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Review JoWPPR

A Study of Groundwater Contamination of Patiala District as a 'HOT SPOT' in Punjab

Hardev Singh Virk*

Abstract

Patiala is a part of Malwa belt of Punjab which has reported highest contamination due to heavy metals and other ionic pollutants in groundwater. The Department of Water Supply and Sanitation's (DWSS) Punjab Statement on Water Quality Monitoring and Mitigation paints a dismal picture of Punjab's current water quality situation. It is estimated that around 50% habitations are having poor quality of water due to high contamination of arsenic, iron, aluminium, magnesium, selenium, fluoride, nitrate and other basic parameters. In Patiala district, contamination by uranium, fluoride, nitrate, and sulphate predominates; heavy metals (aluminum, lead, and nickel) are next as major groundwater pollutants. In two villages in the Patiala district, there were 2553 mg/L of NO_3, the highest level ever recorded in Punjab. The highest value of sulphate contamination, 4980 ppm, was recorded in the Patiala district's Pehar Kalan and Pehar Khurd. The analysis presented in this paper is based on Department of Water Supply and Sanitation (DWSS) data collected in 3 phases during 2009 to 2016 and compiled and analysed in April 2016 using Ion Chromatography and Spectrophotometer in DWSS Laboratory in SAS Nagar (Mohali), India.

Keywords: Groundwater, Heavy Metals, Ionic Pollutants, Hot Spot, Health hazards.

INTRODUCTION

Patiala is known as the royal city of Punjab as it was the seat of Phulkian family which ruled over a vast tract of Punjab. During my B.Sc. in Govt. Mohindra College during 1959-61, our Professor of Chemistry, Mr. Mathur, was engaged in research to determine the source of Fluoride in drinking water supply of Patiala city. There was lack of research facility in our college and Mr. Mathur had to carry out his research on the premises of Rajendra Medical College, Patiala. I could never imagine that after 62 years; I will be working on the same problem to tackle it using state of the art facilities provided by Department of Water Supply and Sanitation (DWSS), Govt. of Punjab in Regional Advance Water Testing Lab (RAWTL) at SAS Nagar (Mohali). RAWTL is equipped with sophisticated instruments, namely, Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS) for Heavy Metals like Uranium & Arsenic and Ion Chromatograph (IC) for anions like Nitrate and Fluoride.

Our investigations of Punjab groundwater contaminants have been reported in various research journals during 2017–22. Heavy metals, namely, uranium (U), arsenic (As), cadmium (Cd), zinc (Zn), copper (Cu), nickel (Ni), lead (Pb), mercury (Hg), iron (Fe), selenium (Se), and chromium (Cr) have been detected in high concentrations in groundwaters of Punjab. High contents of basic parameters, like TDS (Total Dissolved Salts), fluoride, chloride, nitrate,

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sulphate, calcium, and magnesium have also been reported [1–10]. The source of groundwater contamination in Punjab is mostly geogenic but augmented by anthropogenic sources like intense agricultural practices and industrial pollutants released untreated in water channels.

These days, heavy metal contaminants in air and groundwater are one of the most important environmental concerns due to their high toxicities and adverse impacts on human health. According to the World Health Organization (WHO) report [11], 80% of all the diseases and deaths in the developing countries are caused by drinking of contaminated water. The risk of serious illnesses like cancer from drinking water contaminated with heavy metals is present. [12].

A crisis situation exists in Punjab due to heavy metals contamination in the sub-surface water table. Recent reports in the local media regarding the high toxicity of heavy metals in the groundwater of Punjab may create a panic in the minds of public. According to the report, hazardous metals have contaminated Punjab's subsurface groundwater to such an extent that adult cases of cancer and heart disease are on the rise. In the Tribune report published on February 7, 2018, it was reported that 88 percent of habitations affected by heavy metals in groundwater of India belong to Punjab State [13–15].

The basis of this investigation is DWSS data collected in three phases during 2009 to 2016 and compiled in April 2016 [16].

Guidelines from the World Health Organization and Indian Standards for Water

The World Health Organization's (WHO) Drinking Water Quality (GDWQ) Guidelines are created with the protection of the general public's health in mind. International Standards for Drinking-Water were first published in 1958 after WHO organised a series of expert meetings in Geneva during 1956. These Standards were revised in 1963, 1971 and 1984. This process continued and more revisions were carried out in 1993, 1995, 2004 and 2011. We have adopted 1993 edition of GDWQ for this study [17].

