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Study of Uranium in Drinking Water around the Sohna Fault Line in Haryana

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ABSTRACT

Quality of drinking water is associated directly with the health of mass population. Therefore, study on radiation level in groundwater has been taken up around the Sohna fault line, Haryana state, India. Uranium concentration has been measured in drinking water samples collected from sources such as hand pump, tube well from different depths around the Sohna fault line, using LED Fluorimetry Technique. Uranium concentration in study area varies from 0.10 µg/L to 223.16 µg/L with an average value of 22.09 µg/L. The average value of uranium concentration is within the safe limit recommended by World Health Organization (WHO, 2011) and Atomic Energy Regulatory Board. The annual effective dose has also been measured in all the water samples and is found to be below the prescribed dose limit of 100 µSvy^{-1} recommended by WHO (2011). Risk assessment of uranium in water is also calculated using life time cancer risk, life time average daily dose and hazard quotient. The high uranium concentration observed in certain areas is due to interaction of ground water with the soil formation of this region and the local sub-surface geology of the region.

INTRODUCTION

Monitoring of natural radionuclide and their progeny in the environment has been given considerable attention all over the world. Study of natural radioactivity gives the information about the dose rate received by population, changes in background radiations because of nuclear activities, industries, power plants etc. There are two types of sources of natural radiations one is terrestrial and another is cosmogenic. Radionuclides exist in different amount in construction material, soil, water, rocks and air which are the part of terrestrial sources. Man is exposed by these radiations through food or inhalations and primary cosmic radiations which are coming from outer space are the part of cosmogenic sources. Radiations originating from terrestrial radionuclide's such as uranium, thorium which are existing since earth creations are categorized as virgin natural sources (Khater et al. 2008). Radiations originating from mining, production of fertilizers and usage of fissile fuels are classified as modified natural sources and are known as Technologically Enhanced Natural Radiation (TENR) (Gesell and Prichard, 1975). Exposure to natural radiation is correlated with geological and geographical parameters (Fujitaka et al.1981; Florou and Kritidis, 1992). Everybody on the earth are continuously exposed to few ionizing radiations as a background radiations. Irradiation is the medium of external exposure of radiations. Inhalation and ingestion process are the part of internal exposure of radiations. Background radiations are due to natural radioactivity which exists everywhere since earth creation (Puranik et al. 2007). Uranium (^{238}U) and its decay products radon (^{222}Rn) are two natural radioactive which can cause health issues if found in excess amount in groundwater (Kumar et al. 2016). Uranium is a naturally occurring in most rocks, soil, and even in the ocean. It is a radioactive metallic element, is very dense, ductile, silver-white. It is found more commonly than gold, silver or mercury and found as an oxide or complex salt in minerals such as pitchblende and carnotite. Naturally, it has main three isotopes such as ^{238}U (4.5 billion year half life), ^{235}U (700 million years half life), and a very small amount of ^{234}U (25 thousand years half life) and all these are radioactive with very long half lives. ^{238}U is the isotope of interest because of it's high abundance in total natural uranium i.e. 99.3% by weight (Mehra et al. 2007), and in addition it is the parent element of the most frequently studied isotope of radon (^{222}Rn). Uranium isotopes are primarily emitting alpha particles hence they are health hazardous only through ingestion or inhalation.

Uranium concentration depends on the isotopic composition and processing history. Water flowing through and over rock, soil formations dissolves many minerals and compounds, including ^{238}U; so different amount of it are found in few water sources. The average value of ^{238}U in earth crust is 2.7 ppm (Skeppstrom and Olofsson, 2007) and it is very harmful because of its toxicity rather than its radioactivity. The toxicity of uranium depends upon the solubility, ways of elimination, solubility of particle, contact time and way of exposure (ATSDR, 1999). ^{238}U enters into human body mostly by drinking of groundwater (Bajwa et al. 2015), through air or food in which 85% uranium enters through water and 15% due to food (Crawford-Brown and Cothern, 1987). Uranium has been identified as a nephrotoxin which may be the reason of kidney damage (ATSDR, 1999). Because large value of uranium in drinking water may results in health issues, therefore, measurement of ^{238}U concentration becomes very important for health risk assessment (Panghal et al. 2017). If a human body is exposed to dissolve natural uranium approximate 0.1 mg kg^{-1} weight of body, it can result in serious chemical hazards to lungs and kidneys (Panghal et al. 2017, Duggal et al. 2013 Mathew and Edward, 2004).

Human being is always exposed to some amount of uranium from air, food, building material and drinking water as it is present everywhere in earth environment and it becomes impossible to avoid exposure of radiations from uranium (Gahrouei et al.2013).

Uranium is a naturally occurring long-lived radionuclide, which is known for both its radiotoxicity and chemical toxicity (Takeda et al. 2006). In order to assess its effect on public health, knowledge is

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necessary about the distribution and transfer of ^{238}U in the soil-water plant system, especially in agricultural fields (Takeda et al. 2006). Uranium and other heavy metal impurities may accumulate in the soil and be leached into ground and surface water where they can be taken up by plants and transferred into the food chain. The concentration of uranium in water depends on many factors such as its concentration in the aquifer rock, the partial pressure of CO_2, and the presence of oxygen and complexion agents in the aquifer. The characteristics of water that mainly determine its capacity to dissolve, carry or deposit elements are its pH, temperature, redox potential, concentration and properties of dissolved salts, flow rate, and residence time (Khater et al. 2008).

Uranium has produces many health issues in human beings due to exposure to radiations produce from uranium. Most of the isotopes of uranium are alpha emitter which has small penetrating power. Through ingestion or inhalation process, uranium compounds enter into human being and produces radiation hazards. However, worker of uranium minings are exposed by radiations which are decay products of uranium. An individual exposed to uranium at the handling and processing unit and radiation may produce health hazards, increased the probability of cancer during their life time. A health hazard from the radiations is different from the natural occurring health issues because it produces after many years of the exposure takes place. Uranium intake increase the probability of health hazards produces due to radiations (Mathew and Edward, 2004).

In the study area, main source of drinking water is ground water and it become necessary to know the quality of groundwater for radiological safety or not. Radioactivity in water is due to uranium and its decay product radon, so it becomes important to study about these elements in water. Study of uranium in water gives the information of chemical and radiological toxicity in water due to uranium (Kumar et al. 2016).

