Status of Uranium in Ground Water

URANIUM IN GROUNDWATER IN PUNJAB STATE, INDIA : STATUS PAPER

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EXECUTIVE SUMMARY

Uranium content in groundwater varies markedly depending upon geological terrain, climate, proximity of uranium deposits, as well as composition of the water. Results of uranium distribution in groundwater at global scale indicate that most countries do not have uranium hazard except Finland, China, Jordan and Switzerland. In India, the average reported range of uranium in groundwater is from 0.01 to 19.6 micrograms/ litre (ug/L).

Uranium in groundwater drawn from handpumps and shallow tube wells (up to the depth of 45 m) was first reported by Singh (1995) in Punjab State in the year 1995. Subsequently, many more workers reported presence of uranium in groundwater. Uranium content of groundwater in Punjab reported by various workers indicates its concentration range between 1.08 and 244 μg/L. The high values more than the permissible limit of 30 μg/L of United State Environmental Protection Agency (USEPA) and 60 μg/L of Atomic Energy Regulatory Board (AERB) occur at scattered places as hot spots. High concentration hot spots are not uniformally distributed. The hot spots are more common in the south-west parts of the Punjab lying in Bathinda, Faridkot, Monga and Firozpur districts. However, such hot spots also occur at other places like around Amritsar where sample containing 45.5 μg/l of uranium was reported.

Surface water (canal water) has very negligible concentration of uranium and is safe from uranium point of view.

In soils of Punjab, uranium concentration is not posing any hazards as revealed by data. The radioactivity levels in soil samples were found to be comparable to the national global average levels by Bhabha Atomic Research Centre (BARC, 2009).

Radon concentration (indicative of radioactive hazard) in groundwater of Punjab including of Malwa belt of Punjab State varies between 48 and 100 Bq/l. The values are within the permissible limit of 400 Bq/l.

The BARC study found uranium concentration in hair samples ranging from less than 3 ng/g to 248.7 ng/g. This lies within the range of variation according to BARC (2009). It is important to mention here that hair show cumulative concentration of uranium.

Further it may be mentioned here that uranium in the area is in the form of calcium dependent species, which do not cause significant adverse health effects (D.Mehta, personal communication). Therefore, chemical speciation is an important factor for the determination of uranium chemical toxicity in drinking water.

Basement granite core sample from Bathinda area also does not show any significant radioactivity. This rules out the basement granite as the possible source of uranium in groundwater as proposed by Guru Nanak Dev University (GNDU) scientists.

Areas away from flyash ponds have also been found to have uranium hot spots (concentration more than 30μg/l). Preliminary data around fly ash ponds does not indicate any abnormal concentration of uranium in groundwater. However, detailed investigations need to be taken up around flyash ponds to rule out the possibility of flyash as cause on the basis of scientific data.

It appears that use of phosphatic fertilizers along with mineralogical control within the sediments is one of the possible causes of uranium concentration in groundwater in the Punjab State. However, detailed systematic studies are required to confirm this.

Use of Reverse Osmosis should be promoted in the affected area as it will not only filter and remove uranium if present, but also other harmful contents such as fluoride in groundwater which is often high in groundwater of south-west Punjab and responsible for bone and joint problems observed in the local population (Singh and Kishore, 2009).

A detailed multi-disciplinary project involving study of uranium content in sediments, soils and groundwater from shallow and deeper aquifers and health impacts on local population needs to be taken up with the support of Department of Science & Technology, Govt. of India to have a systematic data and to know the exact causes which would help in finalizing the long-term remediation plans.

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INTRODUCTION

Uranium is an essential constituent in about 100 minerals. Of these most important mineral is Uraninite, UO_2 besides others (pitchblende, coffinite, brannnerite, davidite). It is found in small quantities in soils and rocks although the amount varies from place to place.