To maintain the security of water for consumption supplies, national standards are developed using WHO recommendations as a foundation. The purpose of these standards is to keep the level of hazardous contaminants in groundwater to a bare minimum level so that they are not health hazards to public. The suggested guideline values can be used in the creation of risk management plans based on local or national standards, but they are not required limitations. These have been created while taking into account the regional or national social, economic, environmental, and cultural circumstances.

Indian institutions are using the Bureau of Indian Standards (BIS) for most of the heavy metals under the heading "General Parameters Concerning Substances Undesirable in Excessive Amounts (Table 1)" [18]. These parameters have been adopted from WHO Guidelines and Standards. It includes all metals listed in DWSS analysis except arsenic. Annual Water Quality Report of DWSS, Govt. of Punjab has listed all contaminants found in groundwater under two categories: Mandatory Parameters and Emerging Parameters. Further, the amount of contamination allowed is classified in two regimes: Acceptable limit (AL) and Permissible limit (PL). These limits are different for different countries. BIS limit has been adopted by Atomic Energy Regulatory Board (AERB) of Department of Atomic Energy (DAE), Govt. of India and is being implemented in all the states of India as a standard for Water Quality. The values of AL and PL are listed in Table 1, adopted from Annual Water Quality Report of DWSS [19].

Table 1. Water Quality Parameters and their contamination limits for India

Parameters	Acceptable limit BIS/ AERB mg/l	Permissible limit as per BIS/AERB
Mandatory Parameters		
Arsenic	0.01 ppm	No Relaxation
Fluoride	1.0 ppm	1.5 ppm
Nitrate	45 ppm	No Relaxation

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TDS	500 ppm	2000 ppm
Iron	1.00 ppm	No Relaxation
Emerging parameters		
Uranium	30 ppb	60 ppb
Selenium	0.01 ppm	No Relaxation
Mercury	0.001 ppm	No Relaxation
Aluminum	0.3 ppm	0.2 ppm
Cadmium	0.003 ppm	No Relaxation
Nickel	0.02 ppm	No Relaxation
Chromium	0.05 ppm	No Relaxation
Lead	0.01 ppm	No Relaxation

THE STUDY AREA AND GROUNDWATER QUALITY

Location

The location of Patiala district of Punjab state (Figure 1) is defined by 29° 49' to 30° 40' north latitudes and 75° 58' to 76° 48' east longitudes. Total geographical area of the district is 3218 sq. km. It is divided into five administrative units known as *tehsils*, namely Patiala, Nabha, Ghanaur, Rajpura and Samana. There are eight-community blocks for development purpose of the district.

