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ARTICLE

Ingestion doses and hazard quotients due to intake of Uranium in drinking water from Udhampur District of Jammu and Kashmir State, India

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Abstract – Ground water in environment is contaminated by atomic radiations of natural occurring radioactive elements like Uranium and Thorium. The Uranium (^{238}U) concentration has been measured in drinking water samples collected from different sources like the hand pumps and natural spring/bowli from wide range of locations in Udhampur District, Jammu and Kashmir (J&K), India by using LED flourimetry technique. The Uranium concentrations in four tehsils *viz.* Udhampur, Ramnagar, Chenani and Majalta are varied from (0.25–27.15) $\mu g\,L^{-1}$, (0.19–27.93) $\mu g\,L^{-1}$, (0.14–0.68) $\mu g\,L^{-1}$, and (1.63–28.06) $\mu g\,L^{-1}$ with mean value 13.57 $\mu g\,L^{-1}$, 9.67 $\mu g\,L^{-1}$, 0.29 $\mu g\,L^{-1}$, and 17.61 $\mu g\,L^{-1}$, respectively. The values of ingestion dose for different age group and chemical risks have also been calculated. The purpose of this study is to investigate the Uranium concentration in ground water samples and to determine its health effects to the habitants of the study area. All the recorded values of Uranium are compared with the safe limits recommended for drinking water by various health and environmental protection agencies (WHO, USEPA, and AERB). Physico-chemical properties such as pH, conductance and total dissolved solids (TDS) have been determined in water samples.

Keywords: drinking water / LED flourimetry / uranium / ingestion dose / chemical risk

1 Introduction

Uranium is the naturally occurring heaviest radioactive toxic element and occurs naturally in low concentrations of a few parts per million in all type of soils, rocks, plants, sands, bedrocks and water. Due to its presence in the certain types of rocks and soils, the water passing through and over the rock and soil formations dissolves many compounds and minerals; therefore, varying amounts of Uranium are present in some water sources (Rani *et al.*, 2013). Natural water such as seawater contains a few traces of Uranium of range 0–4 ppb and up to 1000 ppb in surface (Singh *et al.*, 1999). Uranium concentration mostly depends upon the geology of the area and it also varies from place to place (WHO, 1998). Uranium is used as fuel in nuclear energy production so it is considered as an important radioelement in present era. The density of Uranium is 70% higher than Lead. In nature, Uranium isotopic composition is equal to Uranium-238 (99.2739–99.2752%), Uranium-235 (0.7198–0.7202%), and a very minute amount of Uranium-234 (0.0050–0.0059%). According to United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), the normal concentration of Uranium in soil is 300 $\mu g\,kg^{-1}$ to 11.7 $mg\,kg^{-1}$ and the mean Uranium daily intake in humans is 2.6 $\mu g\,day^{-1}$ (for a 70 kg man) and one third of this comes from drinking water (ATSDR, 1999).

Generally peoples get exposed to natural Uranium from food, water and air. Ground water is the major source for drinking and for other domestic activities, so the intake of Uranium by water is of greater concern than the other sources. If Uranium concentration is higher in drinking water than the permissible limit, may cause the pathological and other harmful diseases in the body (WHO, 1998; ATSDR, 1990, 1999). Genetic damage has been also found in mammals, micro-organisms, insects and plants. Genetic damage sometimes results in an unviable organism; leading to spontaneous absorption or premature death. Uranium concentration in drinking water is higher than 30 $\mu g\,L^{-1}$ causes numerous harmful biological effects (USEPA, 2011). Some kind of damage results in gross abnormalities or deformities, whereas other types involve subtle differences, which are difficult to

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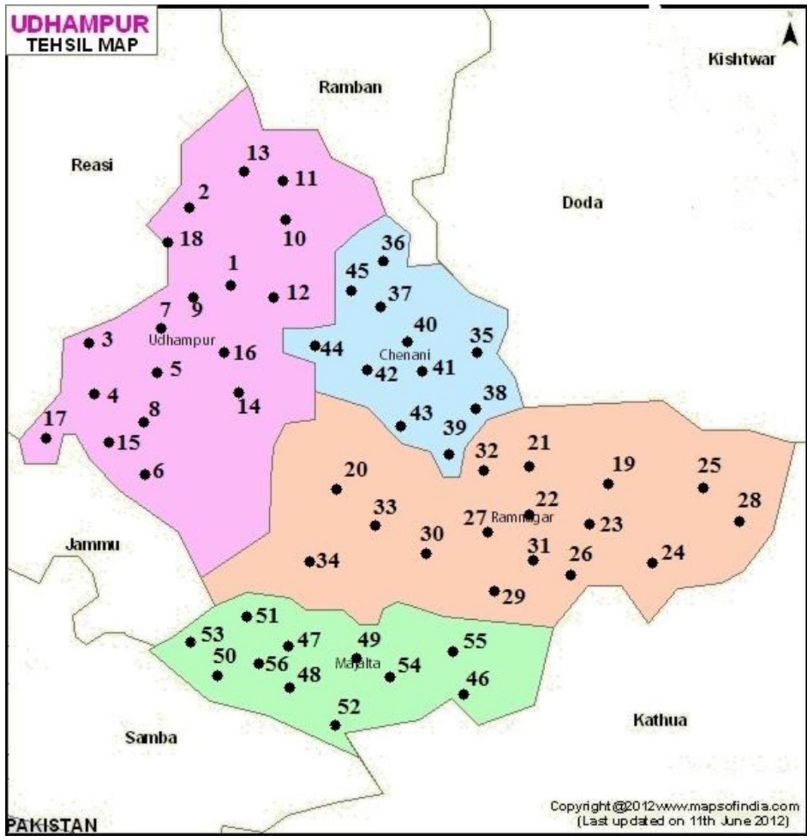