Average concentration of uranium in earth's crust is about 2.7 ppm (parts per million). Amongst igneous rocks, granites are known to contain maximum concentration of about 4.8 ppm. In sedimentary rocks, maximum concentration of about 4 ppm is found in shales. In Lignite, it ranges between 10 and 2500 ppm. Soil is found to contain about 1 ppm though it ranges between 1 to 5 ppm.

From the environmental point of view uranium is important because its hexavalent form is extremely mobile under oxidising conditions, especially in acid or carbonate rich waters. Radioactive decay of uranium produces radium which further decays to form radon gas. Therefore, measurements of radon gas in groundwater and soils etc. are useful in finding out radioactive hazards and such data has been extensively used in USA to find out radioactive hazardous areas.

High radon emissions are associated with some rocks like granites, phosphatic rocks and shales rich in organic materials. The level of radioactivity in air due to radon is measured in becquerels per cubic meter (Bq/m^3). One becquerel represents one atomic disintegration per second. In water, Bq/L is also used to measure radon/radioactivity.

Water in rivers and reservoirs usually contain very little radon, so homes that use surface water do not have a radon/radioactivity problem from their water.

URANIUM IN GROUNDWATER

Uranium content of groundwater varies markedly depending upon bed rock type and on proximity to Uranium deposits as well as composition of the water. Generally, levels of more than 4 ppb (parts per billion) are considered to be anomalous. However, in arid continental conditions, contents of several hundred ppb U or more have been recorded (Bowie and Plant, 1983) and in the vicinity of U deposits these may be as high as 2000 ppm (parts per million) or more. Higher concentration of uranium in drinking water is nephrotoxic and effects kidneys. However, recent studies done by Dr. Kurttio and his research collaborators in Finland and published by American Journal of Kidney diseases show 200 men and women in the age group of 18 to 80 years who used contaminated water for 16 years did not show evidence of renal damage. No direct deleterious effects were found. Further the Finnish study found no increase in the risk of leukemia (cancer of blood or bone marrow) or bladder or kidney (urinary organs) or stomach cancer from ingestion of natural uranium through drinking water even at very high exposure levels.

Average uranium content in groundwater in igneous terrains is 4.5 ppb (parts per billion); in sedimentary terrains about 2.62 ppb; in metamorphics 4.4. ppb and in ground water from sand and gravels about 2.5 ppb though it can range from 0 to 74 ppb.

Maximum contaminant level (MCL) for uranium in drinking water- MCL for uranium in the community water systems, has been set at 30 µg/l by the United States Environmental Protection Agency. The Atomic Energy Regulatory Board, India has set a limit for uranium in drinking water at 60 µg/l. The World Health Organisation (WHO) set a provisional guideline of 15 µg/l. These limits are exceeded in the drinking water for many communities worldwide.

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Global Scenario

Concentration of uranium in drinking water from different countries has been reported by various workers. Table-I summarizes the results of uranium concentration in drinking water of different countries. The results indicate that most of the countries do not have uranium hazard except Finland (0.5 – 6000 µg/l); China (0.1 -28 µg/l); Jordan (0.04 – 1400 µg/l) and Switzerland (0.1 – 40 µg/l).

Table-1: World-wide distribution of Uranium in groundwater.

Sr. No.	Country	Range of Uranium (µg/ltr)
1.	Canada	0.05 - 4.21
2.	Argentina	0.04 - 11.0
3.	New Mexico	More than 20
4.	Central Australia	More than 20
5.	Jordan	0.04 - 1400
6.	Finland, Europe	0.02 - 6000
7.	China	0.004 - 28
8.	Kuwait	0.02 - 2.48
9.	Turkey	0.24 - 17.65
10.	*India **India	0.08 - 471.27 0.01 - 19.6
11.	USA	0.012 - 3.08
12.	France	0.18 - 37.2
13.	Romania	0.02 - 1.48
14.	Itlay	0.02 - 5.2
15.	Germany	0.02 - 24

* Reported by Singh *et. al.*, 1993,2003
**Reported by Sahoo *et. al.*, 2009.