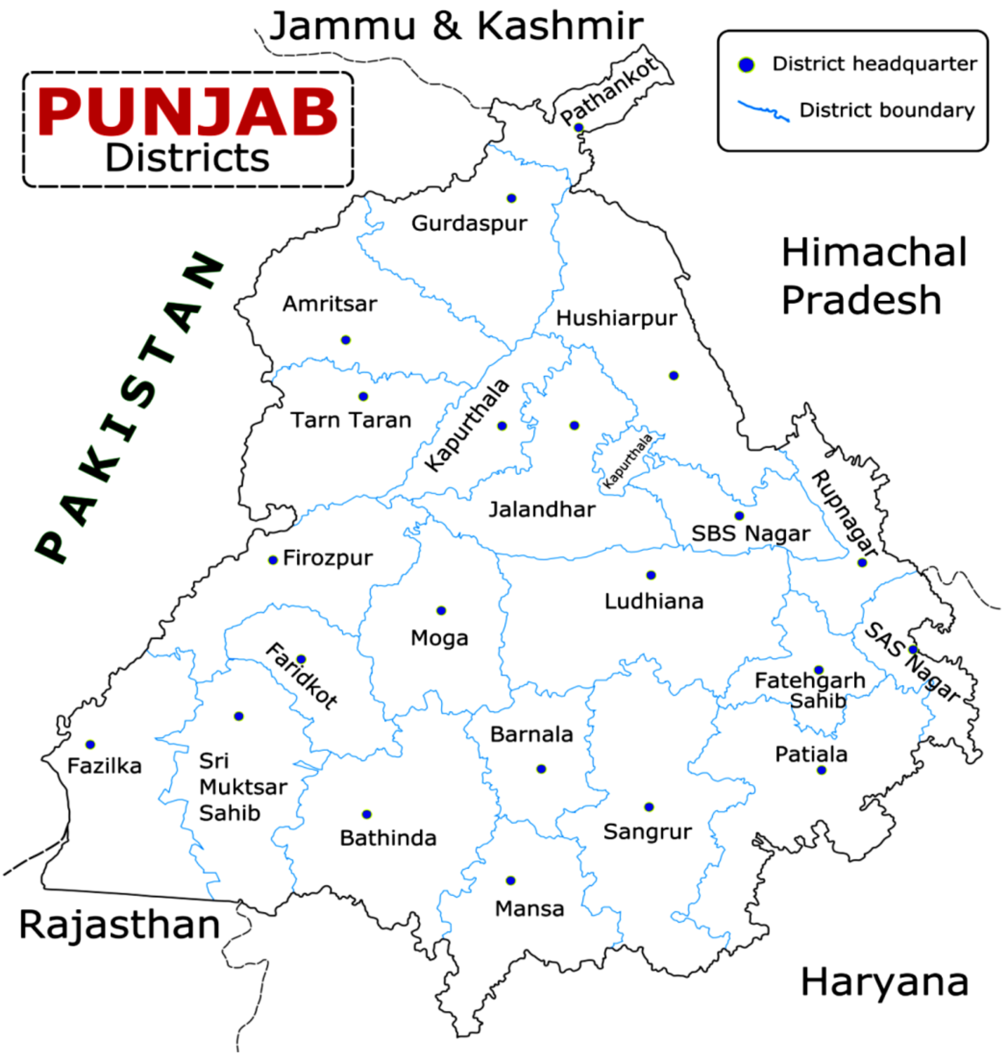

Figure 1. District Map of Punjab Showing District of Patiala.

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Geomorphology and Soil Types [20]

The area under Patiala district belongs to Indo-Gangetic alluvial plain and consists of three types of regions: the Upland plain, the Cho-infested Foothill Plain and the floodplain of the Ghaggar river. Its elevation varies in the range from 240 to 278 m (amsl or above mean sea level). Major parts of the district have arid or tropical climate and the soils are either light coloured or of brown variety. Generally, these soils are deficient in nitrogen, phosphorus, and potassium. In Patran and Samana blocks, soils are arid brown. These are calcareous in nature including *kankar* layers in most of them.

Ground Water Quality

Patiala district is broadly classified under Indo-Gangetic alluvial plain of Quaternary age and it is a part of Ghaggar basin. The prospective aquifers are formed by alluvium formations, which contain fine to coarse sand and contain the ground water. Groundwater occurs under unconfined water table conditions in the shallow aquifer (up to 50m), whereas its occurrence in deeper aquifer is semi-confined or in confined condition. Traditional constructed irrigation wells that tapped the shallow reservoir have been decommissioned. However, this aquifer is being tapped by the hand pumps and shallow tube wells, which are widely used for domestic purposes. In order to determine the chemical quality of the ground water in the region, the Central Ground Water Board (CGWB) has conducted investigations. The district's groundwater is alkaline in composition. The electrical conductivity (EC) in the area ranges from 687 to 4100 micromhos/cm. Nitrate values range between 0.40–200 mg/l and fluoride concentration ranges from 0.20 to 2.8 mg/l [20] and observed beyond the safe limits suggested by the WHO, thus the ground water is harmful for human consumption at these places.

METHODOLOGY

Water samples were collected in 500 ml amber coloured superior quality plastic bottles from the area of study by the field staff of DWSS. The bottles used were subjected to double washing; first with soap solution and then with distilled water. Deionized water was used to rinse and dry these bottles. Before being collected in plastic bottles, the source's groundwater was permitted to flow freely. On the spot filtration of samples was done using the 0.2-micron filters. Samples were labelled after adding 2ml of conc. HNO_3 and transported to Regional Testing Water Laboratory in SAS Nagar (Mohali) for storage on the same day. Nitric acid (0.5M HNO_3) helps in the recovery of total recoverable uranium. It helps in the preservation and digestion of uranium by breaking down the complexes so that the influence of poly-atoms is reduced to the minimum.