GEOGRAPHY OF THE AREA UNDER STUDY

Geographically, Haryana state is situated in north India in between 27°37' and 30°35' N latitude and 74°28' to 77°36' E longitude. The height of the state from the sea level is 213.36-274.32 m. Gurugram is the part of national capital region (30km south of New Delhi) in north India situated in between 28°27'21.6" N latitude and 77°1'44.4" E longitude. The district Gurugram is the second largest city in the Indian State of Haryana and is the industrial and financial center of state. The height of this district from sea level is around 216.99m. Per capita income of Gurugram is third highest in India. Aravalli hills made this city more famous. A famous museum of folk and tribal art is located in this state. Sohna is a small town which is located just 25km in south of Gurugram. Sohna is known for its hot water springs and famous Shiva temple. Sohna is located in between 28°15'0" N latitute and 77°4'12" E longitude and the height of the Sohna from sea level is only 212.14m. There is a fault line (a high risk zone) which lies between the Delhi ridge and Sohna town and falls between the Arjangarh and Manesar outcrops. All the developed area in Gurugram comes within 200 km of the faultline itself. The Sohna fault line is located at the junction between the hard rock terrain of the Aravalli hills and the sandy formation of the Yamuna river. Jhajjar (80 km away from sohna) is one of the famous district in Haryana well known for its developing economy and infrastructural growth. Jhajjar is located at 28°37'12" N, 76°39'0" E. There are lots of fertile soils available and large varieties of crops are also grown in Jhajjar. Dairy products, auto parts, shoes, steel tubes, ply wood, deep fridge, lead pencil, glass, petro chemicals, medical disposables, plastic toys, ammunition box, mustard oils and many more are manufactured in Jhajjar. Many of the major industrial units have been set up in Jhajjar district. Different varieties of rabi and kharif crops are grown. Gudha is also a small village in Jhajjar tehsil (3km north of Jhajjar). Place

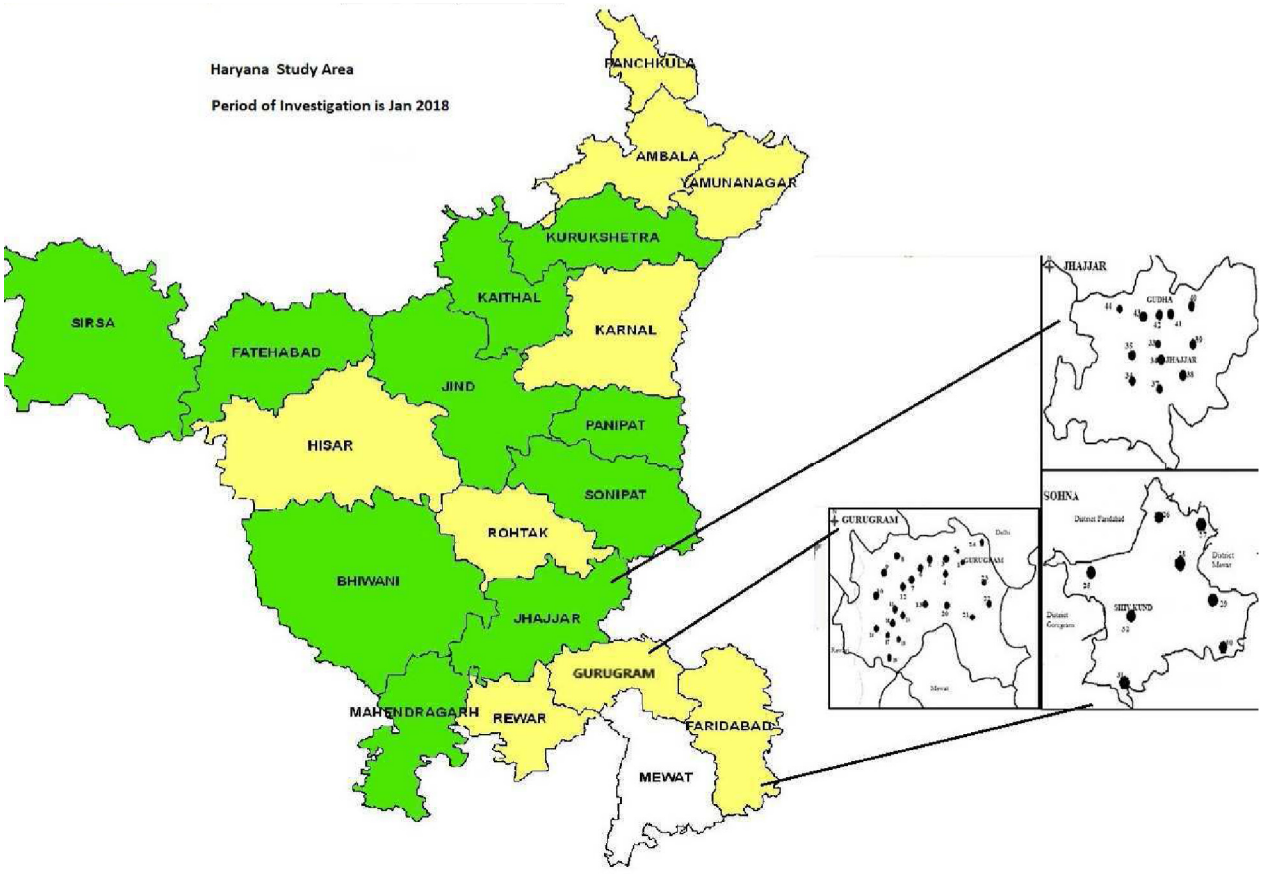

Fig.1. Map of study area, Haryana (period of investigation January 2018

Gudha is located at 28°38'32.06" N and 76°38'25.97" E. Figure 1 shows the geological map of studied area. Groundwater of study area is saline and water depth vary from 194 meter to 250 meter while annual rainfall is 450 mm to 750 mm. Gurugram district area is conspicuously flat topography, however, in the north-eastern part small isolated hillrocks of Precambrian rocks are exposed. The alluvial plain is formed by the Sahibi river which is tributary of river Yamuna. The soil are medium textured loamy sand is the average texture in Gurugram district and Sohna blocks. The climate of the district can be classified as tropical steppe,semi-arid and hot which is mainly characterized by the extreme dryness of the air except during monsoon months, intensely hot summers and cold winters. The normal annual rainfall in Gurgaon district is about 596 mm. The Gurgaon district is occupied by Quaternary alluvium and Precambrian meta- sediments of Delhi Supergroup. The alluvium comprises of thick beds of fine to coarse-grained sand with alternating layers of thin clays. The major part of Gurgaon district is underlain by Quaternary alluvium consisting of sand, clay and silt.