Source : Modified after Sahoo *et. al.*, 2009

National Scenario

In India, concentration of uranium in natural groundwater was measured in various geological environments by Atomic Mineral Division of Govt. of India (Saxena and Verma, 2001; Diwivedy, 1998 and Achar *et. al.*, 1997) specially around mining areas. The study concluded that in the ground water from working mine areas, exploratory mine areas and in areas of uranium deposits, the uranium concentration is well within the limits. Further, in non-uranium deposit areas, the values of uranium concentration in ground water further decreases. These workers have concluded that uranium exploratory or exploiting activity has not contributed any high concentration of uranium in ground water as also reported by Dr. V.P. Saxena, Director, Atomic Mineral Division (Saxena, 2004). Recently, Sahoo *et. al.* 2009 reported uranium concentration ranging from 0.1 ± 0.01 to 19.6 ± 1.8 µg/l in drinking water of India. According to the study, all the values fall within permissible limit of 30 µg/l. The authors also reported that annual dose due to uranium in drinking water ranges from 0.14 to 48 µSv/year for various age groups.

Punjab Scenario

Concentration of uranium and radon in ground water and soils as reported by various workers is described below along with their important observations. The results are summarized in Table-II.

Singh *et. al.* (1995) reported for the first time uranium content of water from Bathinda and Amritsar districts in Punjab. Uranium concentration in water of Amritsar district ranged between 17.87 ± 0.18 and 20.23 ± 0.20 ppb while that of Bathinda samples, it was between 11.71 ± 0.15 and 113.70 ± 0.46 ppb.

Virk (2000) measured indoor radon levels in Punjab and found the radon measurements within the recommended range of 400 Bq/L. However, he observed an increase in radon values (65.1 Bq/m^3) in Bathinda areas in comparison with other areas (35.7 – 64.2 Bq/m^3). Increase in radon values in Bathinda area was attributed to highly porous and permeable soils of the area. ICRP in its publication (ICRP 65) has recommended that remedial action should be taken for radon mitigation if the higher indoor values lie in the range of 200 – 600 Bq/m^3. He concluded that radon exposure in not

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Table-II: Concentration of Uranium and Radon in groundwater from handpumps & shallow tube wells (upto 45 m depth) tapping top pheratic aquifers

Author	Uranium (U) (ug/L) / Radon (R) (Bq/L)	Area	Special observation / technique
Singh *et. al.* (1995)	U-11.71 ± 0.15 - 113.70 ± 46 17.87 ± 0.18 - 20.23 ± 2.0	Bathinda district Amritsar district	
Virk (2001)	U-1.08 ± 0.003 - 19.68 ± 0.12 R-2.3 ± 1.5 - 5.2 ± 2.2	Bathinda & Gurdaspur district	No correlation between uranium and radon concentration observed.
Singh *et. al.* (2003)	U-3.19 - 45.59	Amritsar district	No correlation between uranium and heavy metals concentration.
Kumar *et.* al. (2003)	U-1.65 ± 0.006 - 74.98 ± 0.38	Bathinda district Punjab.	Fission track
Bajwa *et.* al. (2003)	U-4.28 - 16.48 3.17 - 4.19	Bathinda district Amritsar district	Solid state nuclear track detectors.
Bajwa *et. al.* (2005)	R-1.00 - 48	Punjab & Himachal Pradesh	Values within permissible limit of 400 bq/L.
Rani and Singh (2006)	U-1.39 ± 0.96 - 98.25 ± 2.06	Punjab & Himachal Pradesh	
Mehra *et. al.* (2007)	U-5.41 - 43.39	Malwa region, Punjab.	Track etching.
Singh *et. al.* (2008)	U-1.08 ± 0.003 19.68 ± 0.12 R-0.87± 0.29 32.10 ± 1.79	Siwaliks of northern India.	
Singh *et. al.* (2009)	U-0.9 ± 0.08 63 ± 0.21	Amritsar to Bathinda	Solid state nuclear track detectors.
BARC (2009)	U-2.2 - 244.2	Faridkot/ Kotkapura & adjoining area	- Laser uranium analyzer was used. - Some samples exceeded the regulatory limit of 60 ug/l. -Uranium is natural in nature.
Singh and Kishore (2010)	U-5-43 ug/L	Parts of Talwandi Sabo block, district Bathinda	XRF technique used. Values vary within a single village, hot spots occur sparingly.