Fig. 1. Map showing the different villages selected in Udhampur district, J&K.

detect. It was also observed that skin damage can also be caused by prolonged contact with some of radioactive decay products of Uranium. Over a period of years, that damage can lead to many types of illness, including cancers and leukemia. It may also lead to disease and malformation in children, even before they are born (WHO, 1998, 2011).

Human health effects due to the exposition to high levels of natural radiation may be associated to carcinogenic and non-carcinogenic effects (WHO, 1998; Health Canada, 1999). Uranium has both the chemical and radiological toxicity. Many surveys have been carried out in India (Madbouly *et al.*, 2009; Singh *et al.*, 2009; Garg *et al.*, 2014; Kumar *et al.*, 2015) and worldwide (Jobbagy *et al.*, 2010; Wallner and Jabber, 2010; Loannidou *et al.*, 2011; Benedik and Jeran, 2012; Calin *et al.*, 2015; Erden *et al.*, 2014) for the determination of Uranium concentration in water and to assess its harmful impact on human health.

A systematic survey has been conducted in Udhampur district of Jammu and Kashmir of drinking water samples of the study area. Therefore, in present study, Uranium concentration in drinking water was measured in 57 locations of Udhampur district of Jammu and Kashmir, India by using LED Flourimetry technique and resident of this area use these water sources for drinking and other domestic purposes. The main purpose of this investigation is to assess its chemical health risk. Different physico-chemical water quality parameters like pH, conductance and total dissolved solids (TDS) in drinking water samples were also measured in order to assess the quality of drinking water samples.

2 Geology of the study area

The district has a total geographical area of 4540 sq km and altitude varies from 600 to 2500 meters above Mean Sea Level (AMSL). The town is said to have been built in place of dense forest. The Udhampur district is situated in the south-eastern part of the Jammu and Kashmir (J&K) as shown in Figure 1. Udhampur district has a varied topography. It is inter-woven with Shiwalik range of hills and the terrain is mostly mountainous. There are very few inhabited areas above the height of 1112 meters. There is a wide variation in climatic conditions in different parts of the district experiencing a typical temperate climate in high altitude which experience snowfall and cold winter whereas tropical climate at low altitude.

Udhampur city bounds with a number of natural springs locally known as Bowli's. Maximum population of Udhampur goes to these Bowli's for drinking purpose as it is said that the water of Bowli is good for digestion. The district is drained by two major rivers Basantar, and Uri. And a lake, Mansar Lake is also situated in the district. Ground water in this area is present under unconfirmed conditions in underlying rocks of Shiwalik. Perennial springs of good discharge are numerous in whole area and form the major source of water supply. The shiwalik sandstones are good permeable formations, but relatively bad retainer of water. Sirban and numulitic lime stones are not only good water bearing rocks but also contain good quality water, rich in calcium. Udhampur is mostly occupied by talus, scree of purple, buff sandstones, purple and red shales, and clays of Murree Series of Miocene age (Gupta and Verma, 1975).

3 Materials and methods

3.1 Sampling

Fifty-seven ground water samples were collected from the hand pumps; natural spring/bowli's of Udhampur district J&K, India, from December to February. Water samples were collected in polyethylene bottles that were pre-washed with distilled water. Before collecting water samples, bottles were rinsed with water of sampling location and handle with special care to avoid contamination.

3.2 Estimation of Uranium concentration-LED flourimeter

The collected water samples were filtered through Whatman filter paper no. 10 (Kumar *et al.*, 2016) to remove suspended particle and is transferred to 50 mL polyethylene plastic bottles previously cleaned with distilled water. The fluorimetric method for Uranium is among the most sensitive and efficient, of detection limit 0.5 μg L^{-1} to 1000 μg L^{-1} with an accuracy of ±10% or 0.05 μg L^{-1} whichever is greater and repeatability is better than ±5% (Kumar *et al.*, 2016) and in ICP-MS, the precisions achieved were ±5% relative standard deviation (RSD) with comparable levels of accuracy (Rani *et al.*, 2013). Uranium concentration of collected samples was calculated by LED-Flourimeter (Quantalase Enterprise Pvt. Ltd., Indore, India). The instrument was calibrated using standard solution of Uranium, 10 ppb. 5% of Sodium Pyrophosphate ($Na_2P_2O_7$) solution is prepared by mixing 5 g of Sodium Phosphate in 100 mL double distilled water. This solution should be mixed properly so that no granule of sodium pyrophosphate remains and is used as a fluorescence regent because it forms fluorescent uranyl phosphate complexes (Mukherjee *et al.*, 2007; Kumar *et al.*, 2011; Nagaraju *et al.*, 2014; Saad *et al.*, 2014; Kumar *et al.*, 2015). Ortho-phosphoric acid (H_3PO_4) must be added to the solution drop by drop until pH of the reagent reaches 7. This solution is after referred as the buffer solution. 6 mL water sample is added in the clean cuvette to 0.6 mL of buffer solution. The light source sends out light of the excitation wavelength of 400 nm to the compound to be measured. The emitted light is measured by the detector, and the fluorescence value is displayed on the instrument. Each sample was analysed twice and averaged value is taken.