The normal annual rainfall in Jhajjar district is about 532 mm. The area forms a part of Indo- Gangetic alluvial plain ranging from Pleistocene to recent in age aeolian deposits of sub-recent age cap the plains. The sediments comprise of clay, sand and kankar mixed in different proportions. The ground water in the area occurs in the alluvium of Quaternary age. The permeable granular zones comprising fine to medium sand and occasionally coarse grained sand and gravel.

The normal annual rainfall in Faridabad district is about 542 mm. Soils of Faridabad district are classified as tropical and brown soils, existing in major parts of the district. Groundwater occurs in alluvium and the underlying weathered/fractured quartzites. Alluvium comprises sands, silt, Kankar and gravel which form the principal ground water bearing horizon.

MATERIALS AND METHODS

For the measurements of uranium in water samples, there are many methods such as fission track registration, laser fluorimetry, anodic stripping voltammetry, neutron activation analysis and LED Fluorimetry (Zamora et al. 1998; Bhangare et al. 2013; Bajwa et al. 2015; Kumar et al. 2016).

Light Emitting Diode (LED) Fluorimetry is an excellent spectroscopic technique for the detection of uranium in water and high computing speed (Kumar et al. 2003). In the present study, uranium concentration in drinking water of central part of Haryana has been evaluated in January, 2018. LED Fluorimetery methodology has been used for measurements of uranium in drinking water which is based on the principle of measurement of fluorescence of uranium complexes in the groundwater as shown in Fig.2. When ultra violet light of suitable wavelength falls on uranium complex, it excited and emit green fluorescence that can be estimated by a Photomultiplier Tube (PMT) this depend upon the intensity of excitation source and give information about uranium present in the groundwater (Rani et al. 2013).

Fig.2. Quantalase Uranium Analyser

The Quantalase uranium analyser UA2 is used for the estimation of uranium concentration in ground water (Fig.2).

Instrument can evaluate uranium content from 0.5 to 1000 ppb. When 5g of sodium phosphate is mixed with 100 ml double distilled water then 5 % sodium pyrophosphate ($Na_4P_2O_7$) solution is obtained. For achieving the reagent pH equal to 7, orthophosphoric acid (H_3PO_4) is added drop by drop (Kumar et al. 2016; Panghal et al. 2017). Water sample of about 6 ml mixed with 0.6 ml of 5 % $Na_4P_2O_7$ in cleaned cuvette and place in cuvette chamber for fluorescence reading by the instrument (Kumar et al. 2016). For measured blank counts, a blank sample was obtained with the help of double distilled water with same amount of fluorescing reagent for measurement of ^{238}U content (Rani et al. 2013).

RESULTS

The data for uranium concentration (μgL^{-1}), annual effective dose (μSvY^{-1}), Excess cancer rate (^{238}U, ^{235}U, ^{234}U) for cancer mortality (rate of death in a population) and morbidity (rate of disease across a population) and lifetime average daily dose to the uncovered populaces of these regions are abridged in Table 1. All the data is obtained by using L.E.D fluorimeter. The uranium concentration was observed to shift in the range 0.10 – 223.16 μg/L with the mean estimation of 22.09 μg/L. Out of 44 investigated tests, 37 (84.33%) were observed to be underneath 30 μg/L which is the suggested passable breaking point by USEPA, 2003. Two tests out of 44 (4%) were observed to be underneath 60 μg/L which is the suggested admissible point of confinement by USEPA, 2003 and AERB, 2004. 5 tests out of 44 (11.3%) were observed to be over 60 μg/L. Number of samples with different ranges are shown in the pi diagram in Fig.3.

RADIOLOGICAL HAZARDS

The uranium activity concentration (U_{conc}) in Bq/L was calculated using

$$U_{conc}\ (Bq/L) = \text{Measured Value of } U_{conc}\ (\mu g/L) \times \text{Conversion Factor } (0.025\ Bq/L)$$

Radiological hazard which is additionally communicated as Excess tumor chance is assessed utilizing the accompanying condition (Mathew and Edward, 2004):

$$\text{Radiological Cancer Risk} = U_{conc}(Bq/L) \times \text{Risk Factor (per Bq/L)} \quad (1)$$

Risk factor is calculated using equation ((Mathew and Edward, 2004):

$$\text{Risk Factor} = \text{Risk Coefficient } (Bq^{-1}) \times \text{Water Ingestion Rate (L/Day)} \times \text{Total Exposure Duration (days)} \quad (2)$$

Hazard coefficient for mortality and morbidity in condition (2) was taken as 1.19 x 10^{-9} Bq^{-1} and 1.84 x 10^{-9} Bq^{-1} individually. Water ingestion rate was taken as 1.38 L/Day and aggregate introduction term was taken as 25509 days. Hazard Factor for mortality and morbidity was ascertained to be 4.19 x 10-5 and 6.48 x 10^{-5} individually. The malignancy chance for mortality was observed to change in the range from 4.7×10^{-11} to $1.1\times10^{-7}$with the mean estimation of 1.10×10^{-8} for ^{238}U and from 3.96×10^{-11} to 9.21×10^{-8} with the mean value of 9.12×10^{-9} for ^{235}U and for ^{234}U the range from 3.89×10^{-11} to 9.05×10^{-8} with the average value of 8.87×10^{-9}. Also chance for morbidity was observed to change in the range for ^{238}U is from $7.66\times10^{-11}$to $1.78\times10^{-7}$with a mean value of 1.77×10^{-8}, for ^{235}U range from $6.25\times10^{-11}$to $1.46\times10^{-7}$with average value of $1.44\times10^{-8}$and for ^{234}U range from $6.06\times10^{-11}$to $1.41\times10^{-7}$with average value of 1.4×10^{-8}. A

Table 1. Uranium concentration and annual effective dose in study area (January, 2018)

