

An Assessment of Gamma Dose in Air near Yamuna River in Delhi, India

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Detectors play a crucial role in detecting radiation in the surroundings. Environment. They are used to detect radioactivity in soil, water and air. This study examined the natural radioactivity level in air that has been determined using GM counter (i.e. Gamma survey meter) near Yamuna River in Delhi. The main source of radiation in the environment are radioactive nuclei in soil and cosmic radiation. The naturally occurring radionuclides like ²³⁵U, ²³²Th, and ⁴⁰K and presence of Radon (²²⁰Rn) and Thoron (²²²Rn) in soil near Yamuna affect the radioactivity in air of that region. This study considered samples of air near Yamuna bank and Gamma dose in these air samples ranged from 0.320 mSv/y (milli Sievert) to 0.533 mSv/y (i.e. 3 µR/h (microRoentgen) to 5 µR/h) with average outdoor Gamma absorbed dose rate of 0.412 mSv/y which is within corresponding reference value that is 1mSv/y estimated by WHO in 2009 (World Health Organization), and this study did not find any potential health risk due to Gamma dose in study area.

Keywords: Yamuna river, Gamma dose, Gamma Survey meter, Radiation

1 Introduction

Natural radioactivity and radiations have always been a part of the environment since the creation of the earth¹. Everyone in their life is exposed to radiation as the radiation is present everywhere, in air, water and house where humans live (as building materials are made up of soil). The main source of radiation in nature is soil and cosmic radiation. On earth, Gamma waves are generated by nuclear explosion, lightning, and radioactive decay. The radioactive nuclei such as ²³⁸U, ²³²Th, ⁴⁰K present in the soil surface decays by releasing Alpha, Beta and Gamma particle in the environment to gain stability. They decay because they are unstable (explained by binding energy curve) and to gain stability they release energy and become stable.

Radon is a radioactive gas that has no odour, colour, and taste which is produced from the natural radioactive decay of Uranium, which is present on earth surface in the Fig. 1.

Radon is released into the atmosphere by the ground, where it decays and produces further radioactive particles. Lung cancer may result from these particles, which are deposited on the cells lining of the airways during breathing. According to a WHO study, one of the main causes of lung cancer is radon. Depending on the smoking prevalence and the national average Radon level, it is estimated that 3%

to 14% of all lung cancers in a nation are caused by Radon². In India the estimated geometric mean value of Radon concentrations in dwellings is 367.1 Bq/m³. It was shown that the risk of lung cancer was higher among uranium miners exposed to exceptionally high levels of radon.

Additionally, studies from China, North America, and Europe have demonstrated that even low levels of radon, such those present in houses, can be harmful to health and are associated with lung cancers worldwide⁴. According to studies in the USA by U.S. environmental Protection agency, every year approximately 21,000-lung cancer deaths are attributed to radon gas in homes⁵. Gamma radiations need materials like Lead, Steel, or Concrete to stop its travel or penetrating power. It differs from both Alpha and Beta radiation; rather it being particles, Gamma radiation is only pure energy⁶. The radioactive radiations released from these unstable elements affect us and if living organisms are exposed to excessive amount of radiation then it may cause serious health issues. According to WHO, It has been determined that uranium is a nephrotoxin that can harm the kidneys⁷. With their high energy and strong penetration, Gamma rays can penetrate all the way through the human body and induce ionization that damages DNA (Deoxyribonucleic acid) and tissue⁸. Health risk of radiation to living creatures with Dose rate presented in Table 1.

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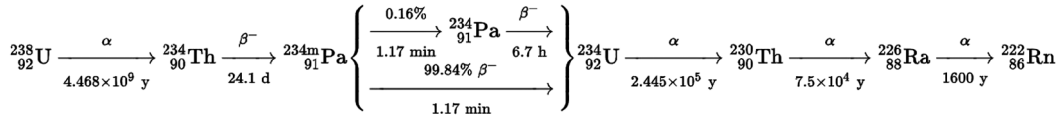


Fig. 1 — The decay of large element Uranium into small elements such as Thorium, Protactinium, Radon by releasing alpha, beta, and gamma particle to gain stability