significant health hazard for the population in Punjab.

Virk *et. al.* (2001) determined radon concentration of groundwater from Bathinda and Gurdaspur districts. The values from Bathinda districts ranged from 2.3 ± 1.5 to 5.2 ± 2.2 Bq/L. These values fall within the safe limits. No correlation between uranium and radon concentration was observed by him.

Kumar *et. al.* (2003) assessed uranium concentration of groundwater in Bathinda district using fission track technique. The values of uranium concentration range between 1.65 ± 0.006 and 74.98 ± 0.38 μg/l. They also analyzed zinc, cadmium and copper to check any co-relation between uranium concentration and heavy metal concentration. They observed weak positive co-relation with lead, cadmium and copper.

Walia *et. al.* (2003) carried out radon measurement in groundwater of Himachal Pradesh and Punjab States and observed that the radon values vary from place to place. They found values in thermal springs to be higher than the values from other sources.

Bajwa *et. al.* (2003) determined uranium concentration in water samples from Amritsar and Bathinda using solid state nuclear track detectors. In Amritsar, uranium concentration in water was

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found to vary from 3.17 to 4.19µg/L and in Bathinda city it varied from 4.28 to 16.48µg/L. A lake sample collected from NFL Water Works site in Bathinda city had uranium content of only 1.21µg/L which was several times lower than samples collected from handpumps and tubewells.

Singh *et. al.* (2003) estimated uranium concentration in groundwater samples of Amritsar district, Punjab and found concentration range of 3.19 to 45.59µg/l.

They also observed positive correlation with conductance, nitrate, chloride, sodium, potassium, magnesium, TDS with uranium concentration. However, no correlation was observed between uranium concentration and heavy metals anlaysed.

Bajwa *et. al.* (2005) studied radon concentration of groundwater from Punjab and Himachal Pradesh. They reported radon concentration ranging from 1.0 to 48 Bq/l from groundwater of hand pumps and tubewells. The values fall within the permissible limit of 400 Bq/l. Similar observations were made by Kochar *et. al.* (2007) though they observed uranium concentration in groundwater of parts of Talwandi Sabo block above the USEPA permissible limit of 30 µg/l.

Rani and Singh (2006) determined uranium concentration in water in Punjab and Himachal Pradesh and found concentration of 1.39 ± 0.96 to 98.25 ± 2.06 ppb in Punjab with mean of 19.84 ± 0.87 ppb.

Mehra *et. al.* (2007) analysed soil samples from 30 locations in Malwa belt and estimated Ra^{226}, Th^{232} and K^{40}. They opined that soil is safe as far as radiation hazard is concerned and can be used for construction material and there is no radiation hazard.

Mehra *et. al.* (2007) also used track etching technique and reported uranium content in ground water ranging from 5.4 to 43.39µg/l. The author observed that the values are lower than those reported from water samples of Himachal Pradesh, India.

Singh *et. al.* (2008) estimated uranium and radon concentration in ground water samples of Siwaliks in northern India and reported uranium concentration varying from 1.08 ± 0.003 to 19.68 ± 0.12 µg/L. Most of the water falls within the safe limits of 15µg/L (WHO, 2004). Radon showed concentration range of 0.87 ± 0.29 to 32.10 ± 1.79 Bq/L.

