

Ground Water Contamination in Shallow Aquifer of Punjab State With Special Reference to Uranium

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Abstract

In Punjab State ground water is in general suitable for drinking uses except at few places in the southern and south western parts where it is not suitable due to high EC or high fluoride or nitrate or combination of all. Almost all ground waters are suitable for irrigation for growing crops like wheat, mustard, rice, barley and maize etc. However, at few places where EC of ground water goes beyond 5000 $\mu\text{S/cm}$, and SAR is more than 10, water is not suitable for customary irrigation. Uranium is a naturally occurring radioactive metal that occurs in low concentrations in nature. It is present in certain types of soils and rocks, especially granites. High concentration of uranium in the body has been linked to chronic kidney disease. In the state of Punjab, Uranium concentration in 302 drinking water samples has been found to vary between 0–156 $\mu\text{g/l}$ with an average of 21.94 $\mu\text{g/l}$. Data analysis revealed that 74 of 302 samples had uranium concentration higher than recommended safe limit of 30 $\mu\text{g/l}$, while 18 of 302 samples exceeded the threshold limit of 60 $\mu\text{g/l}$ recommended by AERB, DAE, India.

Keywords: Ground water Quality, Contamination, Uranium, Anthropogenic, Geogenic.

INTRODUCTION

Punjab is the richest state in India, it throbs with the vibrant culture of equally vibrant people, with its inimitable style of transforming every potential opportunity into a success story through enterprise and endeavour, has always moved on the path of prosperity despite all odds. The State is recognized for its fast-developing economy with an agricultural base throughout the world. Since Agriculture accounts for approximately 80% of the nation's consumption hence the state has exploited the ground/surface water to a large extent. The intense agricultural activity has prompted usage of large quantity of fertilizers and pesticides for better crop yield. This has resulted in both ground water and surface water pollution over space and time. This has expressed as serious concern due to deterioration of water quality in different parts of the State. Water quality problem has posed serious health hazards and people are affected by various water borne diseases. To assess the status of water quality in the State of Punjab, it was felt necessary to make an effort to study the various emerging

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issues in the state with respect to ground water contamination with special reference to uranium in shallow aquifer from different sources like the dug well, hand pumps, tube wells. The occurrence and distribution of uranium in groundwater, is very poorly understood and warrants investigations in detail. Reports of widespread uranium contamination in groundwater across India demand an urgent response [1, 2]. Hence the purpose of this study was also to investigate the uranium concentration levels of ground water being used for drinking purposes and to determine its health effects, if any, to the local population of this region. Preliminary studies on the health effects of drinking uranium-tainted water among animals and

humans have revealed that it causes Nephritis (kidney damage). Notably, this is said to be caused by the chemical effect of uranium, rather than a radiological, even though uranium is radioactive. There is also a chance of getting cancer from radioactive uranium. Nonetheless, we need more comprehensive systematic studies to establish the chronic health effects of uranium exposure [3]. Uranium contaminated groundwater, if consumed has the potential of causing chronic lung diseases and nephrotoxic damage [4-8]. Uranium is a radioactive element occurring naturally in groundwater, soil and sediments.

Hydrogeology of the State

Geologically, the area in Punjab State is covered by Siwaliks and Alluvium deposits of Middle Miocene to Recent age. The Siwaliks (Middle Miocene to Pleistocene) form hilly tract running in northern and north-eastern part of the State and the alluvial deposits (Pleistocene to Recent) constitute the plains of Punjab [9]. The Siwaliks are divided into three parts i.e. lower, middle and upper Siwaliks on the basis of lithology and vertebrate fossils. The Siwalik formations have been folded and faulted due to tectonic activities.

Hydrogeologically the State can be divided into four units i.e. (i) Piedmont deposits occurring along a narrow belt along the Siwaliks, commonly known as “Kandi”; (ii) Alluvial plains; (iii) Aeolian deposits occurring in the south-western part of the State and (iv) an intermontane valley at Anandpur Sahib of Ropar district. The alluvium is divided into newer alluvium occurring along active flood plains of rivers and older alluvium confined to abandoned flood plains. These aquifers are laterally and vertically extensive and persistent in nature. However, in south western parts, the thickness of fresh water aquifer is much less as compared to the other parts because area is underlain by brackish/saline water. At places, the thickness of fresh water bearing aquifer is even less than 10 m. The depth to water level lies between 0.65 m bgl at Kotlain Rupnagar district and 50.70m bgl at Pedolpz in SAS nagar district.

