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Study of Radionuclide Present in Air and Water Around Narora Atomic Power Station (NAPS), Uttar Pradesh, India

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Abstract: In the present study, efforts have been made to estimate the natural radionuclide present in air and water samples in 3Km range around NAPS. The radioactivity level gamma rays in atmosphere in the 15 sites around NAPS in 3Km range were analyzed using "Digital Geiger Muller Counter Nuclear Radiation Detector Model: GQ GMC-300E Plus". The results indicate that ambient gamma dose rates at the sites of study varied in the range 0.4671875Bq to 0.95234375Bq and found within the safety range of 1.796875Bq as per United States Environment Protection Agency recommendations. It depicts that overall air of study region around NAPS is found within the safe range of radiological risk and is not harmfully affecting the environment. The water samples were analyzed for the concentration of the uranium using the L.E.D. fluorim0eter Quantalase LF-2. This fluorimeter measures the uranium concentration in water samples from $0.5\mu g/L$ to $1000\mu g/L$. The concentration of the uranium was found to be varying in a range of 10.58 $\mu g/L$ to 48.12$\mu g/L$. These findings of the study may provide valuable information about radioactivity in air environment and uranium concentration in the ground water samples of study area around NAPS.

Key Words: Radioactivity, Radionuclide, NAPS, Geiger Muller Counter, Air Samples.

1. Introduction

Earlier, the key sources of the radiation exposure for the human were the natural radioactive elements existing in the environment and the earth crust. The cosmic radiations may also contribute to the exposure for living being. The origin of the cosmic radiation lies outside the atmosphere of the earth but when they enter the atmosphere the radiation level further rises. The uranium one of the radionuclide is known as a toxic element not only radio logically but chemically also. Primarily ingestion of Uranium occurs through water and food and then it mainly accumulates in the bones, liver and kidney [1]. Most of the Uranium about 66% excreted by the kidney via urine and the rest 34% get deposited in the kidney and other soft tissues [2]. The gamma radiations emitted by unstable radionuclide beyond an exposure limit can cause cancer.

The gamma radiations are shortest electromagnetic radiations arising from radioactive decay of atomic nuclei. The radiations are present everywhere, human beings therefore, cannot avoid continuous exposure to ionizing radiation both inside and outside their dwellings. The Gamma radiations are

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more penetrating when compared with the alpha and beta radiations. The damages caused by the Gamma radiations include radiation sickness, damage of DNA, cell death resulting from the damaged DNA. The ingested radioactive substances through water or inhaled radioactive substances though gases depending on the chemical nature of substances that can produce both diffuse and localized internal damage [3, 4]. The tissue cancer is one among them. During this study, the recommendations of various national and international organizations have been studied to adjudicate the final outcomes. The gamma radiations are also emitted during nuclear fission process carried out in nuclear reactor power stations. The area of my study has an atomic power station named 'Narora Atomic Power Station (NAPS)'.

In addition to naturally occurring radionuclide, certain industrial and technical activities such as burning coal, mining and modern agriculture practices also have unknowingly added to the prevailing natural radionuclide and raised the radiation level in the environment. This is termed as Technically Enhanced Natural Radioactivity (TENR) [5].

Considering the concerns regarding Uranium and Gamma radiations, it becomes necessary to calculate the radiological and the chemical risks. The motive of the present study is to analyze the gamma radiation level in the air samples and the uranium concentration in ground water samples around the NAPS within a radius of 3km.

2. Geology of Study Area

The study area shown in figure 1 is located on the bank of the Upper Ganga River, in tehsil Dilbai of district Bulandshahar in Uttar Pradesh state of India. It lies in Meerut Region of Uttar Pradesh located in doab of Ganga and Yamuna rivers. The Dilbai tehsil (sub-district) where the sites of study are there lies in a region of Ganga River Valley. The ganga river is the life line of the north India. The sites of the study fall in "Doab of Yamuna and Ganga" river.