Physic-chemical parameters such as pH, Electrical conductivity, TDS were also measured in water samples by using micro processor based water analyser kit (model no. NPC 362D, Naina Solaris Limited, New Delhi). These three factors are important to evaluate the impact on Uranium and also provide the information about suitability of water for drinking purpose.

3.3 Health risk assessment

3.3.1 Age dependent dose

$$\text{Ingestion dose}\,(\text{Sv}\,\text{Y}^{-1}) = \text{U}_a \times \text{W}_{in}(\text{L}\,\text{y}^{-1}) \times \text{DCF}\,(\text{Sv}\,\text{Bq}^{-1}),$$

where U_a is Uranium activity in water (Bq L^{-1}). W_{in} is annual consumption dose of water (L y^{-1}) and DCF is the Uranium ingestion dose coefficient (Sv Bq^{-1}) (ICRP, 2012).

The water intake rates (L day^{-1}) taken for infants of 0–6 and 7–12 month old are 0.7 and 0.8 L day^{-1}, respectively. For the children of age group 1–3 and 4–8 year is 1.3 and 1.7 L day^{-1}, respectively. For 9–13 years, male children 2.4 L day^{-1} and 2.1 L day^{-1} for female. For teenagers (age group 14–18 year), 3.3 L day^{-1} for male and 2.3 L day^{-1} for female and above 18 year (adults), is taken as 3.7 L day^{-1} (for male) and 2.7 L day^{-1} (for female) (DRIs, 2005). During pregnancy and lactation, the water intake rate assumed was 3.0 and 3.8 L day^{-1}. The dose conservation factor taken for infants, 1 year, 5 years, 10 years, 15 years and adults are 1.4×10^{-8}, 1.2×10^{-8}, 8×10^{-8}, 6.8×10^{-8}, 6.7×10^{-8}, and 4.5×10^{-8} Sv Bq^{-1} (ICRP, 2012). The mass to activity conversion factor used for natural uranium was 0.0245 Bq μg^{-1} (ISO 16638-Part 1).

3.3.2 Chemical toxicity risk

The chemical toxicity risk is defined as the lifetime average daily dose (LADD in μg kg^{-1} day^{-1}) of the element through drinking water intake and is given as (WHO, 2011).

$$\text{LADD} = \frac{\text{EPC} \times \text{IR} \times \text{EF} \times \text{LE}}{\text{SW} \times \text{AT}},$$

where EPC is the exposure point concentration (μg L^{-1}). IR is water ingestion rate (4.05 L day^{-1}) (Kumar *et al.*, 2016). EF is exposure frequency (350 days year^{-1}) (USEPA, 1997), LE is the life expectancy *i.e.* 65 year (WHO, 2011). AT is the average time (life expectancy and 365 is conversation factor from year to days) and W is body weight (53 kg for Indian standard man).

The extent of harms from toxic risk is indicated by hazard quotient (HQ):

$$\text{HQ} = \frac{\text{LADD}}{\text{R}_f\text{D}},$$

where R_fD is reference dose and its recommended limits given by WHO and AERB, *i.e.* 1.2 and 4.4 μg kg^{-1} day^{-1} (AERB, 2004; WHO, 2011).

4 Results and discussion

Uranium concentration in water sources of four tehsils (Udhampur, Ramnagar, Chenani and Majalta) of Udhampur district, J&K, Himalayas, was analyzed by LED flourimetric technique and its range, average, standard deviation; geometric mean is given in Table 1. The average value of Uranium concentration in Udhampur tehsil was found to be 13.58 μg L^{-1} with minimum value of 0.25 μg L^{-1} at Chopra Market and maximum value of 27.15 μg L^{-1} at Krimachi, in Ramnagar tehsil the average value was found to be 9.67 μg L^{-1} with minimum value of 0.19 μg L^{-1} at Koyi and maximum value of 27.93 μg L^{-1} at Kaghote, in Chenani tehsil the average value of Uranium concentration was found to be 0.29 μg L^{-1} with minimum value of 0.14 μg L^{-1} at Chokar Nallah and maximum value of 0.68 μg L^{-1} at Baishty, in Majalta tehsil the average value of Uranium concentration was found to be 17.61 μg L^{-1} with minimum value 1.63 μg L^{-1} at Banara and maximum value of 28.09 μg L^{-1} at Mansar. The overall high