Very shallow water levels of 0-2 m (causing water logging) occur in more than 2% of wells and cover nearly 1% area of the state in isolated patches in Muktsar, Fazilka, Faridkot, Gurdas and Pathankot districts. Shallow water levels of 2-5 m have been observed in 10% of the wells and about 10% of the total area that lies in south western parts of Muktsar, Fazilka, Faridkot, and in northern parts of Gurdaspur & Pathankot districts and few isolated patches in north eastern parts. These are mainly canal command areas. The water levels between 5-10 m are observed in the northern parts (Pathankot, Gurdaspur, Amritsar, and Hoshiarpur districts), south and south western parts (Fazilka, Ferozpur, Faridkot, Muktsar, Bathinda and Mansa districts), eastern parts of Ropar district. About 18% of wells and 17% of the area fall in this range [10].

Moderately Deep-water levels (10-20 m) are predominant and observed in 28% wells covering about 32% area of the State in central and western parts. Deep water levels (20-40 m) are also observed covering parts of Jalandhar, Kapurthala, SBS Nagar (Nawashehar), Bathinda, Moga, Ludhiana, Fatehgarh, Patiala, Sangrur, Barnala and SAS Nagar districts and observed in 40% wells covering about 39% area of the State in central and south-eastern part. Very deepwater levels (>40 m) are observed as patches in Patiala, SAS Nagar and SBS Nagar (Nawashehar) districts covering 2% area of the State. [11]

METHODOLOGY

The total 302 ground water samples collected during monitoring of national hydrograph network station established by CGWB. All the samples collected in 100 ml HDPE Bottles and all samples filtered with special filter and also acidified the sample with 0.50 ml suprapure nitric acid (67%). The analysis of Uranium has been carried out by Inductive couple plasma techniques with ICP-MS, (Model No. iCAPRQ01459). The location map of samples collected during the study has shown in Figure 1.