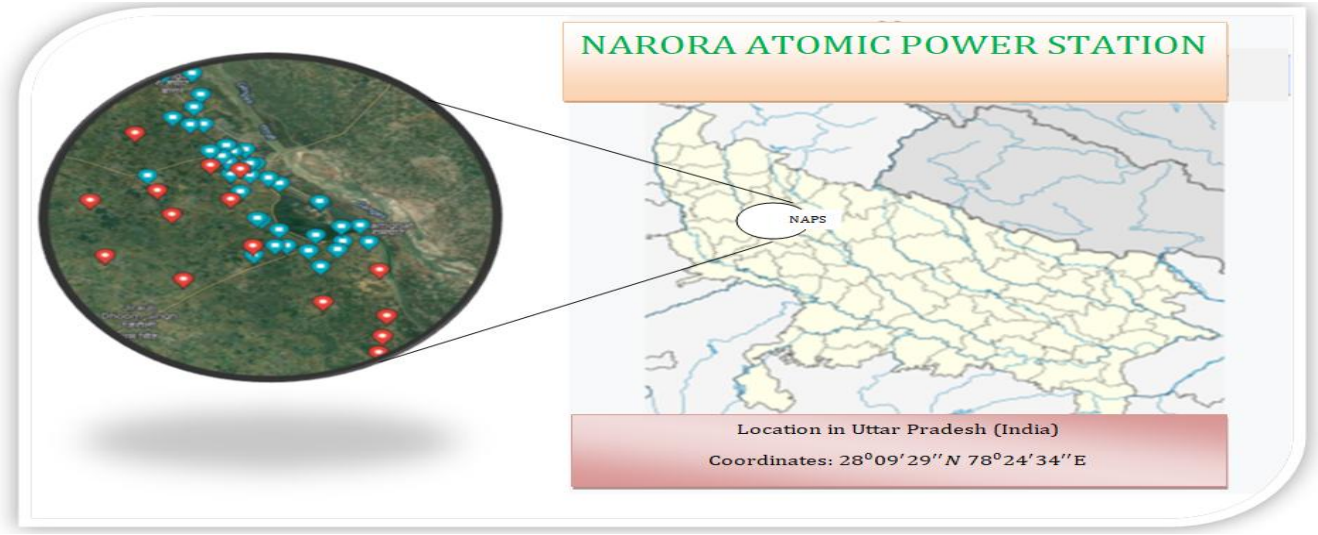

Figure:1 [The above has two parts – left side and the right side. The left side has a circle enclosing the sampling sites. The right side of the figure has the map of Uttar Pradesh State of India with NAPS in oval shape.]

3. Materials and Methods

3.1 Data Collection

Data collection sites were chosen around Narora Atomic Power Station (NAPS) in Bulandsahar

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district of Uttar Pradesh, India. The NAPS has latitude of 28°09'29"N and longitude of 78°24'34"E. The air data was collected when both units of the reactor were in the active mode [6]. The data were noted down at height of 6 feet from the sites where surrounding was clear up to 20m (with no tall trees and buildings). The device used for noting the counts per minute (CPM) was a digital device so no sample preparation was required. The water samples were collected from bore wells and tube-wells from 15 different sites as shown in the figure 1. Before sample collection, it was ensured that water is continuously coming out for at least 10 minutes.

The Cork fitted air tight lab grade polypropylene bottles of 50 ml capacity were used for collecting water samples. Next day, the water of each sample was filtered using filter paper of pore size 0.50 micron. Then analysis for Uranium concentration, pH and TDS of the samples were measured 3 days of sample collection.