The standard procedure has been adopted for the analysis of uranium in collected water samples using Model 7700 Agilent Series ICP-MS in the DWSS laboratory set up in Mohali, Punjab. A radiofrequency inductively coupled plasma (ICP) is used to measure the generated uranium ions. A liquid-based analyte species is nebulized, while the ensuing aerosol is then carried by the gas argon into a plasma torch. A channel electron multiplier is used to quantitatively analyze the ions created by elevated temperatures in the plasma after they have been sorted based on their mass-to-charge ratios. By applying adjustments for background ions supplied by a plasma gas, substances, and components of the sample matrix, interferences must be examined and avoided. Standard analytical techniques were employed for estimation of Uranium and heavy metals in groundwater [4]. All analytical work was carried out using the Merck-grade chemicals while preparing solvents and standards. Ion Chromatography and Photo-spectrometer [9] were used for assessment of ionic contaminants concentration in groundwater. Tables 2 and 3

Table 2. Fluoride Content (>3ppm) in Groundwater of Patiala District

<table>
<tr><th>Villages Covered</th><th>Source of Scheme</th><th>Depth</th><th>Flouride Content (ppm)</th></tr>
<tr><td>Sahal</td><td>Tube well</td><td>1200 ft</td><td>8.517</td></tr>
<tr><td colspan="2">Kattumajra</td><td colspan="2">3.146</td></tr>
<tr><td colspan="2">Bhoglan</td><td colspan="2">3.610</td></tr>
</table>

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Dhakansu Kalan		3.780	
Akbarpur	Tube well	1200 ft	3.470
Bathonia Kalan	Tube well	1200 ft	8.300
Gandian	Tube well	1200 ft	8.300
Chalheri	Tube well	820 ft	3.540
Chatar Nagar	Tube well	1050 ft	8.240
Gandian	Tube well	1200 ft	8.300
Ghagar Sarai	Tube well	932 ft	8.500
Ghungran	Tube well	600 ft	5.800
Hassanpur Jattan	Tube well	950 ft	4.940
Kaboolpur	Tube well	950 ft	4.940
Khairpur Sheikhan	Tube well	1200 ft	5.800
Khanpur Gandian	Tube well	750 ft	3.400
Kutha Kheri	Tube well	300 ft	3.500
Lochwan	Tube well	900 ft	5.850
Lohakheri	Tube well	300 ft	3.500
Magar	Tube well	900 ft	5.700
Nardu	Tube well	750 ft	3.040
Pahairpur	Hand pump	210 ft	3.560
Pipal Mangoli	Tube well	900 ft	5.650
Sahal	Tube well	NA	7.806
Salempur Jattan	Tube well	900 ft	9.220
Salempur Sekhan	Tube well	980 ft	8.700
Sanoulian	Tube well	970 ft	3.100
Shahpur Raian	Tube well	600 ft	5.800
Sheikhupur	Tube well	900 ft	5.700
Sheikhupur Rajputan	Tube well	210 ft	6.465
Bhappal	Tube well	1100 ft	3.067
Bhoglan	Tube well	900 ft	3.910
Dhakansu Khurd	Tube well	NA	3.701
Dhakansu Khurd	Tube well	700 ft	3.520
Dhakansu Majra	Tube well	970 ft	3.749
Faridpur	Tube well	1080 ft	3.020
Gado Majra	Tube well	780 ft	4.080
Islampur	Tube well	855 ft	3.326
Jandoli	Tube well	870 ft	3.620
Khanpur Baring	Tube well	540 ft	3.956
Kharajpur	Tube well	870 ft	4.079
Kheri Gandian	Tube well	510 ft	4.170
Mangpur	Tube well	515 ft	3.020
Mehma	Tube well	840 ft	5.350
Nalas Kalan	Tube well	820 ft	3.220
Nalas Khurd	Tube well	820 ft	3.220
Rangian	Tube well	820 ft	3.220
Sehri	Tube well	855 ft	4.050
Shamdoo	Tube well	885 ft	3.280

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Sural Khurd	Tube well	950 ft	3.305
Sural Khurd	Tube well	900 ft	3.240
Alampur	Tube well	210 ft	3.140