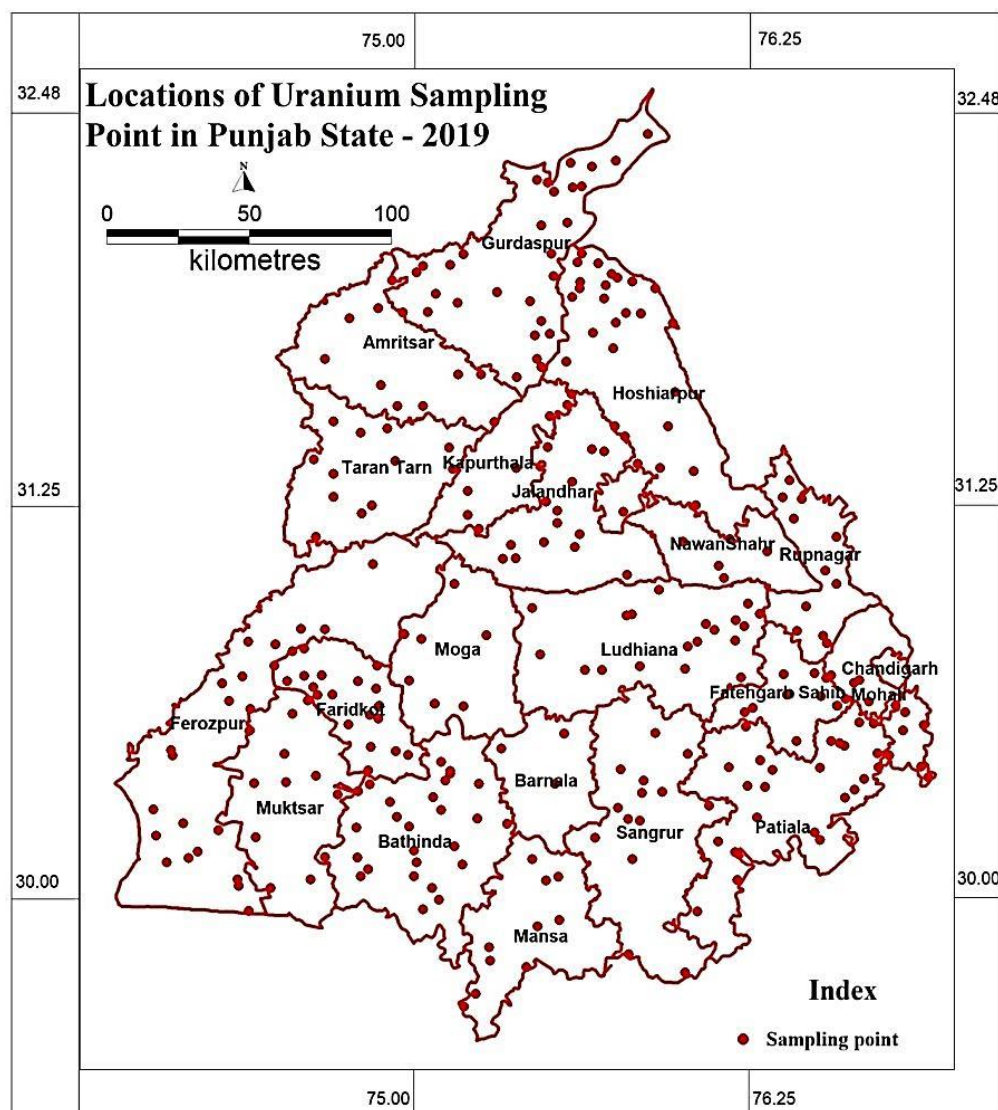


Figure 1. Location map of samples collected during study.

Source of Water Pollution

The quality of groundwater may be impacted by naturally occurring processes as well as by actions directly attributable to human activities. Four general ways in which the chemical composition of groundwater may be changed include natural processes, nonpoint agricultural and urban runoff, waste disposal practices, and spills, leaks and other unintentional/intentional releases. The magnitude of environmental impact associated with each of these processes may be far different.

The nature of contamination impacts may be assessed in terms of the characteristics of the chemicals that are released and in terms of their distribution and difficulty of restoration or containment. In addition, impacts are directly related to potential human and ecological exposures and risk. Groundwater moves slowly, so it takes along time for contamination to appear at potential receptor locations. It follows that it will take a correspondingly long time to remediate the initial release of contaminants. The primary chemicals of concern are classified as organic chemicals, metals and radionuclide, other inorganic chemicals such as chloride, sulfates, nitrates and sodium from irrigation return flows and other sources are also significant.

Broadly, two types of pollution exist and these are as follows:

Table 1. Contaminants, their Possible Sources

S.N.	Contaminant	Possible source
1.	Salinity	Long residence time and geological formations
2.	Fluoride	Lime Stone, sandstone, granite as Fluorspar (CaF_2), cryolite (Na_3AlF_6), fluorite (CaF_2), fluorapatite $\{\text{Ca}_5\text{F}(\text{PO}_4)_3\}$ Insecticides, Disinfectants, Preservatives Phosphatic fertilizers
3.	Arsenic	1. Geothermal/Volcanic activities 2. Weathering of rocks & minerals-Arsenopyrite (FeAsS) Lollingite (FeAs_2) Orpiment Realger Native Arsenic 3. Herbicides 4. Pesticides
4.	Uranium	1. Geothermal/Volcanic activities 2. Nitrate pollution may further enhance uranium mobilisation.

Geogenic

Deterioration of quality of ground water due to natural contamination from aquifers and overlaying soils is called geogenic contamination. This type of contamination occurs due to entrapped water reaction with the strata. Presence of high Fluoride, Selenium and Arsenic are usually a result of geogenic contamination as there are only a very few other source of these ions. The Contaminants, their Possible Sources is presented in Table 1.

Anthropogenic

Agriculture Activities

The initial increase in agricultural production in the state was mainly due to increase in net sown area, however stunning rise of food grain production from 11,717 thousand million tons in 1980-81 to 3135 thousand tons in 2018-2019 [12] can be largely attributed to intensive use of farm chemicals.

The excess use of fertiliser, pesticides, insecticides, herbicides etc. is causing soil and ground water pollution in these areas. The main fertilizers used in the State are nitrogen based. The consumption of chemical fertilizers (NPK) has increased from 5 Thousand Tonnes in 1960-61 to 1819 Thousand Tonnes in 2018-19(P).

High usage of nitrogenous fertilizers with relative under-utilization of other fertilizers and micronutrients has lead to imbalance in micro nutrient in soils of the Punjab. Nitrogenous based fertilizer releases large amounts of NO_3^- which accumulate in the soil profile and is susceptible to leaching. High rates of leaching and nitrification in permeable or porous soils and relatively high use of fertilizer combine to make nitrate-leaching a serious problem in many irrigated soils [13]. Animal wastes also appear to be the major contributors to high NO_3^- -N in groundwater under village inhabitations and feedlots.

