Impact of Uranium Contamination in Water Samples Around 0-3 K.M Radial Range of Panipat Thermal Power Plant

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Abstract

A multitude of anthropogenic undertakings, encompassing the deployment of phosphate-based fertilizers, combustion of coal within thermal power facilities, uranium mining activities, and the utilization of depleted uranium in military conflicts, engenders the dissemination of uranium into the environmental matrices. The present inquiry delves into the provenance of such aqueous contamination, quantification of uranium concentration, evaluation of attendant health perils, and an appraisal of chemical toxicity indices associated with water specimens extracted from the proximate 0-3 km periphery of the Panipat coal-fired thermal power establishment. These aqueous specimens underwent analytical scrutiny utilizing the LED Fluorimeter Quantalase LF-2, an apparatus adept at discerning uranium concentrations spanning 0.5 µg/L to 1000 µg/L. Empirical findings delineate uranium concentrations within the samples as subsisting beneath the stipulated threshold of 30 µg/L, as delineated by the World Health Organization (WHO, 2011). Stratified assessments of the annual effective dose across variegated demographic cohorts revealed maximal accrual in infants. Radiologically, computed metrics for mean cancer mortality risk and cancer morbidity risk yielded magnitudes of 4.7×10^{-5} and 7.3×10^{-5}, respectively, values subordinate to the permissible echelon of 1.67×10^{-4}, as enshrined by the Atomic Energy Regulatory Board (AERB), India. Complementary evaluations of chemical toxicity, encapsulated within the paradigms of the lifetime average daily dose (LADD) and the hazard quotient (HQ), indicate LADD indices inferior to the WHO (2011) benchmark of 1 µg/kg/day. Concomitantly, HQ values manifest below unity, notwithstanding exceptions for dry fly ash and coal specimens, which exceed permissible confines. Noteworthy is the discerned positive correlative interplay betwixt uranium concentrations and total dissolved solids (TDS) within the scrutinized specimens, accentuating the intricate interplay of aqueous physicochemical attributes.

Key words: Uranium contamination, Chemical toxicity risk, Coal based thermal power plant, LED flouremeter, Hazard quotient

The ubiquity of uranium within subterranean aquifers is intrinsically contingent upon an amalgam of litho logical substrata, geomorphological configurations, and diverse geological idiosyncrasies endemic to the locale. Additionally, the aqueous uranium milieu may be anthropogenically augmented through manifold endeavors, including but not limited to mineralogical excavation, the incineration of carbonaceous and ancillary combustibles, the agrarian deployment of phosphate-enriched fertilizing agents, and the operational exigencies of nuclear energy generation [1]. The compositional attributes of fly ash exhibit significant variability, contingent upon the provenance and intrinsic constitution of the coal undergoing combustion. Nonetheless, all fly ash invariably harbors copious quantities of silicon dioxide (SiO_2)—manifesting in both amorphous and crystalline morphologies—and calcium oxide (CaO), constituents intrinsically associated with coal-bearing lithological formations. The qualitative grading of coal is intrinsically linked to its ash content, a pivotal determinant influencing the calorific potential of the coal. In this context, the Bhabha Atomic Research Centre (BARC), Mumbai, posits that the majority of Indian coal reserves are characterized by minimal radioactivity levels, substantially beneath thresholds demarcating hazardous exposure [2]. Ubiquitous in nature and ranking as the second heaviest element occurring naturally, uranium permeates the terrestrial crust with a mean concentration of approximately 1.8 mg/kg. Predominantly, natural uranium comprises the isotope 238U isotope (99.27%); 235U and 234U isotopes 0.72% and 0.0055%, respectively [3]. Uranium exists in quantifiable amounts across a plethora of aquatic systems, with an estimated mean concentration of 3.0 µg/L in oceanic waters. Potable water emerges as the principal vector, accounting for nearly 85% of the uranium assimilated by humans via ingestion [4]. Uranium's dualistic impact on human physiology arises from its intertwined chemical and radiological characteristics. It is widely postulated that uranium's chemical toxicity eclipses its radiological detriments. Uranium's chemical toxicity can cause damage to the liver, kidneys, and reproductive system, and it may also be connected to the development of bone cancer. [5]. In light of these

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considerations, the present investigation was conceived to delineate and quantify uranium concentrations within 15 distinct hydrological specimens extracted from the radial range vicinity of the Panipat Thermal Power Plant.