Table 3. Sulphate Content in Groundwater of Patiala District

S.N.	Village	Source of Water	Sulphate Content (ppm)
1	Kulwanoo	Tubewell	102.23
2	Alampur	Tubewell	64.41
3	Lachkani	Scheme T/W	92.26
4	Kathmathi	Scheme T/W	117.92
5	Shankarpur	Raw Water RO	168.90
6	Rasauli	Tubewell	64.88
7	Harpalpur	Tubewell	74.21
8	Bhoglan	Tubewell	233.51
9	Dhabali	Tubewell	92.47
10	Kharajpur	Tubewell	178.66
11	Kotla	Tubewell	91.02
12	Jhansla	Tubewell	64.77
13	Fatehpur Garhi	Tubewell	64.77
14	Nalas Kalan	Tubewell	92.26
15	Pehar Kalan	Scheme T/W	4980.0
16	Pehar Khurd	Scheme T/W	4980.0
17	Faridpur	Tubewell	245.87
18	Faridpur	Tubewell	245.20
19	Mehergarh Batta	Raw Water RO	206.20
20	Mehergarh Batti	Raw Water RO	206.20
21	Dhakansu Majra	Tubewell	109.06
22	Kaloli	Tubewell	23.93
23	Raipur	Raw Water RO	93.35
24	Islampur	Tubewell	752.20
25	Islampur	Tubewell	
26	Jansua	Scheme T/W	105.43
27	Purbia Basti	Scheme T/W	294.15
28	Kalyan	Scheme T/W	294.15
29	Dera Bahmna Inderpura	Scheme T/W	294.15

DISCUSSION OF RESULTS

Uranium Contamination

Drinking water containing uranium poses both radiological (carcinogenic) and chemical (noncarcinogenic) risks. The assessment of radiological and chemical risks due to ingestion of uranium are calculated by using the standard method developed by the USEPA [21]. Uranium content in groundwater of Patiala district and the corresponding Health Risk Factors are listed in Table 4.

All of the findings of our investigation are published elsewhere. The radiological danger and extra cancer risk owing to consumption of natural uranium in the drinking water of 50 habitations of the Patiala area have been determined. [4]. Our investigation revealed that Patiala district of Punjab has 250% higher cancer risk than the national average with the likelihood of 200 cancers occurring per million of population. Chemical toxicity of uranium is expressed in terms of hazard quotient which needs to be less than 1. However, it is > 1 in 9 villages of Patiala district (Table 4).

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Lead and Nickel Contamination

Lead is one of the most toxic heavy metals; hence its mitigation is a major problem in Patiala district. Lead contamination of groundwater of Patiala district varies from .024 to 0.19 mg/L (ppm) and the average value is .031 ppm (Table 5). The highest value of Lead (0.190 mg/l) in groundwater is recorded in Punia Khana village. The AL and PL (permissible) limits allowed for groundwater in India are 0.01 ppm. The US EPA (Environmental Protection Agency) has set a zero lead contamination level objective for drinking water because lead is a hazardous metal that can be damaging to human health even at low exposure levels. Its hazard quotients are not calculated as it is harmful at all levels.

Patiala district has high contamination of Nickel and Aluminium in groundwater as reported earlier [6]. Nickel contamination in groundwater varies from 0.020 to 0.190 mg/L, with an average level of 0.030 mg/L.

Table 4. Uranium Content in Groundwater of Patiala District and Corresponding Risk Factors.

S.N.	Location	Source	Depth (m)	U Conc. (ppb)	U Conc. (Bq l-1)	Excess cancer risk 10-4	LADD (μg kg−1 day−1)	Hazard Quotient
1	Ahru Kalan	NULL	NULL	267.00	6.75	7.56	15.45	3.41
2	Ahru Khurd	NULL	NULL	267.00	6.75	7.56	15.45	3.41
3	Daun Kalan	Tubewell	285.00	127.60	3.23	3.61	7.38	1.63
4	Dera Xen Retd.	Tubewell	118.26	87.76	2.22	2.49	5.08	1.12
5	Chunagra	Tubewell	118.26	87.76	2.22	2.49	5.08	1.12
6	Todarwal	NULL	NULL	83.34	2.11	2.36	4.82	1.06
7	Purbia Basti	Tubewell	NULL	82.93	2.10	2.35	4.80	1.06
8	Kalyan	Tubewell	NULL	82.93	2.10	2.35	4.80	1.06
9	DeraBahmnaInderpura	Tubewell	NULL	82.93	2.10	2.35	4.80	1.06
10	Dera Xen Retd.	Tubewell	150.00	76.10	1.92	2.16	4.40	0.97
11	Chunagra	Tubewell	150.00	76.10	1.92	2.16	4.40	0.97
12	Birdhno	NULL	NULL	75.80	1.92	2.15	4.39	0.97
13	Dera Bahmna Inderpura	NULL	NULL	73.76	1.86	2.09	4.27	0.94
14	Kalyan	NULL	NULL	73.76	1.86	2.09	4.27	0.94
15	Purbia Basti	NULL	NULL	73.76	1.86	2.09	4.27	0.94
16	AsseMajra	NULL	NULL	73.76	1.86	2.09	4.27	0.94
17	Inderpura	NULL	NULL	73.76	1.86	2.09	4.27	0.94
18	Rathian	NULL	NULL	72.93	1.84	2.07	4.22	0.93
19	Khanora	NULL	NULL	68.81	1.74	1.95	3.98	0.88
20	Dhingi	NULL	NULL	67.04	1.69	1.90	3.88	0.86
21	Seona	NULL	NULL	66.54	1.68	1.88	3.85	0.85
22	Wazidpur	NULL	NULL	62.50	1.58	1.77	3.62	0.80
23	Dera Saini Majra	NULL	NULL	62.50	1.58	1.77	3.62	0.80
24	Paidan	Tubewell	165.00	61.10	1.54	1.73	3.54	0.78
25	Ransihpura	NULL	NULL	61.00	1.54	1.73	3.53	0.78
26	Raipur	Raw Water of RO	42.67	60.63	1.53	1.72	3.51	0.77
27	Rasulpur	Hand Pump	70.00	59.30	1.50	1.68	3.43	0.76
28	Haripur Jhugian	Hand Pump	70.00	59.30	1.50	1.68	3.43	0.76
29	Katlahar	Hand Pump	70.00	59.30	1.50	1.68	3.43	0.76
30	Budanpur	NULL	NULL	51.33	1.30	1.45	2.97	0.66