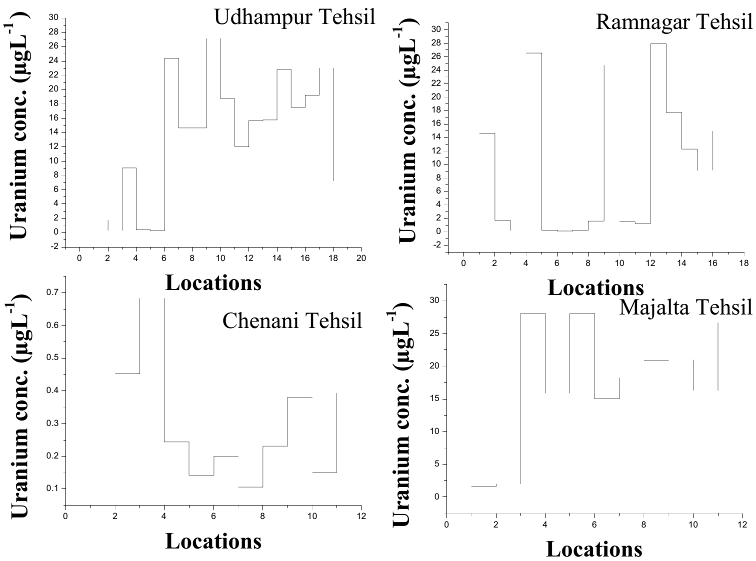

Fig. 2. Uranium concentration in different tehsils of Udhampur district, J&K.

Table 1. Calculated uranium concentration with statistical parameters, LADD and HQ in four Tehsils of Udhampur district, J&K, Himalayas.

	(Udhampur)		(Ramnagar)		(Chenani)		(Majalta)	
Sample collected	18		17		11		11	
Uranium range	0.25–27.15 (ppb)	0.006-0.66 (Bq L^{-1})	0.19–27.93 (ppb)	0.004–0.68 (Bq L^{-1})	0.14–0.68 (ppb)	0.003–0.016 (Bq L^{-1})	1.63–28.09 (ppb)	0.04–0.69 (Bq L^{-1})
Mean	13.58	0.33	9.67	0.24	0.29	0.007	17.61	0.43
Standard deviation	8.47	0.20	8.98	0.23	0.16	0.004	8.71	0.21
Median	15.17	0.37	5.40	0.13	0.23	0.005	18.23	0.45
Geometric mean	7.49	0.18	3.04	0.07	0.25	0.006	13.20	0.32
Harmonic mean	1.60	0.04	0.65	0.015	0.22	0.005	7.41	0.17
LADD (µg kg^{-1} day^{-1})	0.020–2.07		0.015–2.135		0.008–0.052		0.0125–2.14	
HQ	0.0165–1.73		0.012–1.78		0.007–0.043		0.104–1.79	

value of Uranium concentration was found in Mansar (28.09 µg L^{-1}) of Majalta tehsil and low value was found in Choker Nallah (0.14 µg L^{-1}) of Chenani tehsil. The WHO reference level for Uranium is equal to 30 µg L^{-1} (WHO, 2011). According to AERB, Maximum acceptable level of Uranium in drinking water is 60 µg L^{-1} (AERB, 2004). However, UNSCEAR safe limit for Uranium is 9 µg L^{-1} (UNSCEAR, 2011) and the ICRP safe limit is 1.9 µg L^{-1} (ICRP, 1993). And USEPA limit is 30 µg L^{-1} (USEPA, 2003). It was observed that the recorded values of Uranium were within the safe limit recommended by WHO, USEPA and AERB, India. Among 57 water samples, 24 samples (42%) and 27 samples (47%) are found well within safe limit suggested by ICRP (1993) and UNSCEAR (2011) respectively. It can be seen that the Uranium content in the drinking water samples varied from source to source and also with location to location. The variation of Uranium concentration in study area is due to presence of underlying rocks, sandstones, siltstones, shale, and limestone. The high value of Uranium concentration in Mansar of Majalta tehsil is due to lake which contains the highest content of salts in that area. Uranium concentration in different tehsils of Udhampur district is given in Figure 2.

From Uranium concentration, the corresponding ingestion dose rate for different age groups has been calculated in Table 2. The value of ingestion dose rate for different age groups ranged from 0.23 µSv y^{-1} to 60.19 µSv y^{-1} with an average value of 17.48 ± 12.21 µSv y^{-1} in Udhampur tehsil, ranged from 0.12 µSv y^{-1} to 66.24 µSv y^{-1} with an average value 12.86 ± 14.45 µSv y^{-1} in Ramnagar tehsil, ranged from 0.09 µSv y^{-1} to 1.51 µSv y^{-1} with an average value 0.37 ± 0.24 µSv y^{-1} in Chenani tehsil, ranged from 1.43 µSv y^{-1} to 62.27 µSv y^{-1} with an average value 23.60 ± 13.16 µSv y^{-1} in Majalta tehsil and all are within the safe limit of 100 µSv y^{-1} (WHO, 2004).

The chemical toxicity risk such as lifetime average daily dose (LADD) came out to be 0.81 µg kg^{-1} day^{-1} with a range of 0.008–2.14 µg kg^{-1} day^{-1}, considering the body weight as 53 kg of an adult Indian reference man. The permissible limit of LADD given by WHO is 1.0 µg kg^{-1} day^{-1} (WHO, 2011). The data showed that LADD for 54% samples were within permissible limits. Whereas 46% samples have higher LADD than permissible limit. This variation in LADD is due to uneven distribution of Uranium in groundwater. The mean of hazard quotient (HQ) was also found to be 0.68 with range

Table 2. Measured ingestion dose rate of different age group of Udhampur district, J&K, Himalayas.