Singh *et. al.* (2009) observed uranium content of 0.9 ± 0.08 to 63 ± 0.21 ppb in water samples collected from hand pumps and tubewells from Amritsar to Bathinda. They observed higher values in a belt from Zira to Maur toward Haryana border. They attributed higher values to interaction of ground water with the soil formation and local sub surface geology of the region.

GNDU team led by Dr. Surender Singh reported in media in the year 2009 that they analysed 90 samples of ground water from Bathinda and adjoining areas from hand pumps and tubewells using fission track and laser fluorimetry. They found uranium concentration ranging from 9.3 to 56.9 microgram/l. 30% of the samples were reported to contain more than 30 microgram/l and maximum concentration was reported was reported from village Giana, Jajjal in Talwandi Sabo block, Bucho Mandi, JaiSinghwala, Balluaana of Bathinda district.

The radiation and environmental sampling around Faridkot area was conducted by Bhaba Atomic Research Centre (BARC), Mumbai (2009). The results show that uranium content in groundwater samples ranged from 2.2 to 244.2 µg/l, 3 samples

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exceeded the Atomic Energy Regulatory Board limit for uranium in drinking water limit of 60 μg/l. Uranium content was determined by laser uranium analyzer. The details of the results are shown in Table-III.

Table-III: Uranium Concentration in different Water Samples

Sr. No.	Sample Code	Sample Location / Description	Uranium Conc. (μg/l)
1.	W-1	Narayangarh, Gurudhawara, Borewell	-
2.	W-2	Indira Gandhi Nahar Canal Water	3.0 ± 2.3
3.	W-3	Baba Farid Centre for Special Children, Borewell	9.1 ± 3.5
4.	W-5	Tiana Village, 3 km away from Faridkot, Borewell.	109.5 ± 17.2
5.	W-6	Nearby Baba Farid Centre, Borewell.	34.1 ± 6.6
6.	W-7	Makhu, on Faridkot-Amritsar road, Borewell.	2.2 ± 1.3
7.	W-9	Kotkapura, Railway Crossing, Borewell.	244.2 ± 44.6
8.	W-11	10 km away from Faridkot, on the Faridkot-Amritsar road. Borewell.	25.4 ± 6.3
9.	W-12	Chaba, 10 km away from Amritsar, Borewell.	45.5 ± 4.4
AERB Limit for Drinking Water			**60**

Source : BARC (2009)

Further, in the study, two samples were analyzed for uranium isotopic concentration (U-235/U-235 and U-234/U-238 which indicate isotopic composition of natural uranium.

The study also found uranium concentration in hair samples which ranges less than 3 to 248.7 ng/g. This lies between the range of variation (BARC, 2009).

The gamma radiation survey carried out by the study team reveals values of 83.8 – 157.0 nGy/hr which are within normal limits.

The radioactivity levels in soil samples were found to be comparable to the national global average levels. Gross alpha activity (Bq/l) was also analysed for 9 water samples. Values (Bq/l) from samples of NarayanNagar Gurdwara (2.48), Taina village near Faridkot (4.75), Kotkapura railway station crossing bore well (11.1) and Chaba, 10 km away from Amritsar bore well (4.4) exceed the BIS drinking water permissible limit of 0.1 Bq/l. The high values indicate that further radio nuclide analysis is necessary.

Singh and Kishore (2010) reported uranium concentration ranging from 5 to 43μg/l in parts of Talwandi Saboo block of Bathinda district. The author has also analysed ground water samples of Talwandi Sabo Block of Bathinda district using XRF technique available in the Physics Department of Panjab University, Chandigarh. Uranium content in ground water drawn by shallow hand pumps was determined from Giana, Jajjal, Muklana villages of Talwandi Sabo block where higher concentration has been reported by media and GNDU team. GPS measurements were also recorded from the sampling sites in the field for recording proper location. The uranium concentration in groundwater ranges from 5 to 43 μg/l (Singh and Kishore, 2010). The results are shown in Table-IV. The results indicate that the hot spots having concentration more than 30μg/l occur sparingly and the values vary within a single village. The results of analysis of samples supplied by Department of Public Health & Water Supply, Punjab and analysed in the laboratory of Physics Department by Prof. Devinder Mehta are shown in Table-V. The results indicate uranium concentration range of 5.6 – 98 μg/l.