Geology of study area

The study area shown in (Fig 1), "Panipat Thermal Power Plant" is Located in Khukhrana, Panipat in Haryana. The Power Plant is one of the coal-based power plants of Haryana Power Generation Corporation Limited (HPGCL), It was formerly Known as the Tau Devi Lal Thermal Power Station. The site is close to the Asan and Khukrana Railway Station on the Panipat Safido Section of the North Western Railway. Its Primary fuel is Coal. It has Four Operational Units Operated by Haryana Power Generation Corporation Limited (HPGCL). its first unit commission in 1979 with capacity of 448MW. Today with four operational units its total capacity of electricity supply is 1367.8 MW. This area is highly fertile enriched with alluvial soils, flat topography broken by numerous ponds, lakes, and sub-rivers. It is located between 29°23'51"N and 76°53'25"E. It's elevation from sea level is 236 m (774 ft).

Fig 1 Google map view of Panipat thermal power plant

The Panipat Thermal Power Plant Station (PTPS) is one of the coal-based power plant in Panipat Haryana, India. It has four operational units that generate 1367.8MW of power. Its supplier is HPGCL India [6].

MATERIALS AND METHODS

Sample collection

The Water specimens were procured from an array of sources, including bore wells, tube wells, canals, and hand pumps, from 15 different locations around in radial range 0-3 K.M of Panipat Thermal Power Plant. The collection process employed sealed air tight, laboratory-grade polypropylene bottles, each possessing a volumetric capacity of 50 ml. Subsequently, on the next day, the water from each sample underwent filtration facilitated by filter paper with a pore dimension of 0.50 microns. Thereafter, within a temporal interval of three days post-collection, analytical quantification of uranium concentration, alongside assessments of pH levels and total dissolved solids (TDS), was conducted for the respective samples.

Radioactivity measurements

The quantification of uranium concentration within the samples was effectuated utilizing the LED Fluorimeter (Quantalase LF-2a), an apparatus predicated on the fluorescence phenomenon. This technique exploits the differential fluorescence emission exhibited by various uranium complexes. To standardize the fluorescence yield across all uranium complexes, a fluorescence-enhancing reagent was introduced to the samples in a precise volumetric ratio of 9:1 (Sample:Fluoren). This admixture facilitated the conversion of all uranium complexes into a simplified uniform form, thereby ensuring consistent fluorescence response for analytical precision.

RESULTS AND DISCUSSION

Given below in (Table 1) the data of radiological and chemical risks associated with water samples collected 3 Km radial range from Panipat thermal power plant, Panipat (Haryana).

S. No.	Label of Sample	GPS Location Latitude	Longitude	Conc. of Uranium (ug L^{-1})	Uc Bq/L	LADD (ug/Kg/day)	HQ	DE (uSv/Year)	Cumulative Dose (uSv)	TDS mg/L	pH
1	SAM – A	29°23'33.3"N	76°51'59.2"E	16.82	0.4205	0.841	0.185651	2.41735	169.2145	1439	6.7
2	SAM – B	29°23'16.1"N	76°52'20.3"E	12.42	0.3105	0.621	0.137086	1.78499	124.9493	961	7.3
3	SAM – C	29°23'43.2"N	76°51'01.4"E	6.54	0.1635	0.327	0.072185	9.39921	657.9447	759	8.1
4	SAM – D	29°23'30.5"N	76°51'14.2"E	2.13	0.05325	0.1065	0.02351	3.06121	214.2847	186	7.6
5	SAM – E	29°23'09.0"N	76°52'29.5"E	2.86	0.0715	0.143	0.031567	4.11036	287.7252	297	6.9
6	SAM – F	29°23'16.0"N	76°52'21.5"E	2.96	0.074	0.148	0.032671	4.25408	297.7856	317	7.2
7	SAM – G	29°24'13.9"N	76°52'23.9"E	5.74	0.1435	0.287	0.063355	8.24946	577.4622	954	8.0
8	SAM – H	29°24'38.5"N	76°52'28.2"E	4.62	0.1155	0.231	0.050993	6.63981	464.7867	867	7.5