Sample Code	Locations	Latitude & Longitude	Water Sources	Uranium Conc. (µg/l)	U (Bq./L)	Du (µSv/y)	LADD
1	Sec 33 near Sihi Gurugram	28°24'56.5"N 76°57'43.6"E	Submersible	8.29	0.21	13.97	0.59688
2	Tatvam villas Sec 48 Gurugram	28°24'37.0"N 77°02'19.8"E	Well	2.01	0.05	3.39	0.145008
3	Huda city center sec 41 Gurugram	28°27'26.0"N 77°04'10.5"E	Submersible	3.58	0.09	6.04	0.25776
4	Sahara mall Sikanderpur Gurugram	28°28'46.3"N 77°05'13.1"E	Handpump	1.33	0.03	2.24	0.09576
5	Sikandpur badhasc 85 Gurugram	28°24'03.3"N 76°56'54.3"E	Submersible	4.51	0.11	7.61	0.32472
6	Dwarka exprees tecknagar Gurugram	28°29'03.9"N 76°59'25.5"E	Well	21.20	0.54	35.70	1.5264
7	Dundhera ganvidpltwl sec 19 gurugram	28°30'27.6"N 77°04'41.8"E	Handpump	3.36	0.08	5.66	0.24192
8	Phase 3 green polish sec 88 Gurugram	28°24'33.9"N 76°56'59.1"E	Well	7.20	0.18	12.13	0.5184
9	Harbla dhani Sikhopur sec 78 gurugram	28°22'31.0"N 76°58'18.0"E	Submersible	4.80	0.12	8.09	0.3456
10	Udyog vihar sec 20 Gurugram	28°30'23.2"N 77°05'01.4"E	Handpump	0.10	0.002	0.16	0.00684
11	Sankar vihar sec 104 Gurugram	28°29'08.3"N 77°01'09.1"E	Handpump	18.50	0.47	31.15	1.332
12	laknaula sec 81 Gurugram	28°22'50.3"N 76°57'00.8"E	Submersible	4.88	0.12	8.23	0.35136
13	Huda water treatment plant sec 100 Gurugram	28°27'50.0"N 76°58'07.7"E	Submersible	2.73	0.07	4.61	0.19656
14	Allawardi sec-105 Gurugram	28°29'40.0"N 77°01'13.7"E	Handpump	1.64	0.04	2.76	0.11808
15	Manesar power house Gurugram	28°21'06.4"N 76°56'29.1"E	Submersible	6.10	0.15	10.27	0.4392
16	H block Vatikaindia block sec 83 Gurugram	28°23'39.8"N 76°57'05.3"E	Submersible	9.04	0.23	15.22	0.65088
17	sec 29 Patudi road Gurugram	28°25'45.7"N 76°57'38.1"E	Handpump	6.14	0.16	10.35	0.44208
18	Rampura sec 82 Gurugram	28°23'11.1"N 76°57'25.1"E	Submersible	5.91	0.15	9.95	0.42552
19	Dhanvanpur village Gurugram	28°28'24.3"N 76°58'41.3"E	Handpump	12.24	0.31	20.61	0.88128
20	Cartepuri village sec 23a Gurugram	28°30'22.7"N 77°02'21.1"E	Submersible	2.72	0.07	4.58	0.19584
21	Hayatt regency Gurugram	28°23'22.4"N 76°57'18.0"E	Submersible	6.67	0.17	11.24	0.48024
22	CMS complex Ashok vihar Gurugram	28°29'08.3"N 77°01'09.1"E	Submersible	1.68	0.04	2.84	0.12096
23	sec 90 Gurugram	28°24'25.2"N 76°55'49.5"E	Submersible	12.04	0.03	20.29	0.86688
24	sec25 Baluda Sohna	28°14'39.4"N 77°04'14.7"E	Submersible	0.19	0.005	0.32	0.43776
25	Harinagar Baluda Sohna	28°14'56.6"N 77°04'24.8"E	Well	2.34	0.06	3.96	0.013464
26	Sohna Rural	28°15'02.6"N 77°05'07.7"E	Submersible	3.99	0.10	6.73	0.16848
27	Shahid samara kragav vatika Sohna	28°15'18.2"N 77°04'16.9"E	Well	1.45	0.04	2.45	0.28728
28	Pahad colony Sohna	28°14'29.2"N 77°04'01.1"E	Handpump	1.25	0.03	2.11	0.1044
29	Sohna bus stand	28°14'44.0"N 77°04'19.8"E	Handpump	2.27	0.06	3.83	0.09
30	Thakurwara Sohna	28°14'57.2"N 77°03'52.8"E	Spring	4.44	0.11	7.49	0.163584
31	Shiv kund Sohna	28°14'46.8"N 77°03'51.5"E	Spring	0.90	0.02	1.52	0.31968
32	Ambedkar chowk Jhajjar	28°36'30.4"N 76°39'00.5"E	Submersible	29.33	0.74	49.39	0.064872
33	officer colony Jhajjar	28°36'00.8"N 76°40'03.2"E	Submersible	27.35	0.69	46.06	2.11176
34	civil line road Jhajjar	28°36'37.6"N 76°38'42.8"E	Tubewell	36.89	0.93	62.11	1.9692
35	Jaundhi Jhajjar	28°37'58.9"N 76°40'01.6"E	Submersible	30.10	0.76	50.68	2.655936
36	Beri-Jhajjar marg Jhajjar	28°37'44.9"N 76°38'21.5"E	Tube well	115.50	2.92	194.47	2.1672
37	Sita ram lake Jhajjar	28°36'43.1"N 76°39'31.8"E	Tub well	12.06	0.32	20.31	8.316
38	Jhajjar bus stand	28°37'24.4"N 76°38'56.9"E	Submersible	104.80	2.65	176.49	0.86832
39	near govt ITI Gudha, Jhajjar	28°38'19.6"N 76°38'42.3"E	Submersible	223.16	5.64	375.74	7.5456
40	near post office jaundhi Gudha Jhajjar	28°38'11.0"N 76°39'05.5"E	Tub well	31.80	0.80	53.55	16.06752
41	hanuman mandirgudhajhajjar	28°38'35.2"N 76°38'22.7"E	Submersible	78.66	1.99	132.44	2.2896
42	Jhajjar rural Gudha	28°38'26.3"N 76°39'31.5"E	Handpump	29.94	0.76	50.11	5.66352
43	Dhorgudha jhajjar	28°38'41.4"N 76°37'27.2"E	Handpump	82.95	2.10	139.67	2.15568
	Min			0.10	0.002	0.16	5.9724
	Maximum			223.16	5.64	375.74	0.0068
	Average			22.09	0.55	37.20	16.07

variation graph between cancer morbidity and mortality is shown in figure 3(a)

Chances of cancer ncreases due to the illness. The main reason for illness in a particular area can be due to the contaminated food and water they used. Food can be contaminated due to excess use of fertilizers during production (Skeppstrom and Olofsson, 2007) and water can be contaminated due to the mixing of industrial wastages in rivers (Gaskova and Boguslavsk, 2013). So by using this contaminated

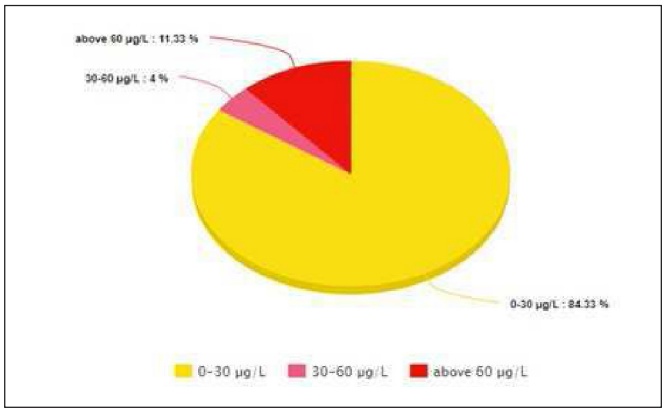

Fig.3. Number of samples in different ranges of uranium concentration.