The state of Punjab is one of the highest users of chemical pesticides especially after the ushering in of green revolution where more than 90% of the pesticides are being used in the cultivation of Cotton, rice and vegetables. The Malwa region (Cotton belt) accounts for nearly 75 percent of pesticides used in the State. A total consumption of pesticides in technical grade has increased from 3200 Metric tons (MT) in 1980-81 to 7300 MT in 1994-95 and then has steadily come down to 5699 MT the during 2014-15. The pesticide consumption in the state has been decreasing since 2000-01, which could be to the introduction of Bt cotton in the state (which requires lesser number of sprays) as well as, better awareness among farmers.

Industrial Wastewater Pollution

Number of Industrial units are rapidly increasing in the State and the organic and toxic wastes generated cause water pollution. Status of Water Polluting Industries in Punjab identified by Punjab Pollution Control Board are summarized in Table 2.

Municipal Waste

Application of sewage sludge to agricultural fields and untreated industrial effluents alone, or in combination with ground/canal water, is a common practice in Punjab, especially in the vicinity of large cities, as these are considered reusable sources of essential plant nutrients and organic Carbon are causing pollution to the ground water. Discharge of partially/untreated water contributes to biological contamination of surface and groundwater.

The rapid increase in population due to urbanisation in various districts since 1951 has lead to proportionate increase in generation of municipal, bio-medical and hazardous waste. The physical composition of municipal solid waste generated in the state indicates that on an average, it contains 13% recyclables, 36.44% compostable matter and 40-50% inert material. The chemical composition indicates that the percentage of nitrogen ranges between 0.6-0.8 and that of phosphorus and potassium between 0.56-0.82 & 0.69-0.83 respectively. The carbon/nitrogen (C/N) ratio in the waste generated in the state is 21-3. The available infrastructure required for treatment of generated municipal waste is grossly inadequate. The landfill sites have been selected randomly and not on scientific basis leading to leaching and contamination of the ground waters.

RESULTS & DISCUSSIONS

Evaluation of ground water quality through concentration of its physical, chemical and biological parameters is essential to determine its suitability for the intended use. In most of rural and semi-urban areas of Punjab State, ground water is a major resource for drinking and irrigation uses especially in areas where surface water is inadequate or unavailable. The water samples were analyzed for major cations (Ca, Mg, Na, K) and anions (CO_3 , HCO_3 , Cl, NO_3 , SO_4) in addition to pH, EC, F, SiO_2 , PO_4 and TH as CaCO_3 following 'Standard analytical procedures' as given in APHA [14]. The district-wise concentration range of few chemical components in ground water is depicted in Table 3 and district wise range of Uranium Concentration in microgram per litre has been summarized in Table 4. Ground water is generally suitable for drinking uses except at few places in the southern and south western parts where it is not suitable due to very high EC (highest value found as 11500 $\mu\text{S}/\text{cm}$ in Firozpur district) or high fluoride (highest value found as 4.4 mg/l in Faridkot district) or high nitrate (highest value found as 460 mg/l in Muktsar district) or combination. Almost all waters are suitable for irrigation on well-drained soils for growing salt tolerant crops like wheat, mustard, rice, barley and maize etc. However, at few places where EC of ground water goes beyond 5000 $\mu\text{S}/\text{cm}$ such waters are not suitable for customary irrigation.

Table 2. Status of Water Polluting Industries in Punjab

Years	Large & Medium		Small Scale Industries		Categories		
	(No. of Units)		(No. of Units)		(No. of units)		
	With ETP	Without ETP	With ETP	Without ETP	Red	Orange	Green
2002-03	386	1	1847	751	7989	-	4916
2005-06	466	-	2145	301	7021	-	7528
2009-10	456	-	3200	106	12238	-	9289
2015-16	590	0	2500	13	15021	185*	68*

*This information is for large and medium scale industry working units only

Table 3. Range of few Chemical Constituents in Groundwater of Punjab State-2019

S.N.	district	No. of	Conc	EC in $\mu\text{S}/\text{cm}$ at 25°C	HCO ₃	NO ₃	F	SAR in meq
		Samples	Range		mg/L			
1	amritsar	11	Min		305	159	4	0.13
			Max	915	317	48	0.57	3.43