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31	Sarkari Farm	NULL	NULL	51.33	1.30	1.45	2.97	0.66
32	Khaktan Khurd	NULL	NULL	51.33	1.30	1.45	2.97	0.66
33	Bugga Khurd	NULL	NULL	50.75	1.28	1.44	2.94	0.65
34	Hariyou Khurd	Tubewell	NULL	49.50	1.25	1.40	2.86	0.63
35	Ohjhan	Hand Pump	80.00	49.30	1.25	1.40	2.85	0.63
36	Rasauli	Tubewell	NULL	46.86	1.18	1.33	2.71	0.60
37	DeraShingara Singh	Hand Pump	90.00	42.20	1.07	1.20	2.44	0.54
38	Birdhno	Tubewell	90.00	42.00	1.06	1.19	2.43	0.54
39	Uppli	NULL	NULL	41.76	1.06	1.18	2.42	0.53
40	Paror	NULL	NULL	41.76	1.06	1.18	2.42	0.53
41	Kathmathi	Tubewell	NULL	39.94	1.01	1.13	2.31	0.51
42	Gandian	Tubewell	300.00	39.30	0.99	1.11	2.27	0.50
43	Bathonia Kalan	Tubewell	300.00	39.30	0.99	1.11	2.27	0.50
44	Bathonia Khurd	Tubewell	300.00	39.30	0.99	1.11	2.27	0.50
	Paror	Tubewell	165.00	38.90	0.98	1.10	2.25	0.50
46	Uppli	Tubewell	165.00	38.90	0.98	1.10	2.25	0.50
47	Ghungran	Tubewell	200.00	38.80	0.98	1.10	2.24	0.50
48	Shahpur Raian	Tubewell	200.00	38.80	0.98	1.10	2.24	0.50
49	Balamgarh	NULL	NULL	38.77	0.98	1.10	2.24	0.50
50	Uppli	NULL	NULL	38.00	0.96	1.08	2.20	0.49
Average			68,70		1.74	1.95 3.97		0.88

Table 5. Lead Contamination in Groundwater of Patiala District (Acceptable limit 0.01 mg/l).

S.N.	Villages surveyed	Source of ground water	Depth (m)	Lead (mg/l)
1	Punia Khana	Tubewell	235	0.190
2	Dera Musalmana	Handpump	90	0.049
3	Kalwa	Handpump	90	0.049
4	Alampur	Handpump	70	0.048
5	Kalburshan	Tubewell	250	0.039
6	Sehajpur Khurd	Tubewell	200	0.033
7	Sehajpur Kalan	Tubewell	200	0.033
8	Dulatpur Fakiran	Tubewell	150	0.032
9	Mirjapur	Tubewell	150	0.032
10	Kakrala	Tubewell	500	0.031
11	Hassanpur Kamboan	Tubewell	180	0.029
12	Paror	Tubewell	165	0.028
13	Uppli	Tubewell	165	0.028
14	Nandpur Kesho	Tubewell	154	0.028
15	Sadh Majra	Tubewell	138	0.028
16	Gurdialpura	Tubewell	138	0.028
17	Bahmna	Tubewell	200	0.027
18	Behmna/Bajigar Basti	Tubewell	200	0.027
19	Harijan Basti	Tubewell	200	0.027
20	Kheri Bheema	Tubewell	116	0.027
21	Niamatpur	Tubewell	242	0.026
22	Shadipur	Tubewell	242	0.026