Villages	Uranium conc. (Bq L^{-1})	Ingestion dose ($\mu Sv\,y^{-1}$)											
		0–6 m	7–12 m	1–3 y	4–8 y	9–13 y		14–18 y		Above 18		Pregnancy	Lactation
						Male	Female	Male	Female	Male	Female		
Udhampur													
1	0.007	0.26	0.26	0.41	0.36	0.43	0.37	0.65	0.41	0.44	0.32	0.32	0.32
2	0.042	1.49	1.50	2.38	2.07	2.49	2.177	3.77	2.35	2.54	1.85	1.85	1.85
3	0.221	7.91	7.90	12.58	10.97	13.16	11.52	20.0	12.43	13.43	9.80	9.80	9.80
4	0.010	0.35	0.35	0.56	0.488	0.58	0.51	0.89	0.55	0.60	0.44	0.44	0.44
5	0.006	0.23	0.23	0.36	0.31	0.38	0.33	0.57	0.36	0.38	0.28	0.28	0.28
6	0.597	21.36	21.36	33.99	29.64	35.57	31.12	54.03	33.58	36.27	26.48	26.48	26.48
7	0.359	12.84	12.84	20.45	17.82	21.39	18.72	32.49	20.19	21.82	15.93	15.93	15.92
8	0.358	12.82	12.82	20.41	17.80	21.36	18.69	32.44	20.17	21.79	15.90	15.90	15.90
9	0.665	23.79	23.79	37.88	33.02	39.62	34.67	60.19	37.41	40.42	29.50	29.50	29.50
10	0.458	16.39	16.39	26.08	22.74	27.29	23.88	41.45	25.77	27.84	20.32	20.32	20.32
11	0.295	10.55	10.55	16.79	14.64	17.57	15.37	26.67	16.59	17.92	13.08	13.08	13.08
12	0.384	13.75	13.75	21.89	19.08	22.90	20.04	34.79	21.62	23.36	17.05	17.05	17.05
13	0.386	13.82	13.82	21.99	19.17	23.01	20.14	34.96	21.73	23.48	17.13	17.13	17.13
14	0.559	20.01	19.99	31.83	27.75	33.30	29.14	50.58	31.44	33.97	24.79	24.79	24.79
15	0.428	15.34	15.34	24.42	21.29	25.55	22.35	38.81	24.12	26.06	19.02	19.02	19.02
16	0.47	16.81	16.81	26.77	23.33	28.00	24.5	42.53	26.44	28.57	20.85	20.85	20.85
17	0.564	20.19	20.19	32.13	28.01	33.62	29.42	51.06	31.74	34.30	25.03	25.02	25.03
18	0.177	6.34	6.35	10.10	8.81	10.57	9.25	16.05	9.98	10.78	7.87	7.87	7.87
Ramnagar													
19	0.041	1.46	1.46	2.32	2.02	2.42	2.12	3.68	2.29	2.47	1.81	1.80	1.81
20	0.357	12.78	12.80	20.37	17.76	21.31	18.65	32.37	20.12	21.74	15.87	15.87	15.87
21	0.005	0.17	0.17	0.27	0.23	0.28	0.24	0.43	0.27	0.29	0.21	0.21	0.21
22	0.005	0.20	0.19	0.31	0.27	0.33	0.29	0.50	0.31	0.34	0.24	0.24	0.24
23	0.65	23.26	23.26	37.03	32.28	38.74	33.89	58.84	36.58	39.52	28.84	28.84	28.84
24	0.003	0.12	0.12	0.19	0.16	0.197	0.17	0.30	0.18	0.2	0.15	0.17	0.15
25	0.0056	0.20	0.20	0.32	0.28	0.33	0.29	0.51	0.32	0.34	0.25	0.25	0.25
26	0.039	1.40	1.40	2.23	1.94	2.33	2.04	3.54	2.20	2.38	1.74	1.74	1.74
27	0.732	26.18	26.18	41.68	36.34	43.61	38.15	66.24	41.17	44.49	32.46	32.46	32.46
28	0.036	1.30	1.30	2.07	1.81	2.17	1.89	3.30	2.05	2.21	1.62	1.62	1.62
29	0.030	1.10	1.10	1.76	1.53	1.84	1.61	2.8	1.73	1.87	1.37	1.37	1.37
30	0.684	24.48	24.48	38.97	33.97	40.77	35.67	61.93	38.49	41.59	30.35	30.35	30.35
31	0.434	15.53	15.53	24.72	21.56	25.87	22.63	39.29	24.42	26.39	19.26	19.26	19.26
32	0.301	10.77	10.77	17.14	14.94	17.93	15.69	27.23	16.93	18.29	13.35	13.35	13.35
33	0.224	8.01	8.01	12.75	11.11	13.34	11.67	20.26	12.59	13.60	9.93	9.93	9.93
34	0.367	13.13	13.13	20.90	18.22	21.86	19.13	33.21	20.64	22.31	16.28	16.28	16.28
Chenani													
35	0.005	0.18	0.17	0.28	0.24	0.29	0.26	0.44	0.28	0.29	0.22	0.22	0.22
36	0.011	0.39	0.39	0.63	0.55	0.66	0.58	1.00	0.62	0.67	0.49	0.49	0.49
37	0.016	0.59	0.59	0.95	0.83	0.99	0.87	1.51	0.94	1.01	0.74	0.74	0.74
38	0.009	0.34	0.34	0.55	0.48	0.57	0.50	0.87	0.54	0.58	0.43	0.43	0.43
39	0.006	0.21	0.21	0.34	0.29	0.35	0.310	0.54	0.33	0.36	0.26	0.26	0.26
40	0.003	0.12	0.12	0.20	0.17	0.21	0.18	0.31	0.19	0.21	0.15	0.15	0.15
41	0.005	0.17	0.17	0.28	0.24	0.29	0.25	0.44	0.27	0.30	0.22	0.22	0.22
42	0.002	0.09	0.09	0.15	0.13	0.15	0.13	0.23	0.14	0.16	0.11	0.11	0.11
43	0.006	0.20	0.20	0.32	0.28	0.34	0.29	0.51	0.32	0.34	0.25	0.25	0.25
44	0.009	0.33	0.33	0.53	0.46	0.55	0.48	0.84	0.52	0.56	0.41	0.41	0.41
45	0.003	0.13	0.13	0.21	0.18	0.22	0.19	0.33	0.21	0.22	0.16	0.16	0.16