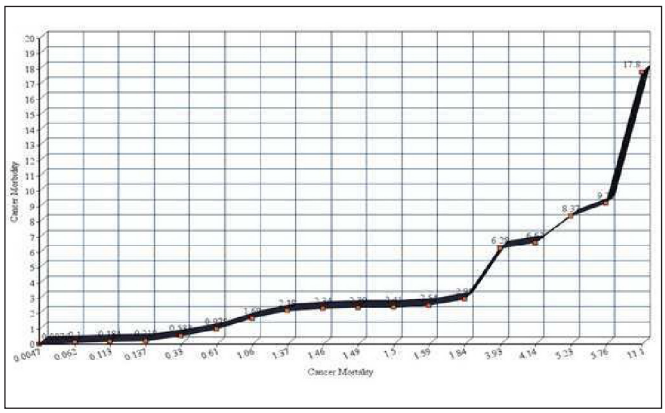

Fig.3a. Cancer morbidity and mortality

Table 2. Cancer mortality and cancer morbidity in study region (January, 2018)

Sample Code	CANCER MORTALITY			CANCER MORBIDITY		
	U-238	**U-235**	**U-234**	**U-238**	**U-235**	**U-234**
1	4.14E-09	3.42E-09	3.37E-09	6.62E-09	5.41E-09	5.24E-09
2	1.01E-09	8.31E-10	8.17E-10	1.61E-09	1.31E-09	1.27E-09
3	1.79E-09	1.48E-09	1.46E-09	2.87E-09	2.34E-09	2.27E-09
4	6.65E-10	5.49E-10	5.40E-10	1.06E-09	8.69E-10	8.42E-10
5	2.25E-09	1.86E-09	1.83E-09	3.61E-09	2.95E-09	2.86E-09
6	1.06E-08	8.75E-09	8.60E-09	1.69E-08	1.38E-08	1.34E-08
7	1.68E-09	1.39E-09	1.36E-09	2.68E-09	2.19E-09	2.12E-09
8	3.60E-09	2.97E-09	2.92E-09	5.76E-09	4.70E-09	4.56E-09
9	2.40E-09	1.98E-09	1.95E-09	3.84E-09	3.13E-09	3.04E-09
10	4.78E-11	3.96E-11	3.89E-11	7.66E-11	6.25E-11	6.06E-11
11	9.23E-09	7.63E-09	7.51E-09	1.48E-08	1.21E-08	1.17E-08
12	2.44E-09	2.02E-09	1.98E-09	3.90E-09	3.19E-09	3.09E-09
13	1.37E-09	1.13E-09	1.11E-09	2.19E-09	1.79E-09	1.73E-09
14	8.19E-10	6.77E-10	6.66E-10	1.31E-09	1.07E-09	1.04E-09
15	3.04E-09	2.52E-09	2.48E-09	4.87E-09	3.98E-09	3.86E-09
16	4.51E-09	3.73E-09	3.67E-09	7.22E-09	5.90E-09	5.72E-09
17	3.07E-09	2.54E-09	2.50E-09	4.91E-09	4.01E-09	3.89E-09
18	2.95E-09	2.44E-09	2.40E-09	4.72E-09	3.85E-09	3.74E-09
19	6.11E-09	5.05E-09	4.97E-09	9.78E-09	7.98E-09	7.74E-09
20	1.36E-09	1.12E-09	1.10E-09	2.17E-09	1.77E-09	1.72E-09
21	3.33E-09	2.75E-09	2.71E-09	5.33E-09	4.35E-09	4.22E-09
22	8.43E-10	6.97E-10	6.85E-10	1.35E-09	1.10E-09	1.07E-09
23	6.01E-09	4.97E-09	4.89E-10	9.62E-09	7.86E-09	7.62E-09
24	3.03E-09	2.51E-09	2.47E-09	4.86E-09	3.97E-09	3.84E-09
25	9.37E-11	7.75E-11	7.62E-11	1.50E-10	1.22E-10	1.19E-10
26	1.17E-09	9.69E-10	9.53E-10	1.88E-09	1.53E-09	1.49E-09
27	2.00E-09	1.65E-09	1.62E-09	3.19E-09	2.61E-09	2.53E-09
28	7.27E-10	6.01E-10	5.91E-10	1.16E-09	9.50E-10	9.21E-10
29	6.27E-10	5.18E-10	5.10E-10	1.00E-09	8.19E-10	7.94E-10
30	1.13E-09	9.37E-10	9.22E-10	1.81E-09	1.48E-09	1.44E-09
31	2.22E-09	1.83E-09	1.80E-09	3.55E-09	2.90E-09	2.81E-09
32	4.50E-10	3.72E-10	3.66E-10	7.20E-10	5.88E-10	5.70E-10
33	1.46E-08	1.21E-08	1.19E-08	2.34E-08	1.91E-08	1.85E-08
34	1.37E-08	1.13E-08	1.11E-08	2.18E-08	1.78E-08	1.73E-08
35	1.84E-08	1.52E-08	1.50E-08	2.95E-08	2.41E-08	2.33E-08
36	1.50E-08	1.24E-08	1.22E-08	2.40E-08	1.96E-08	1.90E-08
37	5.76E-08	4.77E-08	4.69E-08	9.22E-08	7.53E-08	7.30E-08
38	6.27E-09	5.18E-09	5.10E-09	1.00E-08	8.19E-09	7.94E-09
39	5.23E-08	4.32E-08	4.25E-08	8.37E-08	6.84E-08	6.63E-08
40	1.11E-07	9.21E-08	9.05E-08	1.78E-07	1.46E-07	1.41E-07
41	1.59E-08	1.31E-08	1.29E-08	2.54E-08	2.07E-08	2.01E-08
42	3.93E-08	3.25E-08	3.19E-08	6.28E-08	5.13E-08	4.97E-08
43	1.49E-08	1.24E-08	1.21E-08	2.39E-08	1.95E-08	1.89E-08
Min	4.14E-08	3.42E-08	3.37E-08	6.62E-08	5.41E-08	5.24E-08
Max	4.78E-11	3.96E-11	3.89E-11	7.66E-11	6.25E-11	6.06E-11
Avg.	1.11E-08	9.21E-08	9.05E-08	1.78E-07	1.46E-07	1.41E-07

food and water chance of illness increases in body which can cause serious diseases in future.