Table 1 — The health risk of radiation on the life of living creatures

Dose Rate, $\mu\text{Sv/h}$	Health Risk
>10,000,000	Lethal: Organ failure and death within hours!
1,000,000	Severe: Vomiting
100,000	Severe: Radiation poisoning
1,000	High danger: Evacuate immediately!
100	High danger: Heightened sickness risk!
20	High danger: Sickness risk!
10	Danger: Relocate now!
5	Danger: Relocate ASAP!
2	Elevated risk: Take safety precautions e.g. in an airplane at a cruising height
1	Safe: Short term habitation only, e.g. in an ascending or descending airplane
0.5	Safe: Medium to long term habitation, e.g. surrounded by granite walls.
<0.2	Safe: Normal levels...

In soil surface radioactive nuclei such as ${}^{238}\text{U}$, ${}^{232}\text{Th}$, ${}^{40}\text{K}$ are present which decays and release various type of radiation and energy in surroundings⁴. They decay in small nuclei to become more stable. As humans are living on earth surface so they are exposed to radiation that are present in environment. Radiation exposure can lead to a range of health effects depending on the type, dose, and duration of exposure. Ionizing radiation, such as X-rays, gamma rays, and radioactive particles, is the most harmful to human health⁹. Long-term or chronic exposure, even at low levels, can increase the risk of cancer (especially leukemia, thyroid, and breast cancer), cause genetic mutations, lead to cataracts, and raise the risk of cardiovascular disease⁵. Children and fetuses are particularly vulnerable, as radiation can interfere with development and increase the risk of birth defects and future cancers⁷. Safety precautions including shielding, limiting exposure time, and

keeping a safe distance from sources are essential to reducing these dangers, particularly for employees in the nuclear, medical, or industrial sectors.

Soil is the primary source of radiation on Earth, and hence, water reservoirs contain radiation. As Yamuna River is flowing through Delhi, so to understand the effect of it on outdoor Gamma absorbed dose rate and whether it falls in safety limit or not, we conducted this study. Large population reside close to Yamuna River in Delhi, which has an impact on people’s lives either directly or indirectly. As a result, to understand the impact of it on people’s lives study of Gamma dose in the air is necessary.

This research focus on the estimation of Gamma dose concentrations and their health risk assessments in air sample within the 1km radius of Yamuna in Delhi. This study measured seven air samples within 1 km range of Yamuna bank in Delhi. Gamma dose in these air samples ranged from 0.323 mSv/y (milliSievert) to 0.558 mSv/y (i.e. 3 $\mu\text{R/h}$ (microRoentgen) to 5 $\mu\text{R/h}$) which is within the recommended average annual dose per person from all sources of radiation in the environment by WHO in 2011 is approximately 1 mSv/y⁹.

1.1 Various Type of Doses⁹

1.1.1 Absorbed Dose - It is the quantity of energy that radiation deposits in a mass. Anything can be the mass, including humans, rock, water, and air. Absorbed dose is expressed in milliGrays (mGy).

1.1.2 Equivalent Dose - Each organ's equivalent dose is determined. It is adjusted to account for the effectiveness of the radiation type and is based on the quantity of radiation absorbed by an organ.

1.1.3 Effective Dose - The entire body's effective dose is determined. It involves giving each organ an equivalent dose that is modified to take into consideration the organ's radiation sensitivity. Effective dose is expressed in milliSieverts (mSv).

1.2 Geological Significance of Study Area

The Yamuna River is the longest and the second-largest tributary of the Ganges in India. It rises