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23	Alampur	Tubewell	200	0.026
24	Balamgarh	Tubewell	200	0.026
25	Fatan Majri	Tubewell	277	0.026
26	Basti Harchandpura	Tubewell	250	0.026
27	Nanhera	Tubewell	250	0.026
28	Talwandi Malik	Tubewell	200	0.026
29	Sullar	Tubewell	198	0.026
30	Thakurgarh	Tubewell	250	0.025
31	Hussainpur	Tubewell	250	0.025
32	Dera Alipur	Tubewell	250	0.025
33	Massingan	Tubewell	273	0.025
34	BirKauli	Tubewell	250	0.025
35	Rongla	Tubewell	107	0.025
36	Lang	Tubewell	107	0.025
37	Dera Banta Singh	Tubewell	74	0.025
38	Lalgarh	Tubewell	74	0.025
39	Dera Balbir Singh	Tubewell	74	0.025
40	Bahadurgarh	Tubewell	74	0.025
41	Danipur	Tubewell	74	0.025
42	Dodra	Tubewell	150	0.025
43	Gajewas	Tubewell	250	0.025
44	Basti Channa	Tubewell	126	0.025
45	Sapperheri	Tubewell	126	0.025
46	Assmanpur	Tubewell	126	0.025
47	Patti Sodhian	Tubewell	200	0.025
48	Shahpur Afgana	Handpump	70	0.024
49	Rajgarh	Tubewell	240	0.024
50	Rattanheri	Tubewell	240	0.024
Average			0.031	

Fluoride Contamination [3]

There is a global problem with fluoride pollution of groundwater. Its abundance varies throughout India and Punjab. The Fluoride contamination shows a variation from 3.140 to 8.517 ppm in groundwater of Patiala district. The distribution of fluoride in the groundwater of the Patiala district and associated non-carcinogenic health risks to the local population (men, women, and children individually) during the fluoride endemic zone of the Patiala district have been documented in our earlier study [10]. According to the study, fluoride levels are frequently beyond the allowed level of 1.5 ppm in the communities that were sampled. Based on our study, which shows that the hazard quotient of fluoride (HQFluoride) is bigger than the unitary value, an incidence of painful fluorosis and chronic health hazards is predicted. Children are most susceptible to fluoride poisoning, followed by men and women, based on data. The results obtained [10] are in line with current trends that show an increase in dental care, skeleton fluorosis, and liver functional impairment issues among children and adults in the examined region. [22].

Nitrate Contamination [9]

The highest level of NO_3 content of 2553 mg/L has been recorded in two villages of Patiala district. This figure is significantly higher and causes worry when compared to the limitations established by the World Health Organization (50 mg/L) and the Bureau of Indian Standards (45 mg/L). Geogenic and human-made sources are both responsible for the NO3 in groundwater. Serious health hazards, especially in children (< 5 years), are posed due to consumption of high NO_3 containing water. The

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non-carcinogenic health risks of high NO_3 intake have been estimated using US-EPA model for both adults and children [23, 24]. $HQ_{Nitrate}$ values have been found significantly higher than 1 in most of the habitations studied both for adults and children. The HQ values for adults and children are 45.59 and 106.38, respectively, for Patiala district which must set the alarm bell ringing for the safety of children in this district.

Sulphate Contamination

Sulphate concentration in groundwater has not been considered under mandatory or emerging parameters by DWSS Report [19]. However, if its concentration is higher than 400 ppm, its health hazard cannot be ignored. BIS has set Al and PL limits of 200 ppm and 400 ppm, respectively, for Sulphate in water. Out of 29 habitations studied in Patiala district, 12 have Sulphate values higher than 200 ppm and only 4 with values >400 ppm. In case of 2 villages, Pehar Kalan and Peher Khurd, Sulphate concentration is 4980.0 ppm, which is 12 times the PL value; hence a “Hot Spot” to be considered for immediate action. What causes this anomaly in sulphate concentration in groundwater of these villages? It is a matter for discussion by expert epidemiologists.