Variance Graph between Morbidity and Activity Concentration

Naturally occurring radionuclides of the uranium-radium series, such as ^{210}Pb and ^{210}Po have long been associated with tobacco plants (Papastefanou, 2009). Deposition of ^{210}Pb by rainfall is the principal mechanism of ^{210}Pb entry in plants. Radionuclides which were deposited onto the plant leaves, captured on tobacco trichomes. This is how radionuclides mixed with tobacco (Papastefanou, 2009). According to Global Adult Tobacco Survey, 2009-10, 23.7% adults in Haryana are using tobacco in any form and among them 22.7% are daily tobacco users (GAT, 2017). Additional 70.2% of adults are exposed to second hand smoke at home and nearly 53% of adults are exposed to second hand smoke in public places (GAT, 2017). During the smoking of tobacco, radon is released which is the main reason for lung cancer (Samet, 1989).

Concentration of uranium also effect the life average daily dose. LADD also increases the activity concentration of uranium increases.

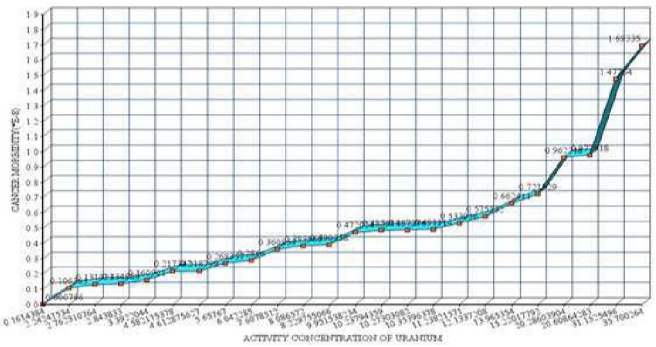

Fig.4. Cancer morbidity vs. activity concentration (Gurgaum)

CHEMICAL HAZARDS

Poisonous quality hazard related with any compound is assessed regarding LADD (Lifetime Average Daily Dose). This can be assessed utilizing the accompanying conditions (Gahrouei et al., 2013)

$$LADD = \frac{EC}{A} \times \frac{WIR}{W} \times F \times L \quad (3)$$

Where LADD in μg kg^{-1} day^{-1}, EC in condition (3) is the U_{conc} (μg/L), WIR is the ingestion rate (L/Day) which is taken to be 1.38 L/Day. F is the presentation recurrence (Days/year) which is taken to be 365 days for each year (Gahrouei et al. 2013). L is the life expectancy (Years) which is taken as 69.89 years. W is the body weight (kg) which is taken as 70 kg. A is the average time (Days) which is taken as 25509 days (Gahrouei et al. 2013). Chemical hazard (LADD value) was varying in the range of 0.006 – 16.06μg kg^{-1} day^{-1} with the mean value of 1.59 μg kg^{-1} day^{-1} which exceeded the threshold daily intake for LADD of 1.0μgkg^{-1} day^{-1} accepted by WHO (2011).

EVALUATION OF ANNUAL EFFECTIVE DOSE

Yearly Effective Dose is the measure of the entire body dosage (Yadav et al. 2014). It was assessed utilizing the change factors given by WHO (2011).

$$DE = U_{conc} \times EF \times I_{annual} \quad (4)$$

Where DE in equation (4) is the annual effective dose (μSv/Y), U_{conc} is the activity concentration (Bq/L), EF is the effective dose per unit intake (μSv/Y/Bq/L) which is taken to be 4.5 x 10^{-8} and I_{annual} is the annual ingestion which was taken to be 1480L (4.05 x 365) (Mathew and Edward, 2004; Yadav et al. 2014).

Annual Effective Dose was found to be varying in the range from 0.16 – 375.75 μSv/Y with the mean value of 37.19 μSv/Y, which is below the recommended limit of 0.1 mSv (WHO, 2011).

pH of the samples was observed to differ from 7.13 to 8.31 with the mean estimation of 7.65 which is well within the adequate range of 6.5 – 8.5.

DISCUSSION

Average value of uranium activity concentration lies below the safe limits recommended by WHO (2011) and AERB (2004).

The health and environmental protection agencies had recommended safe limit of uranium in drinking water for human beings. ICRP-30, 1979 has suggested this limit as 1.9μg/l (USEPA, 2011). However UNSCEAR, 2000 recommended safe limit as 9μg/l. The WHO (2011) and U.S. Environmental Protection Agency (2003, 2011) have recommended 30μg/l of uranium in water as the safe limit. AERB (2004) has recommended safe limit of 60 μg/l in water samples.

The uranium concentrations higher than 30 μg/l are generally observed in drinking water coming from uranium rich zones. The

Table 3. List of studies conducted for the uranium concentration in drinking water samples of North India

Locations	Uranium Conc. (µg/l)	Water Source	Technique	References
Kullu	0.56 - 2.63	Handpum	Fission Track Technique	Singh et al.2001
Bathinda	1.65 – 74.98	Hand pump and tubwell	Fission Track Technique	Kumar et al. 2003
Malwa Region	5.41 – 43.39	Handpump	Fission Track Technique	Mehra et al. 2007
Upper Siwallik	1.08 – 19.28	Handpump, well	Fission Track Technique	Singh et al.2009
Ropar	1.93 - 20.19	Handpump, well	Fission Track Technique	Singh et al.2009
Western Haryana	6.37 – 38.43	Hand pump, tub well	Fission Track Technique	Kansal et al. 2011
Hanumangarh, Rajasthan	4.74 – 98.7	Hand pump	ICPMS	Rani et al., 2013
Shri Ganga Nagar, Rajasthan	4.42 – 133.0	Hand pump	ICPMS	Rani et al., 2013
Churu, Rajasthan	10.75 – 81.3	Hand pump	ICPMS	Rani et al., 2013
Sikar, Rajasthan	2.54 – 28.38	Hand pump	ICPMS	Rani et al., 2013
Uttar Pradesh	0.20 – 64.0	Drinking water	Laser Fluorimetery	Yadav et al., 2014
Kathua	0.26 - 21.92	Drinking water	Laser Fluorimetery	Singh et al.2015
Kangra	0.64 - 19.23	Drinking water	Laser Fluorimetery	Singh et al.2015
Hamirpur	1.66 - 29.5	Drinking water	Laser Fluorimetery	Singh et al.2015
Jammu	0.18 - 20.8	Groundwater	LED Fluorimetery	Kumar et al.2016
Mansa	5.9 - 645.22	Hand pump	LED Fluorimetery	Saini et al. 2016
Bathinda	7.9 – 323.93	Hand pump	LED Fluorimetery	Saini et al. 2016
Faridkot	7.62 – 375.85	Hand pump	LED Fluorimetery	Saini et al. 2016
Jind	7.31 – 34.05	Hand pump, tub well and submersible	LED Fluorimetery	Panghal et al. 2017
Rohtak	6.97 – 37.84	Hand pump, tub well and submersible	LED Fluorimetery	Panghal et al. 2017
Sonipat	7.11 – 40.25	Hand pump, tub well and submersible	LED Fluorimetery	Panghal et al. 2017
Panipat	7.95 – 39.43	Hand pump, tub well and submersible	LED Fluorimetery	Panghal et al. 2017
Near Sohna Fault region	0.10 – 223.16	Groundwater	LED Fluorimetery	Present study