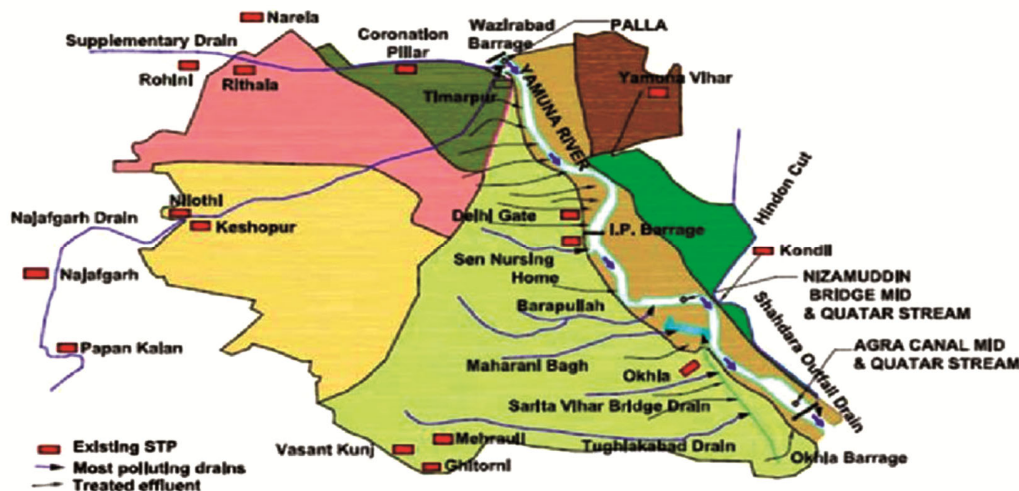


Fig. 2 —The entrance and exit of Yamuna River and its direction of flow in Delhi

approximately 4,500 meters (14,800 feet) on the southwest slopes of the Lower Himalaya in Uttarakhand and flows 1,376 kilometers (855 miles) with a drainage system covering 366,223 square kilometers (141,399 square miles), or 40.2% of the Ganges Basin. It travels around 23km in Delhi starting from Wazirabad barrage in the upstream to Okhla barrage at the downstream located between $28^{\circ} 24' 17''$ and $28^{\circ} 53' 00''N$ and between $76^{\circ} 50' 24''$ and $77^{\circ} 20' 37''E$ in Delhi (Fig. 2). According to a Central Pollution Control Board (CPCB) survey in 2023, 413 industries in the state of Delhi have been dumping untreated wastewater into the Yamuna when it joins the river. The Yamuna is contaminated by untreated water from the textile, oil and refinery, fertilizer, chemical, food, and beverage industries, which are concentrated in Gurugram, Ballabgarh, Faridabad, Panipat, and Sonipat. These factories create effluents that are rich in nitrates and ammoniacal nitrogen because they use a significant amount of chemicals in their manufacturing process. Since most of these units lack treatment facilities, the polluted effluents wind up in the Yamuna, increasing its toxicity and contaminating its water.

The Yamuna River meanders through a wide alluvial floodplain, which has been historically fertile and prone to seasonal flooding in Delhi. Depth and width of the river varies according to season as in monsoon it expands, while in summer it shrinks and is often reduced to a narrow stream due to upstream damming. The Yamuna floodplain in Delhi stretching on both sides of river, the floodplain is flat, low-lying, and fertile with the elevation of 200-210 meters above sea level. To the west of Yamuna lie the Delhi Ridge

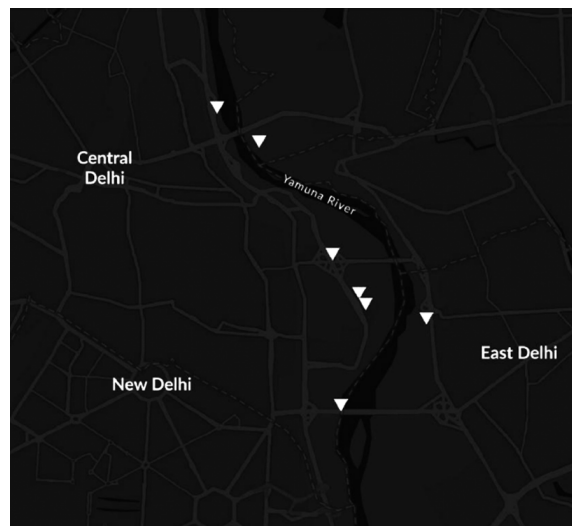


Fig. 3 —The white triangular mark on the Google Earth map shows the location of sample collection

hills, part of the Aravalli range, these are elevated terrains with rocky outcrops, rising to 260-320 meters. The bridge acts as a barrier and divides the flood plain from the main Delhi plateau¹⁰.