Table 2. (continued).

Villages	Uranium conc. (Bq L^{-1})	Ingestion dose (μSv y^{-1})											
		0–6 m	7–12 m	1–3 y	4–8 y	9–13 y		14–18 y		Above 18		Pregnancy	Lactation
						Male	Female	Male	Female	Male	Female		
Majalta													
46	0.04	1.43	1.43	2.28	1.99	2.38	2.09	3.62	2.25	2.43	1.78	1.78	1.78
47	0.048	1.74	1.74	2.78	2.42	2.90	2.54	4.41	2.74	2.96	2.16	2.16	2.16
48	0.69	24.59	24.59	39.15	34.13	40.95	35.83	62.21	38.67	41.78	30.49	30.49	30.49
49	0.39	13.93	13.93	22.17	19.33	23.19	20.29	35.23	21.90	23.66	17.27	17.27	17.27
50	0.69	24.62	24.62	39.18	34.16	40.99	35.87	62.27	38.71	41.82	30.52	30.52	30.52
51	0.37	13.17	13.17	20.97	18.28	21.93	19.19	33.32	20.71	22.38	16.32	16.33	16.33
52	0.45	15.99	15.99	25.46	22.19	26.63	23.30	40.45	25.15	27.17	19.83	19.83	19.83
53	0.51	18.33	18.33	29.18	25.44	30.52	26.71	46.36	28.82	31.14	22.72	22.72	22.72
54	0.51	18.38	18.38	29.27	25.51	30.62	26.790	46.51	28.91	31.23	22.79	22.79	22.79
55	0.40	14.27	14.27	22.71	19.80	23.76	20.790	36.09	22.43	24.24	17.69	17.69	17.69
56	0.65	23.36	23.36	37.18	32.41	38.89	34.03	59.08	36.73	39.68	28.96	28.96	28.95

Table 3. Variation of uranium concentration in different sources of water in Udhampur district, J&K, Himalayas.

Source	Udhampur		Ramnagar		Chenani		Majalta	
	H.P.	N.S./Bowli	H.P.	N.S./Bowli	H.P.	N.S./Bowli	H.P.	N.S./Bowli
Samples	12	6	9	8	5	6	9	2
Range (μg L^{-1})	0.25–27.15	0.29–23.03	0.19–27.93	0.13–17.72	0.15–0.68	0.10–0.39	1.63–28.06	26.65–28.09
pH	7.37–8.70	6.84–8.54	7.50–8.56	7.80–8.45	7.40–8.57	7.58–8.47	7.02–7.91	7.02–7.96
Conductivity (mS cm^{-1})	0.27–0.844	0.126–0.42	0.456–0.65	0.256–0.56	0.184–0.55	0.17–0.54	0.551–1.258	0.673–0.689
TDS (ppt)	0.13–0.422	0.063–0.22	0.224–0.32	0.128–0.28	0.091–0.27	0.084–0.162	0.276–0.629	0.666–0.728
WHO (μg L^{-1})	30		30		30		30	
USEPA (μg L^{-1})	30		30		30		30	
AERB (μg L^{-1})	60		60		60		60	
UNSCEAR (μg L^{-1})	9		9		9		9	
ICRP (μg L^{-1})	1.9		1.9		1.9		1.9	

H.P., hand pump; N.S., natural spring.

0.007–1.79 as given in Table 1. R_fD recommended by WHO and AERB, *i.e.* 1.2 and 4.4 μg kg^{-1} day^{-1}, respectively. According to AERB standards (2004), HQ for all samples was <1.0, indicating no risk due to chemical toxicity but according to WHO standards, HQ was >1.0 for 35% indicating some non-carcinogenic risk due to the drinking of groundwater as shown in Table 1.