S.N.	district	No. of	Conc	EC in $\mu\text{S}/\text{cm}$ at 25°C	HCO ₃	NO ₃	F	SAR in meq
		Samples	Range		mg/L			
2	barnala	3	Min	305	159	4	0.13	2.39
			Max	915	317	48	0.57	3.43
3	bhathinda	27	Min	258	85	1.46	0.08	0.30
			Max	6210	818	554	3.8	26.74
4	faridkot	21	Min	410	104	3.9	0.14	1.20
			Max	4590	756	180	4.6	41.30
5	fatehgarh sahib	11	Min	470	168	2	0.19	0.78
			Max	1940	629	52	0.69	10.79
6	fazilka	15	Min	745	74	1.5	0.32	3.03
			Max	8320	574	253	3.1	35.00
7	firozpur	7	Min	478	118	2.4	0.14	1.03
			Max	1641	370	172	1.21	10.04
8	gurdaspur	18	Min	220	98	0.2	0.14	0.42
			Max	1214	464	100	0.86	13.02
9	hoshiarpur	26	Min	200	84	2	0.18	0.33
			Max	1750	377	48	0.67	1.93
10	jalandhar	15	Min	315	122	0.65	0.24	0.51
			Max	1070	378	138	4.00	6.77
11	kapurthala	8	Min	302	134	23	0.3	1.43
			Max	710	256	68	0.7	10.71
12	ludhiana	19	Min	270	110	2.5	0.11	0.23
			Max	1220	696	78	1.62	6.59
13	mansa	10	Min	268	100	3.6	0.4	1.14
			Max	5140	1062	71	2	22.89
14	moga	7	Min	465	134	0.4	0.36	1.11
			Max	1368	549	46	1.72	14.16
15	muktsar	10	Min	760	74	4	0.12	1.35
			Max	5840	816	900	3.41	16.48
16	nawanshahr	6	Min	420	224	2	0.26	1.23
			Max	1220	363	48	0.79	5.59
17	pathankot	14	Min	195	98	2	0.08	0.35
			Max	1108	317	60	0.6	3.23
18	patiala	24	Min	355	171	0.35	0.19	0.69
			Max	4060	573	358	4.12	22.87
19	ropar	11	Min	300	70	2	0.1	0.37
			Max	900	409	52	0.98	2.63
20	sangrur	13	Min	329	150	5.7	0.15	0.58
			Max	1715	683	105	1.2	17.84
21	sas nagar	14	Min	450	182	0.4	0.32	0.93
			Max	6480	699	407	1.52	11.54
22	tarantaran	12	Min	362	134	0.28	0.2	1.14
			Max	1720	720	120	8	25.84
	Total	302	Min	195	70	0.2	0.080	0.23
			Max	8320	1062	900	8.00	41.30

Table 4. District Wise Range of Uranium Concentration in microgram per litre.(ppb).

S.N.	District	No.of Samples Analysed	Uranium Concentration in ppb		
			Min	Max	Average
1	Amritsar	11	0.026	17.393	6.811
2	Barnala	3	0	11.894	3.956
3	Bathinda	27	2.272	82.507	23.331
4	Faridkot	21	0.043	38.985	14.457
5	Fazilka	11	5.126	156.468	35.517
6	Fatehgarh Sahib	15	0.028	71.972	27.175
7	Firozpur	7	0.020	30.533	13.859
8	Gurdaspur	18	0.023	23.244	7.529
9	Hoshiarpur	26	0.787	135.188	36.527
10	Jalandhar	15	0.040	140.405	31.439
11	Kapurthala	8	1.778	36.104	20.401
12	Ludhiana	19	0.137	150.402	36.501
13	Mansa	10	0	23.722	9.849
14	Moga	7	1.230	39.929	14.791
15	Muktsar	10	0.852	41.543	19.762
16	Nawashaher	6	3.570	19.596	8.515
17	Pathankot	14	3.308	44.269	13.939
18	Patiala	24	0.536	66.941	22.075
19	Roop Nagar	11	0.172	44.046	18.308
20	Sangrur	13	2.487	44.269	18.879
21	SAS Nagar	14	4.675	56.618	28.170
22	Tarantaran	12	0.312	18.088	5.332

District Wise Uranium Concentration

The varied hydrogeological conditions in the alluvium of Punjab are also reflected in the type and nature of the Heavy Metals present in ground water of the State. On the basis of present studies, the concentration of uranium more than 30 ppb and 60 ppb respectively describe in Figure 2. In the State 73 samples (24.2% samples) have been found to have Uranium more than 30 ppb that is the guidelines value as per WHO [15] and 18 samples having more than 60 ppb (6% samples) as per the limit of Atomic Energy Regulatory Board of India [16]. The highest value has been found as 156.5 ppb in Fazilka district. The Districts which are partly affected by high Uranium in ground water are-Bathinda, Moga, Faridkot, Fatehgarh Sahib, Fazilka, Ferozepur, Hoshiarpur, Jalandhar, Kapurthala, Ropar, Ludhiana, Muktsar, Pathankot, Patiala, Sangrur and SAS Nagar.