9	SAM – I	29°24'37.3"N 76°52'44.7"E	41.71	1.04275	2.0855	0.460375	5.99451	419.6157	2893	6.8
10	SAM – J	29°23'39.2"N 76°51'58.0"E	23.20	0.58	1.16	0.256071	3.33428	233.3996	1639	7.3
11	SAM – K	29°23'32.5"N 76°52'03.6"E	4.86	0.1215	0.243	0.053642	6.98473	488.9311	943	6.7
12	SAM – L	29°23'09.4"N 76°51'50.4"E	28.98	0.7245	1.449	0.319868	4.16497	291.5479	2149	7.9
13	SAM – M	29°23'19.6"N 76°51'49.5"E	16.81	0.42025	0.8405	0.185541	2.41591	169.1137	924	7.7
14	SAM – N	29°23'29.4"N 76°52'00.6"E	12.04	0.301	0.602	0.132892	1.73037	121.1259	708	6.9
15	SAM – O	29°23'30.4"N 76°51'16.6"E	33.67	0.84175	1.6835	0.371634	4.83901	338.7307	2631	7.2

Risk factors and assessments

Risk in the water samples from the Panipat thermal power plant due to the uranium concentration was estimated in terms of the lifetime average daily dose using equation given by USEPA [7]:

$$LADD = \frac{Uc \times Ing R \times EF \times L.E}{AT \times BW}$$

Where, LADD = lifetime average daily dose (mg.kg^{-1}.day^{-1}) Uc is the concentration of uranium element in the water sample (ug/l)

("exposure point concentration"),

IngR is the ingestion rate,
EF is the exposure frequency (days/year),
L.E. is the Life Expectancy which taken (70 years),
AT is the average time (days) and BW is the body weight.
The ingestion rate = 3.5 L/day [8].
The total exposure frequency = 365 days.
The total exposure duration = 70 years [9].

The average time calculated (70 x 365 days) = 25,550 days and the average body weight taken of an Indian man = 70 kg [10].
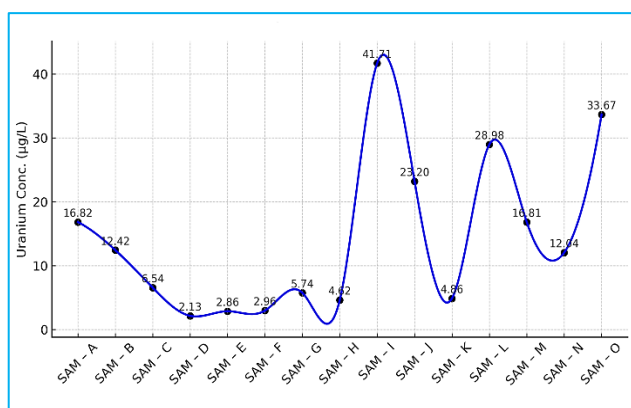

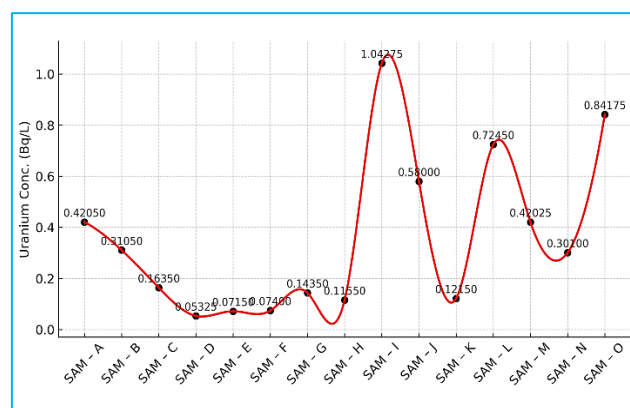Fig 2 (Uranium Concentration Graph in ug/L from Data Table 4.2)

Fig 3 (Uranium Concentration Graph in Bq/L from Data Table 4.2)

Uranium concentration

The conversion of concentration from ug/L to Bq/L takes place using following formula:

Uc (in Bq/L) = Uc (ug/L) x C.F ………. (1)

Here C.F is the conversion factor taken as 0.025 Bq/ug.