From the data reported by various workers and discussed above, it can be inferred that uranium content of groundwater in the State drawn from hand pumps and shallow tube wells having depth upto 45m ranges between 1.08 and 244.2 μg/l. The high values more than permissible limit of 30 μg/l of USEPA and 60 μg/l of AERB do occur at scattered places as hot spots. The hot spots are

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more common in south western parts in the State covering Bathinda and Faridkot districts. However, concentration of more than 30 μg/l in ground water (USEPA limit) has also been reported from areas not lying in south-west Punjab i.e. from Amritsar district. Further it may be mentioned here that uranium in the area is in the form of calcium dependent species (D. Mehta, 2010, personal communication), which do not cause significant adverse health effects. Therefore, chemical speciation can be an important factor for determination of uranium chemical toxicity in drinking water.

Table-IV: Concentration of Uranium & Strontium in groundwater from hand pumps & shallow tube wells (depth up to 45m), Talwandi Sabo Block, District Bathinda.

Location (village)	Uranium (μg/L)	Strontium (μg/L)
Jajjal (n = 3)	5 -12 (0,5,12)	130 - 810 (130, 250, 810)
Giana (n = 3)	5 - 18 (5,16,18)	330 - 810 (330, 700, 810)
Malkana (n = 4)	0 - 43 (Nd, 2, 42, 43)	100 - 730 (70,100, 650)

n = number of samples

Singh & Kishore, 2010

Table-V: Concentration of Uranium & Strontium in surface & groundwater, SW Punjab (Samples by Deptt. of Water Supply & Sanitation, Mohali Punjab)

Sample No.	Location	Source	Depth (m) (μg/L)	Uranium (μg/L)	Strontium
1	Malkana	H.P.	12.80m (42 ft)	5.6	970
3	Jajjal-1	H.P	19.20m (63 ft)	98	1650
5	Malkana	CWT	--	Below detection	319
7	Jajjal-3	H.P	15.80m (52 ft)	32	1550
4	Giana	CWT	--	7	110
6	Jajjal-2	CWT	--	6.5	150

H.P. = Groundwater drawn from Hand Pump.
CWT = Surface water sample collected from Community Water Treatment Plant.

In view of the above, there is a need to carry out detailed studies at micro and macro level to know the extent of distribution pattern of hot spots to find out geological / geomorphological controls, if any, so that remedial / preventive measures are accordingly taken. People using water for drinking use around hot spot areas may be advised not to drink this water.

POSSIBLE CAUSES OF HIGH CONCENTRATION OF URANIUM

The causes of high concentration of uranium in ground water can be Geogenic (natural) or Anthropogenic (man's activities). Both types are discussed as under

- **Geogenic:**

Basement Rocks (Granites) The granitic rocks form the basement for overlying sediments in Bathinda area. Though granites are known to contain uranium which may occur in accessory minerals or mineralized veins/zones but the alluvium of Punjab is deposited by rivers Sutlej, Ghaggar, Beas and Ravi.The alluvium is deposited over the basement of granitic rocks which occur at 400 to 500 meter depth. It does not appear to have influenced the composition of groundwater at shallow depths in the area (upto 40m). Core of basement granite rock collected by the author (KPS) earlier during drilling while working with the UNDP project in the year 1975 was also got analysed from Physic Department, P.U. in December 2009. The results do not indicate any significant radioactivity. Therefore, basement granite as a source of uranium as advocated by workers of GNDU, Amritsar does not get the support from this data. However, minor minerals present in the alluvium could also be the source of hot spots. It needs to be investigated further.