3.2 Radioactivity Measurements

The data for radioactivity in air was collected using a "Digital Geiger Muller Counter Nuclear Radiation Detector Model: GQ GMC – 300E Plus". The device is sensitive to the Gamma Radiation of range 0.1 to 1MeV with Instrument Background radiations < 0.2 pulses/s. The data is shown on the LCD display dot matrix calibrated with the device. The data observed is tabulated in table no. 1. The Samples for Uranium concentration were analyzed using LED Fluorimeter (Quantalase LF-2a). Its working is based on Fluorescence phenomenon that it shown up to different level for different complexes of the Uranium. A Fluorescence enhancing Reagent was added to the samples in 9:1 (sample: fluren) to convert all the complexes into simple form having same fluorescence yield.

4. RESULTS AND DISCUSSION

4.1 Results and discussion for Air Data

The GMC is capable of showing the gamma radiation dose in counts per minute (CPM) and mSv. The CPM reading was noted down. It converted into Becquerel (Bq) [7].

The activity concentration for the air of Narora found to be within the range of 0.503125 to 0.88046875Bq. The air data collected from the surrounding of the NAPS is tabulated in Table (1) as shown below.

Tabele 1: Radioactivity Concentration in Air around NAPS

Sr. No.	Label of Sample	Name Of Location	GPS Location		Radiation Level		Distance from NAPS	
			Latitude	Longitude	CPM	Becquerel (Bq)	(in miles)	(in Km)
1	Sam – A	Silhari	28°09'48.3"N	78°22'52.3"E	31	0.55703125	1.8	2.896819
2	Sam – B	Niwari Bangar	28°10'22.3"N	78°23'04.8"E	26	0.4671875	1.7	2.735885
3	Sam – C	Rampur	28°08'55.5"N	78°23'14.4"E	36	0.646875	1.5	2.414016
4	Sam – D	Dharkpur	28°08'00.5"N	78°23'37.1"E	51	0.91640625	1.9	3.057754
5	Sam – E	Ganga Garh	28°08'01.0"N	78°23'51.8"E	34	0.6109375	1.8	2.896819

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6	Sam – F	Bijau	28°08'21.9"N	78°24'28.8"E	30	0.5390625	1.3	2.092147
7	Sam – G	Retuka Nagla	28°07'53.2"N	78°24'57.3"E	44	0.790625	1.8	2.896819
8	Sam – H	Niwari Bangar	28°10'15.7"N	78°23'28.3"E	34	0.6109375	1.5	2.414016
9	Sam – I	Badipur	28°08'41.5"N	78°25'26.1"E	53	0.95234375	1.2	1.931213
10	Sam – J	Retuka Nagla	28°08'38.5"N	78°25'02.2"E	49	0.88046875	1	1.609344
11	Sam – K	Retuka Nagla	28°08'09.4"N	78°25'03.8"E	33	0.59296875	1.6	2.57495
12	sam – L	Bijau	28°08'32.2"N	78°23'42.5"E	37	0.66484375	1.4	2.253082
13	Sam – M	Rampur	28°08'51.9"N	78°23'19.9"E	28	0.503125	1.4	2.253082
14	Sam - N	Retuka Nagla	28°08'08.2"N	78°25'37.0"E	43	0.77265625	1.8	2.896819
15	Sam - O	Ganga Garh	28°08'08.2"N	78°25'37.0"E	39	0.70078125	1.9	3.057754
Mean					37.86667	0.680416667	1.573333	2.532035
Median					36	0.646875	1.6	2.57495
Standard Deviation					8.433493	0.151539333	0.273774	0.440597