The Hazard Quotient (HQ) is given by:

$$HQ = \frac{LADD}{RFD} \qquad ………. (2)$$

Here, RFD is the reference dose calculated on the basis of the AERB permissible limits (60 μg/l) and turned out to be 4.53 μg.kg^{-1} day^{-1} [11].
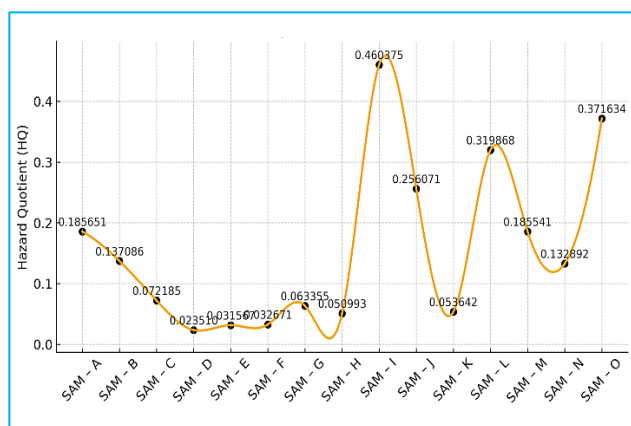

Fig 4 (Hazard Quotient HQ Graph from Data Table 4.2)
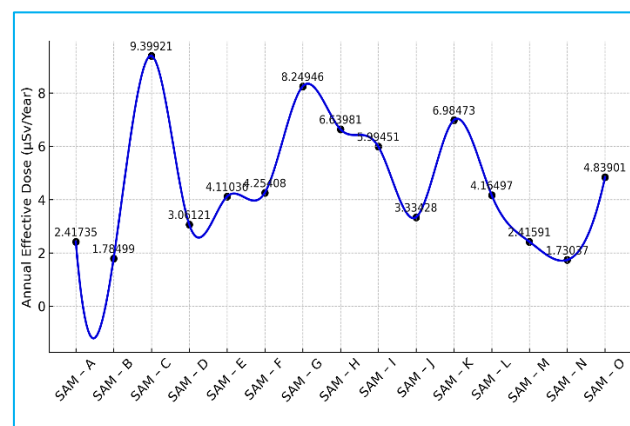

Fig 5 (Annual Effective Dose Graph from Data Table 4.2)

Annual effective dose (DE)

The A.E.D (DE) is the measure of the whole-body dose. It was estimated using the conversion factor given by W.H.O.

DE = Uc × F × I annual

Here, DE represents the annual effective dose (uSv/year) Uc represents the activity concentration (Bq/L), F represents the effective dose per unit intake (uSv/year/Bq/L) which is taken as 4.5x 10-8 and I annual is the annual ingestion which was taken to be 1277.5 L (3.5 × 365)

The annual effective dose is found within the range of 1.73 – 9.39 uSv/ year [13], [15]

Cumulative dose (uSv)

It is given by the product of the annual effective dose and the life expectancy, i.e. effective dose over the life.

$$Cumulative\ Dose = DE \times Life\ Expectancy$$

It is found to vary form 121.12 – 657.94 uSv.

Total dissolved salts (TDS)

It is a measure of the dissolved content organic and inorganic substances present in a liquid in molecular, ionized or micro-granular colloidal sol suspended from. TDS concentration is represented in parts per million (ppm) [14]. The TDS of the 15 samples was found to vary from 186 mg/L to 2893 mg/L. The TDS of 5 samples is found above the WHO recommendations, 1000mg/L. The TDS of 12 sample is found above the BIS recommendations, i.e. 500mg/L.

The pH of water sample (pH)

The pH of the samples was found in the range of 6.7 to 8.1. It is within the limit's recommendations by WHO, i.e. 6.5 -8.5. [13], [15].

CONCLUSION

The present studies found that the contamination of the uranium in water samples from the Panipat thermal power plant is not harmful and within the limit recommended by international bodies. The findings indicate that two samples surpassed the WHO PGV. Variations in uranium concentration in groundwater are mainly influenced by recharge and discharge processes, which facilitate the dissolution or leaching of uranium from weathered soil into the groundwater. The positive correlation between TDS and uranium in groundwater suggests that total dissolved salts (TDS) influence the mobility of uranium in groundwater. Because none of various water samples from surrounding of the Panipat thermal power plant shows unusual high concentrations of uranium. The water samples were found to have hazard quotient value below to the safe limit of 1.0, indicating no chemical toxicity risk due to uranium from the different type of water samples.

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