The District-Wise Occurrence of Uranium In Ground Water

District: Amritsar

The minimum concentration of uranium has been found at Metha (0.026 ppb) block Raiya and maximum concentration of uranium has been found at Amritsar (17.393 ppb) block Verka of the district and the Average concentration of uranium is 6.811 ppb. It reveals that there is no contamination of uranium in the entire district.

District Barnala

The minimum concentration of uranium has been found at Bhadaur (0.0 ppb) block Sehna and maximum concentration of uranium has been found at Barnala (11.89 ppb) block Barnala of the district and the Average concentration of uranium is 3.956 ppb. It reveals that there is no contamination of uranium in the entire district.

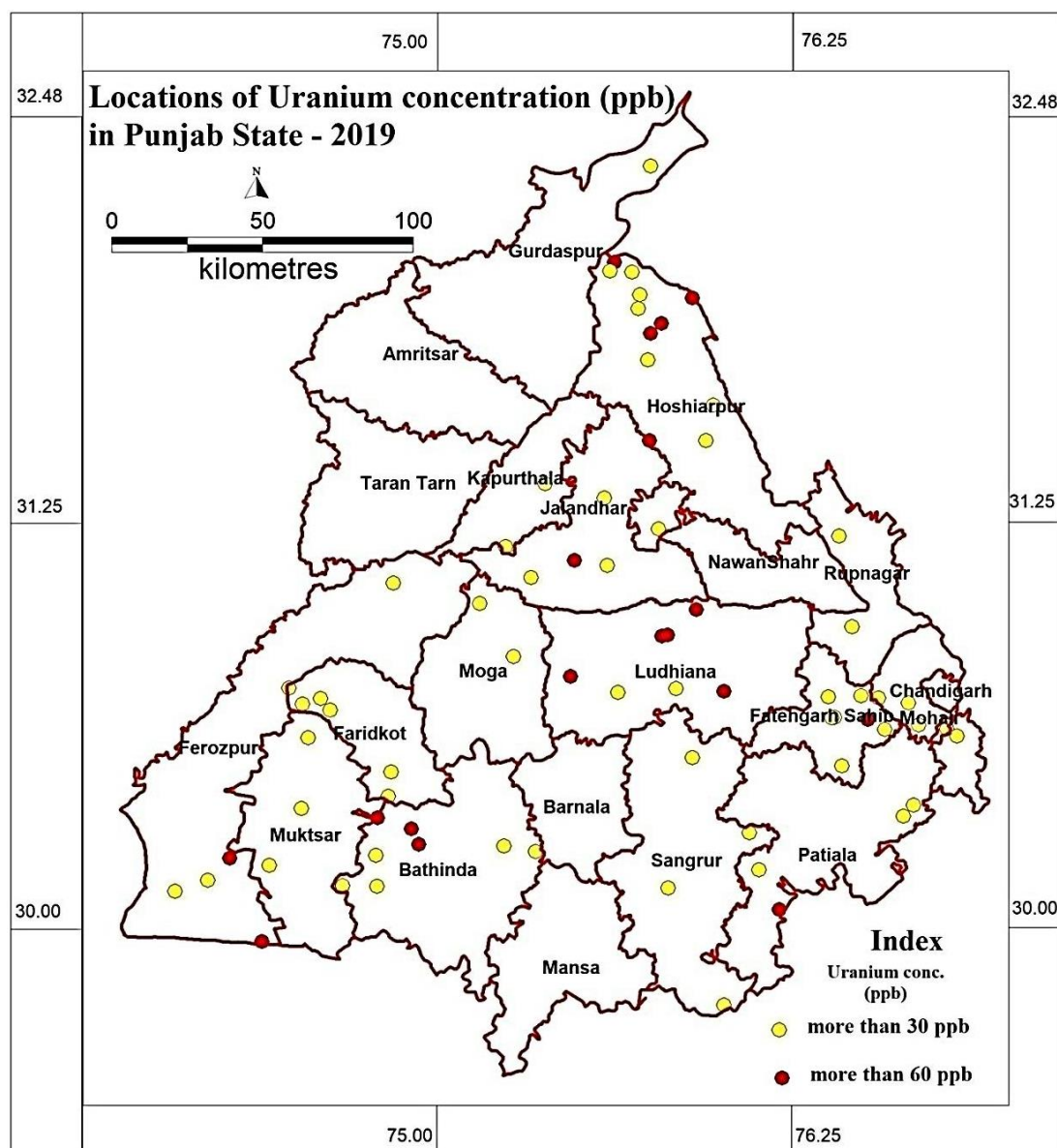


Figure 2.Concentration of Uranium more than 30 ppb and 60 ppb.