Uranium concentration is mainly due to geology and type of rocks in that area. The variation of Uranium in groundwater samples is due to varied topography and lithology of the Udhampur district. Ground water in the study area occurs under alluvium and confined condition in the underlying rocks of the older age. The ground water occurrence is mainly controlled by topography, drainage, structure and lithology. Ground water occurs in the pore spaces of saturated part of the alluvium and underlying Siwalik groups of the rocks. Hard rock of Murree, Siwalik and older rocks comprises of fissured formations where ground water occurs in weathered, jointed and fractured parts. Ground water mainly occurs under certain condition with variable depth to water level depending upon hydro-morphic set up (Gupta and Verma, 1975).

The high value of Uranium concentration in Udhampur, Ramnagar and Majalta tehsils are may be due to igneous rocks such as granite and pegmatites, which are radioactive in nature and to phosphate rocks. High Uranium concentrations were found in Phosphate fertilizers in these regions and low value in Chenani. This may be due to sedimentary rocks such as sandstones, and siltstone (Singh *et al.*, 2015). The natural weathering of rocks (such as granite) dissolves the natural Uranium, which goes into the groundwater. Once in the water, Uranium does not transfer into the air.

The variation of Uranium concentration in ground water samples such as hand pumps and natural spring or bowli's has been also reported in Table 3. It has been found that the Uranium concentration is higher in hand pumps as compare to natural spring. The migration or mixing of chemicals in groundwater may be due certain reasons, These reasons can be anthropogenic factors, such as drainage, irrigation, groundwater pumping, waste or wastewater disposal from industry and other is man-made activities such as the use of Phosphate fertilizers, Pesticides, combustion of coal in thermal power plants, mining, depleted uranium from the wars.

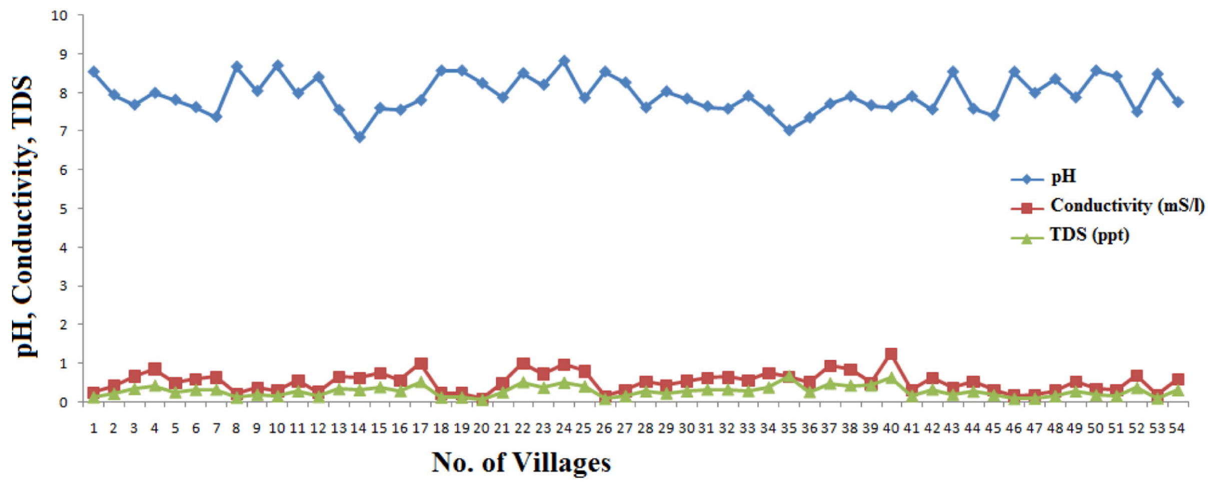

Fig. 3. Graphical representation of pH, TDS and conductivity with different locations of Udhampur district.

Table 4. Uranium concentration in drinking water samples in different parts of India.

S.No.	District name	Uranium concentration range ($\mu g\,L^{-1}$)	References
1.	Amritsar	6.87–45.42	Rani *et al.* (2013)
2.	Gurdaspur	1.24–24.30	Rani *et al.* (2013)
3.	Kangra (H.P)	0.64–19.9	Singh *et al.* (2015)
4.	Kullu	0.56–2.63	Singh *et al.* (2001)
5.	Ghaziabad	4.2–11.4	Singh *et al.* (1999)
6.	Kolar dist. (Karnataka)	0.3–1442	Babu *et al.* (2008)
7.	Fatehbaad, Haryana	0.6–21.9	Singh *et al.,* (2015)
8.	Bathinda	<0.2–571	Bajwa *et al.* (2015)
9.	Nalgonda, Andra Pradesh	0.2–118	Brindha and Elango (2013)
10.	Bhlwani, Haryana	19.72–43.31	Kansal *et al.* (2011)
11.	Hisar, Haryana	9.23–17.44	Kansal *et al.* (2011)
12.	Sirsa, Haryana	6.37–24.99	Kansal *et al.* (2011)
13.	Northan Rajasthan	0.9–3.0	Bansal *et al.* (1988)
14.	Cochin, Kerala, India	0.3–2.5	Prabhu *et al.* (2008)
15.	Jharkand	<0.5–27	Giri *et al.* (2011)
16.	Western Haryana, India	0.3–256.4	Singh *et al.* (2014)
17.	Coastal Districts, Kerala, India	0.3–4.9	Byju *et al.* (2012)
18.	Allahabad	0.08–471.27	Singh *et al.* (2006)
19.	Hydrabad	0.6–82	Balbudhe *et al.* (2012)
20.	Roper	1.93–20.19	Singh *et al.* (2008)
21.	Malwa region of Punjab	5.41–43.39	Mehra *et al.* (2007)
22.	Kathua (J&K)	0.48–21.92	Singh *et al.* (2015)
23.	Jammu (J&K)	0.18–20.81	Kumar *et al.* (2016)
24.	Udhampur	0.14–28.06	Present study