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- **Anthropogenic :**

i) Flyash - Flyash is known to contain uranium and other heavy metals (chromium, lead, nickel, cobalt, etc.). Data from Bathinda flyash reported by Singh and Jain (1998) of Geological Survey of India (GSI) indicate that groundwater near ash ponds gets affected by elements like chromium, lead and nickel which have been found to be above the permissible limits. However, data for uranium was not reported by these workers (Singh and Jain, 1998). In case, flyash is the cause, plumes showing high concentration of uranium in groundwater should be confined only to ash ponds. However, high concentration of uranium has been observed in areas located far off from ash ponds like Chaba (10 kms from Amritsar); KotKapura and Taina (3 kms from Faridkot). However, there could be a possibility of local contamination of groundwater around flyash ponds. This aspect is being investigated / studied in detail by PPCB in association with Prof. Mehta of Physics Department of P.U. Preliminary results do not indicate abnormally high values of uranium in groundwater around flyash ponds (Mehta, D., personal communication).

ii) Airblown from Afganistan/Nuclear Reactors - Some workers from GNDU attribute high concentration of uranium in groundwater to the air blown from Afghanistan / nuclear reactors (which are about 150 km away). However, if such a contamination takes place, it would be of regional mega scale nature and not localized as is the case in the study area.

iii) Fertilizers- Phosphatic fertilizers are known to contain uranium concentration ranging from 20 to 300 mg/kg. Such fertilizers are used extensively in the Punjab State. It appears that high concentration of uranium observed in ground water of shallow aquifer could be because of the use of such fertilizers in the area. Similar observations have been made by the workers in West Bengal (Banerjee, DM, personal communication, June 2009). This aspect needs to be further investigated by mapping uranium content for shallow and deeper aquifer.

REMEDIAL MEASURES

The best remedial method recommended by USEPA is the use of Anion Exchange and Reverse Osmosis for uranium separation in water is also being successfully followed in U.S.A. The major precaution one has to take is regarding the safe disposal of effluents/reject which may be become rich in radionuclides.

RECOMMENDATIONS

1. Detailed micro level study on the uranium content in ground water, soils and aquifer materials needs to be taken up. Such a study should help in finding out the extent of hot spots having higher concentration more than the 30 μg/l (permissible limit of USEPA) and 60μg/l (AERB).

2. Systematic studies and sampling for uranium contamination of ground water drawn from shallow and deeper aquifers around fly ash ponds needs to be carried out.

3. Uranium concentration in water should preferably be also measured by ICP MS using international reference standards. The instrument can detect uranium upto 0.001 μg/l. It will also cross check the data.

4. Areas away from flyash ponds should also be investigated by sampling and analyzing top soils, aquifer materials for mineralogical data and water samples drawn from shallow and deeper aquifers for uranium concentration.

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5. Remedial measures as discussed (use of Reverse Osmosis) should be promoted as it will not only filter and remove uranium if present, but also other harmful contents such as fluoride in groundwater which is often high and responsible for bone and joint problems observed in the local population (Singh and Kishore, 2009).

Acknowledgements :

The author is thankful to Sh. Viswajeet Khanna, IAS, Secretary, Department of Science, Technology & Environment, Punjab for giving an opportunity to prepare the report. Thanks are also to Sh. H.S.Kandhola, Additional Secretary, Science Technology and Environment, Punjab for making useful suggestions. Sincere thanks are also to Dr. (Mrs) Neelima Jerath, Executive Director, Punjab State Council for Science & Technology. Thanks are also due to Prof. R.C. Sobti, Vice-Chancellor, Panjab University for encouragement. Sincere thanks are also due to Prof. Devinder Mehta of the Department of Physics, Panjab University for analyzing the samples for uranium in water and granite (core sample).

Views in this article are that the author but not of the Council.

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