depth on fluoride and chloride and depth on arsenic and lead. The results showed that F-value is greater than F-critical in said correlation analysis which is in accordance with the results obtained. Also, to adjudge the overall quality of groundwater in Ferozepur district, the water quality index has been calculated on the basis of large number of physico-chemical characteristics of groundwater. This value of water quality index indicates that the groundwater quality in Ferozepur district of Punjab state can be considered of 'Good Quality' when the groundwater is used at the depth ranging from 100 ft to 360 ft.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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