The importance of this study lies in the fact that a large population in Delhi residing near the Yamuna and directly or indirectly they are connected to it so detailed study of Gamma dose in the area with the help of digital instruments Gamma dose in air is calculated to spread awareness among the residents of the area. To detect ionized radiation in air digital GM counter is used to determine the influence of radiations on people life living near that study region.

In the above picture (fig. 3), white marked triangles represent area where Gamma doses in air were measured.

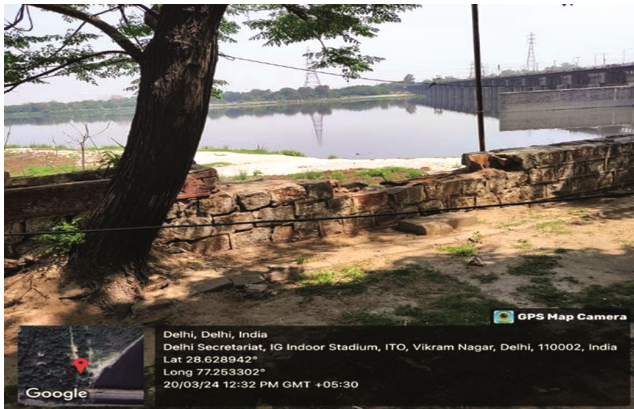


Fig. 4 — Live image with geotag at the site of sample collection with GPS



Fig. 5 — GSM used to detect Gamma dose

2 Materials and Methods

2.1 Sample Collection

In this study, initially a total of seven air samples from various locations near Yamuna River in the month of march 2024 were collected to determine the Gamma dose in the region. Each data is observed very carefully by placing GM counter at a plane surface to minimize the error and GPS coordinates (Fig. 4) noted positions.

2.2 Gamma Survey Meter

In this study, outdoor Gamma absorbed dose rate were measured at 7 sites within 1 km range of Yamuna River in Delhi using micro R survey meter (Model:-PRM-121S) weighted approx. 1.75kg including detector and batteries. (Fig 5) Dimensions of this instrument is 23cm × 9cm × 10cm approx. handle dimensions extra¹¹. It is designed by PLA Electro Application Pvt. Ltd. Mumbai and is ideally suited

for radiometric, geophysical and environment reconnaissance survey. With its integrated NaI Scintillator 1"× 1" plain detector and 1" PM tube, this portable survey meter will provide the best performance while counting low-level gamma radiation dose rate¹¹. This unit's response is highly accurate and dependable, and it can measure and display dose rates in the range of 0 to 50 μR/hr, 0 to 500 μR/hr, and 0 to 5000 μR/hr. It can read between 20% and 100% of full-scale on any range with an accuracy of ±15%. It is calibrated with Cs-137 as a standard source. As a field instrument, it functions on readily accessible battery cells, and its carefully engineered low current drain circuit provides long cell lifespan¹². Gamma radiation present in the surroundings of Yamuna River in Delhi were observed at a plane surface at a height of one meter above the earth surface¹³. The minimum value that can be observed with the PRM-121S Gamma survey meter is 1.0 μR/h with least count of 1 μR/h.

The outdoor absorbed dose rate (nGy/h) was derived from external influence rate data measured in micro-Roentgen per hour by applying the conversion factor of 1 μR/h = 8.77 nGy/h¹².

2.3 Annual Dose

Annual effective Gamma dose from background radiation can be calculated using the formula

$$E \text{ (mSv/y)} = D \text{ (nGy/hr)} \times \text{OF}_{\text{out}} \times T \times \text{CC} \text{ (Sv/Gy)} \times 10^{-6}$$

where OF out is outdoor occupancy factors (0.2), CC is the conversion coefficient (0.7 for adults) published by UNSCEAR to convert absorbed dose in air to the effective dose in humans, E (nanoSievert) is the yearly effective dose, and T (h) is the time to convert from year to hour (8760 hours/year).

D (nSv/h) is the Gamma absorbed dose rates¹⁴. In 1993, UNSCEAR report determined that the conversion factor between the absorbed dose in air and effective dose received by adult is 0.7 Sv/Gy. The average annual dose per person from all source of radiations recommended by WHO, 2011 is 1 mSv/y.