uranium levels in a number of drinking water samples in study region cross the safety limit. This may be attributed to the geological formations of the study area due to the influence of the Aravalli hills present in vicinity. Population can be the main factor which can be responsible for the high dose of uranium in Gurugram. Rampant urbanization and industrial growth have resulted in a 73.93% increase in Gurugram's population in the last 10 years (Census, 2011). The growth could have been because of the migration of people from Delhi due to availability of affordable housing in the city in comparison to the national capital. There has also been a significant migration of working population from the nearby districts because of job opportunities that Gurugram offers. As per the provisional data released by the state, Gurugram population in 2011 stands at 15, 14,085 persons against 8,70,539 in 2001 (Census, 2011). The provisional Census report also shows that the density of population in the district is 1,241 persons per sq km (NDMAGI). Biological mass is responsible for the transfer of uranium. As we know Punjab is the main source for the production of wheat and famous for the export of wheat in all India (Saini et al. 2016). Wheat and other food material are exported from Punjab (Bajwa et al. 2017) and is also well known as cancer state particularly its Malwa region (Mehra et al. 2007). The wheat which is exported from Malwa region is specifically responsible for the uranium.

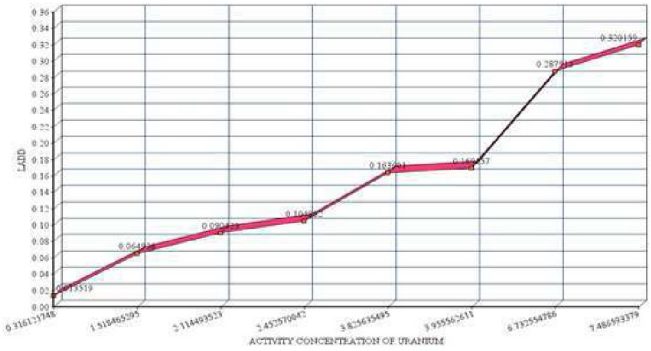

Fig.5. LADD vs. Activity concentration (Sohna).

A large number of people dies every year due to cancer as observed during the last 3 years in the states of Punjab and Haryana. A total of 12,091 deaths took place due to various forms of cancer in state (India Today Report, 2018). Health Ministry of Haryana confirmed 4,592 people died due to cancer in all 22 districts of Haryana in 2017. This is due to the rapid industrialization in different district of Haryana, such as Gurugram, Faridabad, Jhajjar and Rewari etc (India Today Report, 2018). These are generating huge amount of industrial sewerage & waste which are disposing of directly in rivers without undergoing treatment & recycling process in Effluent Treatment Plants (ETPs) & Sewage Treatment Plants (STPs). Gurugram has 3 STPs but their capacities to recycle are only 160 Million Gallon Daily (MGD) where the city is generating over 400MGD per day of sewage. So this industrial and sewage wastage are responsible for the uranium concentration in Gurugram (India Today Report, 2018).

Jhajjar is the new upcoming developing district of Haryana which established lots of new industrial projects. With the benefits, these industries also have lots of disadvantages. Bahadurgadh is the main industrial area of Jhajjar district. Bahadurgadh is famous for the production of glass, fiber and for the pesticides. In the glass industry from preparing material to glass melting process and preparation of the final product is due to the combustion and melting material (Jebelli et al. 2018). Silica is one of the most necessary materials to make glass. It has serious complications on our body system particularly on respiratory system and cause silicosis and respiratory cancer (Jebelli et al. 2018). Among adverse effects in mines and industries silica dust often been the subject of many controversies. 96% of the glass is made of silica. Bahadurgadh is famous for the manufaction of the glass like "Hindustan National Glass", "HNG Plant" are two main manufacturing industries for glass. This silica is responsible for the uranium. High concentration of uranium is commonly observed in silica (Micheal, 2014).

Uranium concentration is also high for some places of Jhajjar like Gudha. Flood is also responsible for the uranium concentration. Floods have been a recurrent phenomenon in Haryana from time immemorial. The devastating floods hit Haryana many times. In 1977, 78, 80, 83, 88, 93, 1995 and 1996 floods occurred in Haryana (NDMAGI). The

Table 4. Uranium concentration in water samples of some parts of world.

Country	Uranium Conc. (μg/l)	References
Turkey	0.24–17.65	Kumru 1995
New York	0.03–0.08	Fisenne and Welford 1986
USA	2.55	USEPA 1990, 1991
Argentina	0.04–11.0	Bomben et al. 1996
Jordan	0.04–1400	Gedeon et al. 1994, Smith et al. 2000
Kuwait	0.02–2.48	Bou-Rabee 1995
South Greenland	0.5–1.0	Brown et al. 1983
Amazonas (Brazil)	0.01 – 1.36	Silva and Bonotto, 2015
Southwestern Sinai (Egypt)	328 - 560	Aly and Ragab 2013
Northern Greece	0.01 – 10	Katsoyiannis et al., 2007
Russia	>477	Gaskova,Boguslavsky, 2013
Ulaanbaatar (Mongolia)	<0.01 – 57	Nriagu et al., 2012
Switzerland	0.05 – 92.02	Stalder et al., 2012
India	0.10 – 223.16	Present work (January, 2018)

floods in Haryana can occur because of some natural reasons such as its physiographic situation which makes a depressional saucer shape zone around the Delhi-Rohtak-Hisar-Sirsa axis. It has a poor natural drainage system and sometimes the heavy precipitation becomes a major contributing factor in causing flood as such in case of Rohtak flood, 1995 (NDMAGI).