HEALTH HAZARDS OF GROUNDWATER CONTAMINANTS IN PATIALA DISTRICT

Malwa belt of Punjab is a cancer belt of India due to high occurrence of cancer in some districts. Because of its chemical and radioactive properties, uranium is a radioactive heavy metal that poses a health risk. The most vulnerable organ to uranium's chemical toxicity is the kidneys, and at lower exposure levels, it generally outweighs its radiation toxicity [25]. From the LADD and hazard quotient values previously reported in our work, the chemical toxicity has been estimated [4].

Lead is tenacious and over time, it may bioaccumulate in the body. All ages are adversely affected by lead in water, but young children, newborns, and fetuses are most susceptible. In comparison to adults, children are more susceptible to the physical and behavioral effects of lead exposure. Low exposure levels have been associated with learning impairments, shorter stature, hearing impairment, and problems with the development and function of blood cells in children, in addition to harming the central and peripheral nervous systems. [26].

Nickel compounds are, in general, inactive in bacterial mutation assays but not so in mammalian cell systems [27]. Nickel-induced reactions including cell toxicity were noted in all investigations utilizing mammalian cells to study gene mutation. There is a great deal of interest in the subject of the carcinogenicity of nickel compounds in lab animals [28].

The fundamental justification for dental and skeletal fluoridation is consumption of fluoride at levels above the recommended limit. According to estimates, fluoride-contaminated water is to blame for the major health issues of 62 million Indians, especially 6 million children [29]. There are 6 million persons impacted by skeletal fluoridation in 17 of the 32 states in India that have been designated as endemic locations. Patiala district has been identified as a ‘Hot Spot’ of fluoride in Punjab [10]. Pain in the bones and joints, muscle weakness, occasional pain, joint stiffness, and chronic weariness are signs of skeletal fluoridise in its early stages. Pain in the bones and joints, muscle weakness, occasional pain, joint stiffness, and chronic weariness are signs of skeletal fluoridise in its early stages. deformities in RBCs, excessive thirst, headache, skin rashes, nervousness, neurological manifestations, depression, gastrointestinal problems, urinary tract malfunctioning, nausea, abdominal pain, tingling sensation in fingers and toes, reduced immunity, repeated abortions or still births, male sterility, etc. [30].

The ingestion of water with high NO_3 content can cause various health issues in affected population, for example, methemoglobinemia, neural effects, gastric and respiratory problems, etc. Infants (< 6 months) compared to children are always at greater risk for NO_3 toxicity mainly due to their smaller body weight and lower metabolic activities [31]. The link between the large intake of nitrate with thyroid dysfunction and gastrointestinal cancer has been established by some studies [32]. There is an urgent need to undertake an epidemiological study of Patiala district.

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Like other ionic contaminants, excess of sulphates in water can cause health problems. Drinking water with excessive sulphate (>500 ppm) causes laxative effect, diarrhea and dehydration, but at moderate levels it is harmless. Infants are often more sensitive to sulphate contamination than adults. Ingestion of 8 g of sodium sulphate and 7 g of magnesium sulphate caused catharsis in adult males. People consuming drinking-water containing sulphate in concentrations exceeding 600 mg/litre are reported to suffer from cathartic effects [33]. Excessive sulphate is a cause of sudden deaths and an outbreak of diarrhea in horses [34].

CONCLUSIONS

1. Several villages of Patiala district have Uranium concentration in groundwater higher than the safe limits of 30 ppb and 60 ppb recommended by the WHO and AERB, respectively.
2. The source of uranium enhancement in Patiala district of Punjab may be attributed to mobilization of uranium from the Siwaliks [35] by Ghaggar river and its tributaries, for example, Patiala Ki Rao, a seasonal stream flowing within the limits of city.
3. The cause of cancer is not yet fixed precisely due to Uranium in water. However, kidneys are most sensitive and affected by the chemical toxicity of uranium.
4. Patiala district is a ‘Hot Spot’ for Fluoride, Nitrate and Sulphate contaminants in water.
5. Out of all the districts of Punjab, Patiala demands the attention of DWSS and other concerned agencies of the Punjab government to implement proper cost-effective mitigation measures to reduce the current and future chronic health risks associated with high levels of Uranium and other heavy metals, and ionic contaminants like Fluoride, Nitrate, and Sulphate in the groundwater.

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