3 Result and Discussion

The study is conducted to detect Gamma dose in air within the 1 km range of Yamuna bank and to observe the consequences of these radiation in that area. This study has measured Gamma dose in air at seven locations that are listed below in Table 2. In this table, location code with their doses is mentioned in mSv/y and μR/h. The Gamma dose in air in the study

Table 2 — Measured Gamma dose in air at seven locations are listed below

S.no.	Location	Latitude	Longitude	Annual effective dose(μ R/h)	Annual effective dose(mSv/y)	Absorbed dose(nGy/h)
1	RCY01	28.674967	77.231501	4	0.427	34.80
2	RCY02	28.669676	77.238899	5	0.533	43.50
3	RCY03	28.652274	77.25183	4	0.427	34.80
4	RCY04	28.644591	77.257652	4	0.427	34.80
5	RCY05	28.645065	77.259564	3	0.320	26.10
6	RCY06	28.628942	77.253302	3	0.320	26.10
7	RCY07	28.642377	77.268352	4	0.427	34.80

Average annual effective dose in air of seven locations is 0.418mSv/y (i.e. 3.857 μ R/h).

Table 3 — Statistical parameters of the data

Parameters	Annual effective dose(mSv/y)	Absorbed dose(nGy/h)
Min.	0.320	26.10
Max.	0.533	43.50
Average	0.412	33.56
Median	0.427	34.80
Standard deviation	0.068	5.56
Geometric mean	0.406	33.09

area ranges from 3 μ R/h to 5 μ R/h with average annual effective dose of 3.86 μ R/h (i.e. 0.412 mSv/y) that is within the range recommended by WHO, 2009¹. Out of seven samples five lies above the average measured dose (i.e. 71 %) and two samples lies below average measured dose (i.e. 29 %). At every study location the dose lies within safe limit. The variation in Gamma dose in study is due to the geology of the study area and variation in radioactivity in soil and water of that region¹⁵. Out of sample collected the minimum value of Gamma dose in outdoor is at RCY 05 and RCY 06 that mean the radioactivity in soil and water is small at these locations. Highest value of Gamma dose is in the air of Location RCY 02, which is the bank of Yamuna, river at Nigam Bodh ghat, which is famous place for Tourism. In this region water is flowing from the hills, which may be the cause for high dose in this location.

But the overall average value of the study area lies withing the safe limit hence this area is safe from the radiological effect of radiation.

The average rate of terrestrial Gamma absorbed dose at each site of measured Gamma dose in Delhi near Yamuna River is shown in Table 2. The Table 3 shows the average absorbed dose rate is 33.56 nGy/h, with a range from 26.10 nGy/h to 43.50 nGy/h which is within the global average (UNSCEAR, 2000). The highest value i.e. 43.50 nGy/y is measured at Delhi metro red line, Metro Vihar, Shastri Park, Shahdara, Delhi and minimum value is at IG indoor stadium, ITO, Vikram Nagar, New Delhi. Out of seven