Physico-chemical parameters (pH, TDS and Conductivity) for water samples are also reported in Table 3. These parameters are important for the quality assurance and suitability of water for drinking purpose. pH is important measure of water quality because it represents the chemical nature of water such as its corrosive tendencies. Low pH values indicate the acidic nature of water and high values indicates the alkaline nature. In present study, the pH in water samples has been varied from 7.02–8.47 and all values is within the safe limit of 6.5–8.5 given by Bureau of Indian Standards (BIS limits, 1991). The variation in pH value is due to the contact of water with underground rocks, limestone, and slates. A negative correlation is observed between pH and Uranium which shows that Uranium concentration increases with decreasing pH (Kumar *et al.,* 2016). Figure 3 shows the graphical representation of pH, TDS and Conductivity with different locations of Udhampur district. TDS concentrations of water samples are vary from 0.063–0.728 ppt, only 2–3%

Table 5. Comparison chart uranium concentration of drinking water reported in worldwide.

S.No.	Country	Uranium concentration range ($\mu g\,L^{-1}$)	References
1.	Ontario, Canada	0.05–4.21	OMEE (1996)
2.	Central Australia	>20.0	Hostetler *et al.* (1989)
3.	China, Asia	0.004–28	UNSCEAR (2008)
4.	United States	0.012–3.08	UNSCEAR (2008)
5.	Okchun belt, Korea	0.5–263	Lee *et al.* (2001)
6.	Ogun state, Nigeria	20–267	Amakom and Jibiri (2010)
7.	Ghana	0.001–266	Rossiter *et al.* (2010)
8.	Algeria and Tunisia	0.01–3.4	Chkir *et al.* (2009)
9.	Germany	0.001–16.0	Birke *et al.* (2010)
10.	Europe	0.02–8.6	Sparove *et al.* (2013)
11.	Ulaanbaatar, Magnolia	0.01–57.2	Nriagu *et al.* (2012)
12.	Faislabaad, Pakistan	1.04–21.08	Akram *et al.* (2013)
13.	Udhampur, India	0.14–28.06	Present study

values lies above the safe limit 600 ppm (WHO, 2011). Electrical conductivity is related to the amount of salts dissolved in water. The EC in water samples varies from 0.126–1.258 mS cm^{-1}, and lies within the safe limit (WHO, 2011) and has no health significance.

The variation of Uranium concentration in different parts of India and worldwide are reported in Tables 4 and 5. It clearly shows that the Uranium concentration in water samples of Gurdaspur (Rani *et al.,* 2013), Roper (Singh *et al.,* 2008), and Malwa (Mehra *et al.,* 2007) of Punjab; Kangra (Singh *et al.,* 2015) of Himachal Pradesh; Fatehbaad (Singh *et al.,* 2015), Hisar (Kansal *et al.,* 2011) and Sirsa (Kansal *et al.,* 2011) of Haryana; and Kathua (Singh *et al.,* 2015) and Jammu (Kumar *et al.,* 2016) districts of Jammu & Kashmir are comparable to present work and Lower than Amritsar (Rani *et al.,* 2013), Bathinda (Bajwa *et al.,* 2015), Andrah Pradesh (Brindha and Elango, 2013), and Western Haryana (Singh *et al.,* 2014) as shown in Table 4. The reported values were also compared with worldwide as shown in Table 5.

5 Conclusions

Uranium concentration in water samples are found in the range of 0.14 to 28.06 $\mu g\,L^{-1}$ in Udhampur district of Jammu & Kashmir, Himalayas, and all values lies within the safe limit given by WHO, USEPA and AERB. So there is no health effect on the habitants of the study area.

– Uranium concentration is higher in ground water source (hand pumps) and lower in natural spring/bowli. High values in ground water is may be due to depth of water and underground rocks.
– The annual ingestion dose due to intake of uranium through drinking water for all age groups varied between 0.09 to 66.23 $\mu Sv\,y^{-1}$ with an average value of 14.61 $\mu Sv\,y^{-1}$ and all are well below the recommended limit suggested by WHO (2004).
– A variation 0.14–28.6 ppb in the uranium concentrations has been observed. This is due to geological construction of the entire study region and of different levels of surface mineralization.
– The mean chemical toxicity risk such as lifetime average daily dose (LADD) came out to be 0.81 $\mu g\,kg^{-1}\,day^{-1}$. The Hazard Quotient (HQ) was also varied from 0.007–1.79.

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