District: Bathinda

The minimum concentration of uranium has been found at KotShamir (2.272 ppb) block Bhatinda and maximum concentration of uranium has been found at Dera Tappa (82.507 ppb) block Bhatinda of the district and the Average concentration of uranium is 23.331 ppb. It reveals that the 1.11% ground water samples having uranium concentration more than limits for drinking water recommended by AERB 60 ppb, and 25.9% samples having uranium more than 30 ppb describe by WHO. On comparing the concentration values of uranium with the standard concentration limits for drinking water recommended by AERB60 ppb, it is found that only about 74% ground water are suitable for drinking purposes in respect to the Uranium.

District Faridkot

The minimum concentration of uranium has been found at Dal Singh Wala (0.043 ppb) block Kotkapur and maximum concentration of uranium has been found at Sadiq (38.985 ppb) block Faridkot of the district and the average concentration of uranium is 14.457 ppb. It reveals that the 28.57% ground water samples having uranium concentration more than 30 ppb describe by WHO

limits for drinking water. 71.43% samples having safe in the entire district and water use for drinking purposes.

District Fatehgarh Sahib

The minimum concentration of uranium has been found at Amloh (5.126 ppb) block Amloh and maximum concentration of uranium has been found at Badli Ala Singh (71.972 ppb) block Khera of the district and the Average concentration of uranium is 35.5177 ppb. It reveals that the 63.64% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 9.09% ground water samples having uranium concentration more than limits for drinking water recommended by AERB 60 ppb, and it is found that only about 27.27% ground water are suitable for drinking purposes in respect to the Uranium. Average concentration of uranium is 35.517 ppb.

District: Fazilka

The minimum concentration of uranium has been found at NurKe Uttar (0.028 ppb) block Jalalabad and maximum concentration of uranium has been found at Khundal (156.468 ppb) block Abohar of the district and the average concentration of uranium is 27.175 ppb. It reveals that the 28.57% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 71.43% samples having safe in the entire district and water use for drinking purposes

District: Ferozpur

The minimum concentration of uranium has been found at Shayam Singh Wala (0.020 ppb) block Mamdot and maximum concentration of uranium has been found at Lauke Kalan (30.533 ppb) block Makhu of the district and the average concentration of uranium is 13.859 ppb. It reveals that the 14.28% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 85.72% samples having safe in the entire district and water use for drinking purposes.

District: Gurdaspur

The minimum concentration of uranium has been found at Kalanaur (0.023 ppb) block Gurdaspur and maximum concentration of uranium has been found at Dera Baba Nanak (23.244 ppb) block Dera Baba Nanak. It shows that the ground water of the district free from uranium contamination.

District: Hoshiarpur

The minimum concentration of uranium has been found at Phuglana (0.787 ppb) block Hosiarpur - II and maximum concentration of uranium has been found at Dulmiwal (135.188 ppb) block Dasuya of the district and the average concentration of uranium is 36.527 ppb. It reveals that the 46.15% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 15.38% ground water samples having uranium concentration more than limits for drinking water recommended by AERB 60 ppb,

District: Jalandhar

The minimum concentration of uranium has been found at Kartarpur (0.040 ppb) block Jalandhar West and maximum concentration of uranium has been found at Nakodar (140.405 ppb) block Nakodar of the district and the average concentration of uranium is 31.439 ppb. It reveals that the 26.66% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 6.25% ground water samples having uranium concentration more than limits for drinking water recommended by AERB 60 ppb, rest of the ground water free from uranium contamination of the district.

District Kapurthala

The minimum concentration of uranium has been found at Bholath (1.178 ppb) block Dhilwan and maximum concentration of uranium has been found at Dalla (36.104 ppb) block Sultanpur Lodhi of

the district and the average concentration of uranium is 20.401 ppb. It reveals that the 37.5% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water free from uranium contamination of the district.

District Ludhiana

The minimum concentration of uranium has been found at Sharian (0.137 ppb) block Macchiwara and maximum concentration of uranium has been found at Jagraon (150.402 ppb) block Jagraon of the district and the average concentration of uranium is 36.501 ppb. It reveals that the 36.84% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 26.31% ground water samples having uranium concentration more than limits for drinking water recommended by AERB 60 ppb. 36.85% ground water of the district free from uranium contamination.