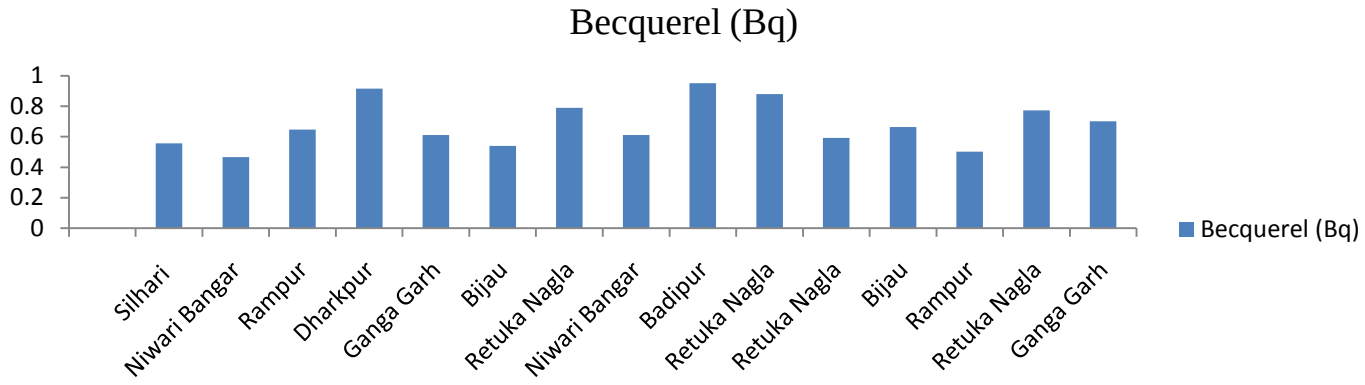

Figure 2: Activity Concentration of Air near the NAPS, Narora, UP, India

The air, we breath is one of the primary essentiality. The activity level of the air below the recommendation of IAEA is desirable. The radiological pollution must be lower down in the favour of mankind. The data collected will be helpful to monitor and compare the activity of radionuclide in the air around the NAPS, Narora, Bulandsahar district, Uttar Pradesh, India.

In this study, two types of risks associated with uranium are estimated individually. One is the radiological risk due ionizing radiations and second is the chemical risk as uranium is a heavy metal. The chemical risks associated with uranium badly affect the human health so it cannot be neglected.

4.2 Result and Discussion for Water Samples

4.2.1 Uranium Concentration

The conversion of concentration from $\mu g/L$ to Bq/L takes place using following formula.

$$U_c(in\ Bq/L) = U_C(\mu g/L) \times C.F \quad (1)$$

Here, C.F. is the conversion factor taken as $0.025\ Bq/\mu g$. [8]

4.2.2 Excess Cancer Risk Assessment

There can be a number of reasons for falling the human body in cancer trap. The nuclear radiations are one of them. Due to exposure to radiations the risk of

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cancer goes on high. A simplified approach is used to determine the Excess Cancer Risk (ECR).

The uranium concentration was found in the range of 10.58 - 48.12$\mu g/L$ with mean value of 24.306$\mu g/L$. Out of the 15 analyzed water samples, the concentrations only in two samples were below 15 $\mu g/L$, the recommendations of WHO (2004) [9].

In the fifth and sixth columns, the Risk Factors (R.F.) – $R_{MORTALITY}$ and $R_{MORBIDITY}$ are calculated using following relations:

$$R.F. = R.C. \times W.I.R. \times T.E.D. \quad (2)$$

Here, R.C. is the risk Coefficient for mortality and morbidity taken as $1.19 \times 10^{-9} Bq^{-}$and $1.84 \times 10^{-9} Bq^{-}$respectively. The W.I.R. stands for water ingestion rate taken as 1.38 L/Day and the T.E.D. stands for total exposure duration taken as 25527 days (365.25×69.89).

The risk factor for mortality and morbidity came out to be 4.19×10^{-5} and 6.48×10^{-5} respectively. After these findings, the excess cancer risk was computed using following relation [10]

$$E.C.R. = U_C\ (Bq/L) \times R.F.\ (L/Bq) \quad (3)$$

The excess cancer risk for mortality came out within the range of $1.11 \times 10^{-5} - 5.041 \times 10^{-5}$ with mean value of 2.546×10^{-5} and the excess cancer risk for morbidity came out to be within the range of $1.714 \times 10^{-5} - 7.795 \times 10^{-5}$ with average value of 3.9378×10^{-5} respectively.