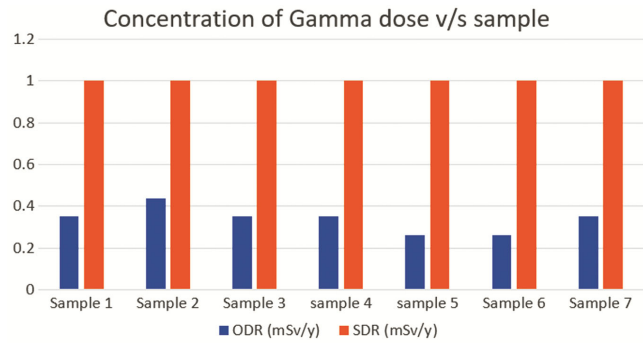


Fig. 6 — compared observed Gamma dose with estimated Gamma dose

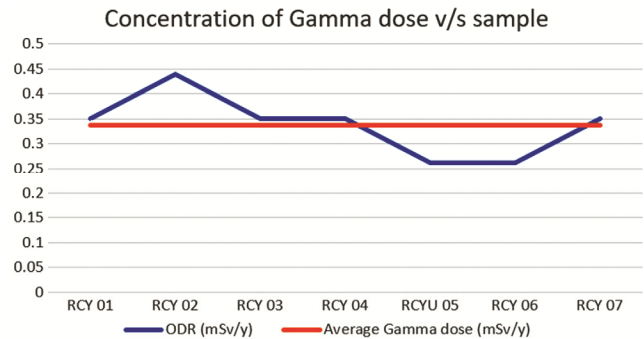


Fig. 7 — Deviation of Gamma dose in air with average value samples all are within the safe limit and within global average (UNSCEAR, 2000).

Figure 6 shows a multi bar graph for concentration of Gamma dose in air v/s sample. The outdoor Gamma dose in air within 1 km range of Yamuna bank is compare with the standard dose rate recommended by WHO, 2009¹.

Figure 7 shows the line graph plotted to compare deviation of Gamma dose in air with respect to average Gamma dose.

On comparing various research in Table 4, the average annual effective dose rate for different cities of India and world, it is observed that out of twelve mentioned locations in table maximum annual effective dose is at federal university Owerri, Nigeria with 1.26 mSv/y and minimum at Thanjavur, Tamil

Table 4 — Comparison of this study data with average annual effective dose of other studies

S.no.	Location	Average annual effective dose (mSv/y)	References
1	Bengaluru	0.08	[16]
2	Hyderabad, Telangana	0.15	[17]
3	Shimoga dist. Karnataka	0.235	[18]
4	Kolkata West Bengal	0.13	[19]
5	Along Alaknanda and Ganga	0.10-0.18	[20]
6	Thanjavur, Tamil Nadu	0.053	[21]
7	Eastern Deccan Plateau, India	0.20-1.89	[22]
8	Bhilai, Chhattisgarh	1.11	[23]
9	India	0.11	[24]
10	Federal university Owerri, Nigeria	1.26	[30]
11	Istanbul	0.08	[25]
12	Bushehr city, Iran	0.452	[28]
13	Delhi	0.412	Present Study

Nadu. Whereas locations such as Bengaluru, Hyderabad, Shimoga, Kolkata, Along Alaknanda and Ganga, Eastern Deccan Plateau, Bhilai, India, Istanbul, and Bushehr city have average annual Gamma dose rate range from 0.08 (Bengaluru) to 1.11 (Bhilai, Chhattisgarh). Bhilai, an industrial area in Chhattisgarh may be a cause of such high average annual Gamma dose rate. This study measured average annual effective dose lies in between both extreme values mentioned in the table.

The reason of deviation of Gamma dose in air within 1km range of Yamuna bank in Delhi and Gamma dose in air at different locations because of the geology and variation of radioactivity in water and soil at different locations. For example, the average Gamma dose in air at Owerri, Nigeria is larger than the average Gamma dose in air at Yamuna bank in Delhi shows that the federal university of technology Owerri, Nigeria has high concentration of radioactivity in soil and water than that in Delhi, India.

4 Conclusion

The study on the measurement of Gamma dose in air has been completed, with the important findings :-

- i Maximum Gamma dose in air within the 1 km range from Yamuna bank is found at RCY 02 with longitude 77.238899° and latitude 28.669676°.
- ii By comparing between measured Gamma dose in air and the recommended average by WHO, it is found that the radiation in the area are not

hazardous to human health of the people living there.

- iii Human body absorbs the radiation so it is important to routinely measurement of radiation so that it doesn't cause severe health problem to people living in study area.

In this study a well calibrated Digital Geiger Muller counter is used to detect natural background Gamma dose in the air near Yamuna bank Delhi, India. The concentration of Gamma dose in air of all samples lying under the WHO safe limit. The concentration of Gamma dose in air ranged from 0.320 mSv/y to 0.533 mSv/y with an average value of 0.412 mSv/y which is within the permissible limit. Therefore, here it can be concluded that as all the measured Gamma dose in air is within the safe limit so there is no radiation risk due to ionizing radiation in the study area.

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