District: Mansa

The minimum concentration of uranium has been found at Mofer (0.0 ppb) block Budhwala and maximum concentration of uranium has been found at JhandaKhurd (23.722 ppb) block Sardulgarh of the district and the average concentration of uranium is 9.849 ppb. It shows that there is no contamination of uranium in ground water of the district.

District: Moga

The minimum concentration of uranium has been found at DameruKhurd (1.230 ppb) block BaghaPurana and maximum concentration of uranium has been found at Chogawan (39.929 ppb) block Moga-II of the district and the average concentration of uranium is 14.791 ppb. It reveals that the 28.57% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water of the district free from uranium contamination.

District: Muktsar

The minimum concentration of uranium has been found at Khundebalal (0.852 ppb) block Malot and maximum concentration of uranium has been found at Baloch Khera (41.543 ppb) block Mukatsar of the district and the average concentration of uranium is 19.762 ppb. It reveals that the 30% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water of the district free from uranium contamination.

District: Nawanshahr

The minimum concentration of uranium has been found at Raipur Dhaba (3.570 ppb) block Aur and maximum concentration of uranium has been found at Mauhra (19.596 ppb) block Balachor of the district and the average concentration of uranium is 8.515 ppb. It shows that there is no contamination of uranium in ground water of the district.

District: Pathankot

The minimum concentration of uranium has been found at Ghoh (3.308 ppb) block Pathankot and maximum concentration of uranium has been found at Permota (44.269 ppb) block Dhar Kalan of the district and the average concentration of uranium is 13.939 ppb. It reveals that the 7.14% ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water of the district free from uranium contamination.

District: Patiala

The minimum concentration of uranium has been found at Rajpura (0.536 ppb) block Rajpura and maximum concentration of uranium has been found at Mardanheri (66.941 ppb) block Sanour of the district and the average concentration of uranium is 22.075 ppb. It reveals that the 20.83 % ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. 4.16% ground water samples having uranium concentration more than limits for drinking water

recommended by AERB 60 ppb. About 75% ground water of the district free from uranium contamination.

District: Ropar

The minimum concentration of uranium has been found at Chak Dehra (0.172 ppb) block Ropar and maximum concentration of uranium has been found at Dumewal (44.064 ppb) block Narpur Badi of the district and the average concentration of uranium is 18.308 ppb. It reveals that the 18.18 % ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water of the district free from uranium contamination.

District: Sangrur

The minimum concentration of uranium has been found at Bhugra (2.487 ppb) block Dhuri and maximum concentration of uranium has been found at Maler Kotlai (44.269 ppb) block Amargarh of the district and the average concentration of uranium is 18.879 ppb. It reveals that the 23.07 % ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. About 77% ground water of the district free from uranium contamination.

District: Sahibzada Ajit Singh Nagar

The minimum concentration of uranium has been found at Joli (4.675 ppb) block Dear Bassi and maximum concentration of uranium has been found at Goga (56.618 ppb) block Kharar of the district and the average concentration of uranium is 28.170 ppb. It reveals that the 35.71 % ground water samples having uranium concentration more than 30 ppb describe by WHO limits for drinking water. Rest of the ground water samples of the district free from uranium contamination.

District: Taran Taran

The minimum concentration of uranium has been found at Aminsha Kalan (0.312 ppb) block Bhikki Wind and maximum concentration of uranium has been found at Dabuji (18.088 ppb) block Tarantaran of the district and the average concentration of uranium is 5.332 ppb. It reveals ground water of the district is free from uranium contamination.

CONCLUSIONS

Ground water is generally suitable for drinking uses except at few places in the southern and south western parts where it is not suitable due to high EC or high fluoride or nitrate or combination of all. Almost all waters are suitable for irrigation on well-drained soils for growing salt tolerant crops like wheat, mustard, rice, barley and maize etc. However, at few places where EC of ground water goes beyond 5000 $\mu\text{S}/\text{cm}$ and SAR is more than 10, such waters are not suitable for customary irrigation. The areas identified with high uranium more than 60 ppb water quality should be monitored on micro level to effectively delineate such areas and use suitable management measures. The Uranium affected wells should be clearly demarcated and not used for drinking purposes if it is not possible to seal. Tapping of Uranium safe alternate aquifers should be tried in the affected areas.

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