This region is also famous for agriculture and use of phosphate fertilizers resulting in enhancement of the concentration of uranium in water. The high uranium concentration may be due to leaching through soil by heavy use of fertilizers in the agriculture lands and due to squanders discharged from factories in this region (Duggal et al. 2013). Higher concentration of bicarbonate and phosphate observed in shallow groundwater indicates their leaching from soil and also resulting in enhancing of leaching & mobility of uranium also (Puranik et al. 2005) .Overall, the quite higher uranium levels observed in water samples of the region may be due to anthropogenic activities. The presence of uranium in the environment is mainly due to the leaching from natural deposits, release from uranium industry, combustion of coal and other fuels and also from the extensive use of phosphate fertilizers etc. Various commercial industries including thermal power plants, oil refinery and fertilizer plant have been established in Gurugram district. Industrial wastes and fertilizers lead to add various salts in the soil and consequently in the groundwater (Stalder et al. 2012). Leaching of uranium from soil also increases with increase in salinity (TDS) and high level of TDS has been observed in this region. Carbonate and phosphate ions form complexes with total dissolved ^{238}U concentration as compared to carbonate, phosphate free water (Kumar et al. 2011). Fertilizers may also contain very high levels of uranium as phosphate fertilizers are prepared from phosphate rocks which are enriched with uranium. Thus urbanization and wide spread use of pesticides/fertilizers are certainly responsible for increased uranium concentration. Most of the cancer cases have been reported in this region and which may be the effect of uranium on the population. From the results it has been reflected that uranium in water may depend upon the geology and geographical conditions of the region. Uranium concentration is highest in Punjab and Haryana as compare to other states of north India (Saini et al. 2016). These two states have used the highest quantity of fertilizers for farming. Study revealed that uranium in the water may be increased by the using of Phosphate fertilizers. Agriculture chemicals, such as fertilizers enter in groundwater in two ways. From the first way, the chemical can enter the groundwater by rainwater into a stream as run off. This is especially problematic in urban environments where hard-surfaced roads allow rainwater to move over them without benefit of soil acting as a filter.

The water in streams replenishes groundwater. So the chemical are absorbed into the groundwater as well. The second way of contamination is through leaching which is the downward movement of a substance through the soil. These fertilizers may also dissolve into the surface water, which recharge the groundwater.

Organic farming is the best option to prevent these issues. Manures are plant and animal wastes which are used as sources of plant nutrients. They release nutrients after their decomposition. The art of collecting and using wastes from animal, human and vegetable sources for improving crop productivity is as old as agriculture. Arravalli Hill also effected the concentration of uranium in water and may be the region of high uranium concentration in some locations of study region.

In the work reported so far for north India, emphasis has been placed on the health hazards associated with the intake of uranium from water. Most of the studies related to uranium have been conducted using SSNTD (Singh et al. 2009). However, in several reported studies; ICPMS and LED Fluorimetery technique has been used (Gesell and Prichard, 1975). The reported values for uranium show a wide variation in the uranium of interest in different types of sources of water. However, work in this area is scarce and requires further research. According to the reported data, uranium is present in water at relatively low concentrations and is within the permissible limits and thus does not pose a serious threat to the public. The lowest reported uranium concentration is 0.10 μg/l for Udhyog Vihar in Gurugram whereas the highest is 223.16 μg/l for Gudha & Jhajhar. All the reported values of uranium in water of Jammu and Himachal Pradesh are within recommended limits and do not pose a serious threat to the population of North India (Singh et al. 2001). While some samples collected from Punjab and Haryana states show that uranium concentration in groundwater is very high as compared to recommended limits. Data is compared with worldwide studies is given in Table 3. Highest value of uranium in water samples of North India is very high as compare to Turkey (Kumru, 1995), New York (Fisenne and Welford, 1986), USA(USEPA, 1990,1991), Argentina (Bomben et al., 1996), Kuwait (Bou-Rabee, 1995), Amazonas (Brazil)(Silva and Bonotto, 2015), Northern Greece (Katsoyiannis et al. 2007), Ulaanbaatar (Mongolia) (Nriagu et al. 2012) Switzerland (Stalder et al., 2012) and South Greenland (Brown et al., 1983) while less than Jordan (Gedeon et al., 1994, Smith et al., 2000), Southwestern Sinai (Egypt) (Aly and Ragab, 2013), Russia (Gaskova and Boguslavsk, 2013).

The dose due to uranium in drinking water samples has large uncertainties which may be due to various types of underlying bedrocks present in the study region. Since the total doses being received by the inhabitants from uranium content in drinking water are quite below the prescribed dose limit recommended by WHO, 2011, drinking water is safe for the population of this region from the health hazard point of view.

Average value of LADD is more than the safe limit given by WHO, 2011 resulting in chemical effect of the uranium on the residents of the studied area.

CONCLUSION

Uranium concentration in study area varies from 0.10 μg/L to 223.16 μg/L with an average value of 22.09 μg/L. Out of 44 investigated tests, 37 (84.33%) were observed to be underneath 30 μg/L which is the suggested passable breaking point by USEPA, 1990. 2 tests out of 44 (4%) were observed to be underneath 60 μg/L which is the suggested admissible point of confinement by AERB, DAE, 2004. 5 tests out of 44 (11.3%) were observed to be over 60 ìg/L. The average value of uranium concentration for the entire study area has been found to be less than safe limits recommended by WHO, 2011 and AERB, DAE, 2004. Fault line is a natural phenomenon which occurs due to the natural activities like earthquake or any other internal movement of earth. As the average value of uranium is below the safe limits, so we can concluded that the activity concentration of uranium

is not affected by this fault line phenomena. The uranium concentration for the regions (Gurgram, Sohna and Jhajjar) from where Sohna fault line passes is observed normal. Thus, uranium concentration in groundwater is not affected by this natural fault line in the study area.

The ingestion dose due to uranium in drinking water varies from 0.16 – 375.75 μSv/Y with the mean value of 37.19 μSv/Y, which is below the recommended limit of 0.1 mSv recommended by WHO, 2011. The lifetime cancer mortality and morbidity risks possess no significance as the calculated risk is much lesser than the permissible risk limits, but Chemical hazard (LADD value) was varying in the range of 0.0069 – 16.01 μg kg^{-1} day^{-1} with the mean value of 1.59 μg kg^{-1} day^{-1} which is exceeded the threshold daily intake for LADD of 1.0μgkg^{-1} day^{-1} accepted by WHO (2011). So, there is no carcinogenic risk to humans, but non-carcinogenic health risks may be due to chemical toxicity of uranium in the study area. From all these it is concluded that radiological risks are not affected by this fault line but may be due to this chemical toxicity is varied. Life time daily dose (LADD) is affected by this fault.

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