4.2.3 Chemical Risk Assessment

The Life Time Average Daily Dose (LADD) has been taken as standard of the chemical toxicity risk associated with the uranium [11]. This can be estimated using the following equation:

$$\text{LADD}\ (\mu g/kg/Day) = \frac{[U_C \times I.R. \times E.F. \times L.E.]}{[BW \times AT]} \quad (4)$$

Here, U_C is the concentration of the uranium in the water samples ($\mu g/L$), I.R. is the ingestion rate of water taken as 1.38 L/Day. The E.F. represents the exposure frequency, i.e. 365.25 days per year. The L.E. represents the Life Expectancy which taken 69.89 years. [12] The BW stands for the body Weight taken as 70 kg. The AT stands for the average time which is taken as 25509 days. The chemical toxicity risk (LADD) found within the range from 0.209 $\mu g/kg/Day$ to 0.949 $\mu g/kg/Day$ with average value of 0.479$\mu g/kg/Day$.

4.2.4 The Hazard Quotient (HQ)

It is the ratio of the lifetime average daily dose (LADD) to the reference dose (RF.D.).

$$HQ = \frac{LADD}{RF.D} \quad (5)$$

The reference dose is taken as 0.6 $\mu g/kg/Day$ [13]. The Hazard Quotient (HQ) was found within the range from 0.348 to 1.582 with average value of 0.796.

4.2.5 Annual Effective Dose (D_E)

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The A.E.D. (D_E) is the measure of the whole body dose. It was estimated using the conversion factor given by W.H.O. [14]

$$D_E = U_c \times F \times I_{annual} \quad (6)$$

Here, D_E represents the annual effective dose ($\mu Sv/year$), U_c represents the activity concentration (Bq/L), F represents the effective dose per unit intake ($\mu Sv/year$/Bq/L) which is taken as 4.5×10^{-8} and I_{annual} is the annual ingestion which was taken to be 504L (1.38×365.25).

The annual effective dose is found within the range of 6.01 – 27.28 $\mu Sv/year$with average value of 13.78 $\mu Sv/year$.

4.2.6 Cumulative Dose (μSv)

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

$$Cumulative\ Dose = D_E \times Life\ Expectancy \quad (7)$$

It is found to vary from 420.04 – 1906.6 μSv with average value 963.32μSv.

4.2.7 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 form. TDS concentration is represented in parts per million (ppm). The TDS of the 15 samples was found to vary from 105 mg/L to 3257 mg/L with mean value of 1137.59 mg/L. The TDS of 9 samples is found above the WHO recommendation, 1000mg/L. The TDS of 14 samples is found above the BIS recommendation, i.e. 500mg/L.

4.2.8 The pH of Water Samples (pH)

The pH of the samples was found in the range of 6.9 to 7.8 with average value of 7.4. it is within the limits recommended by WHO, i.e 6.5 – 8.5.[15]

Table 2: Uranium Concentration and Calculated Radiological And Chemical Risks Associated with Each Water Sample

Sr. No.	Name of Site	Conc. Of U. (µg/L)	Uc (Bq/L)	R (Mortality)	R (Morbidity)	ECR (Mortality)	ECR (Morbidity)	LADD (µg/Kg/Day)	HQ	D_E (µSv/year)	Cummulative Dose (µSv)
1	Silhari	17.1	0.428	0.0000419	0.0000648	0.00001791	0.0000277	0.337	0.526	9.71	678.63
2	Niwari Bangar	10.58	0.265	0.0000419	0.0000648	0.0000111	0.00001714	0.209	0.348	6.01	420.04
3	Rampur	31.08	0.777	0.0000419	0.0000648	0.00003256	0.00005035	0.613	1.021	17.62	1231.46
4	Dharkpur	48.12	1.203	0.0000419	0.0000648	0.00005041	0.00007795	0.949	1.582	27.28	1906.6
5	Ganga Garh	16.23	0.406	0.0000419	0.0000648	0.00001701	0.00002636	0.32	0.534	9.21	643.69
6	Gopalpur	19.56	0.489	0.0000419	0.0000648	0.00002049	0.00003169	0.386	0.643	11.09	775.08
7	Retuka Nagla	37.69	0.942	0.0000419	0.0000648	0.00003947	0.00006104	0.743	1.238	21.37	1493.55
8	Niwari Bangar	11.52	0.288	0.0000419	0.0000648	0.00001207	0.00001866	0.227	0.378	6.53	456.38
9	Badipur	38.56	0.964	0.0000419	0.0000648	0.00004039	0.00006247	0.76	1.267	21.86	1527.8
10	Retuka Nagla	25.78	0.645	0.0000419	0.0000648	0.00002701	0.00004176	0.508	0.847	14.63	1022.49

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11	Retuka Nagla	18.56	0.464	0.0000419	0.0000648	0.00001944	0.00003007	0.366	0.61	10.52	735.24
12	Bijau	24.89	0.622	0.0000419	0.0000648	0.00002607	0.00004032	0.491	0.818	14.11	986.15
13	Rampur	27.65	0.691	0.0000419	0.0000648	0.00002896	0.00004479	0.545	0.908	15.67	1095.18
14	Retuka Nagla	15.68	0.392	0.0000419	0.0000648	0.00001642	0.0000254	0.309	0.515	8.89	621.32
15	Ganga Garh	21.59	0.54	0.0000419	0.0000648	0.00002262	0.00003498	0.426	0.71	12.25	856.15
Mean		24.306	0.60773333	--------	--------	2.5462E-05	3.9379E-05	0.47926667	0.7963	13.783333	963.3173333
Median		21.6	0.54	-------	--------	0.00002262	0.00003498	0.426	0.71	12.25	856.15
Standard Deviation		10.741629	0.26842942	-------	-------	1.125E-05	1.7396E-05	0.2117662	0.3548	6.0874305	425.4513861

Table No. 3 (Range, Average, Median and Standard Deviation of all statistical parameters)

Table 3 : Statistical Parameters (Water Samples)										
Statistical Parameters	**Ur. Conc. (µg/L)**	**Uc (Bq/L)**	**ECR (Mortality)**	**ECR (Morbidity)**	**LADD (µg/kg/Day)**	**HQ**	**DE (µSv/year)**	**Cumulative Dose (µSv)**	**TDS (mg/L)**	**pH**
Range	10.58 - 48.12	0.265 -1.203	0.0000111 - 0.00005041	0.00001714 - 0.00007795	0.209 - 0.949	0.348 - 1.582	6.01 - 27.28	420.04 - 1906.6	6.4 - 7.9	6.9 - 7.8
Average	24.306	0.6077	0.00002546	0.00003937	0.4793	0.7963	13.78	963.32	7.073333	7.073
Median	21.6	0.54	2.55E-05	3.94E-05	0.479266667	0.7963333	13.7833333	963.3173333	6.9	6.9
Standard Deviation	10.7416292	0.268429418	1.13E-05	1.74E-05	2.12E-01	3.55E-01	6.09E+00	4.25E+02	4.91E-01	0.490578

5. Conclusion

The level of the activity concentration of the natural radionuclide in most of the air were found within the range of the world average, it might not pose any radiation threat to the people staying in the surrounding of the NAPS. Also, the concentration of the uranium in the samples collected from the surrounding of the NAPS has been found within the limit recommended by international bodies. But the science society has to be vigilant so that proper management of nuclear devices, nuclear power stations and nuclear waste material carried out. The continuous investigation should be undertaken to detect the concentration of radionuclide in the air. Early measures can prevent the mankind from radiological hazards. The findings in the research may help to take idea of a base line in the region surrounding the NAPS.

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