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Assessment of Alpha Radioactivity in different Matrices along Subarnarekha River around Jaduguda Uranium Mine area, India

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Abstract

Mining effect generally increases the level of radioactivity of the surrounding environment. Our previous work already showed that alpha activity in water of Subarnarekha River is enhanced due to the effect of Jaduguda uranium mine. The question that consequently pops up is whether the associated materials like soil, sand and gravel along the river path will also be contaminated with radionuclides. Such contamination will cause severe harm to public health because these objects are often used as building materials. We have collected soil, sand and gravel samples from different locations along the river path starting from the area near Jaduguda upto the river mouth and have measured their alpha activity using SSNTD. The measured activity ranges from 55 – 2116 Bqkg^{-1}, 933 – 2075 Bqkg^{-1} and 979 – 1924 Bqkg^{-1} for gravel, sand and soil samples respectively. In majority of the sites soil samples show highest activity among all the samples. This is the first ever attempt to measure and analyse the radioactivity pattern of soil, sand and gravels along the Subarnarekha river path and the study reveals some noticeable facts that are not only important from academic point of view but also crucial for the health of the local people.

Keywords: Jaduguda Uranium mine, Gravel, Sand, Soil, LR - 115, and alpha activity.

Introduction

The environmental radiation is ubiquitous and every human being on globe is being exposed to natural radiation comprising of mainly the cosmic rays and terrestrial radioactivity. Terrestrial sources of radiation are mainly due to the naturally occurring radionuclides present in varying amounts in all soil and rocks[1]. These radionuclides decay to attain the stable state and thereby produce ionizing radiation in various degrees. These radionuclides and their decay products pose a serious health problem to common people worldwide. To assess the health risk it is necessary to know not only the activity levels of the radionuclides but also their distribution in our environment.

Large amount of waste products are generated due to mining and milling activity of metals. These waste materials generally dumped on land surface or tailing ponds may spread into surrounding water and surface bodies causing environmental pollution. Special attention has to be paid on such pollution if it is due to the mining of radioactive materials like Uranium as we know radioactive pollution can affect the people fatally. It is observed globally that mining effect can lead to considerable enhancement in the level of activity of radionuclides in the surrounding areas.

Uranium is present almost everywhere on the earth surface in varying amounts. It is the heaviest naturally occurring radioactive element. Its concentration depends upon its origin, and so is much higher near its mine areas. In the earth's crust, it is found at an average concentration of 0.0003 percentage[2]. Natural uranium (U) or uranium dioxide (UO_2) can be used as fuel in nuclear reactors. Triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2) are the common forms of uranium oxide. It is also well known that at ambient temperatures, UO_2 will gradually convert to U_3O_8. U_3O_8 is (depending on the environmental conditions) also found in nature and it is the most stable compound of uranium. Uranium has both chemical and radiological toxicity which affects mostly two important organs — kidney and lungs[1-3,6,7]. One of the most common ionic forms of uranium is uranyl ion [UO_2^{2+} (yellow)] which represents the uranium (VI) state. Its target organs are kidney, lungs, liver and brain[8]. Within our body it circulates in the plasma of our blood as a relatively inert but acid liable bicarbonate-uranyl complex which could be filtered into the kidney tubules. Then the uranyl ion is set free by the action of hydrogen ions. Due to normal tubular action the uranyl ion is liberated and finally assumed to be accumulated on tubular lumen. Accumulation of uranyl ion in tissues including gonocytes[8] produces congenital disorders, and in white blood cells causes immune system damage[9].

The spreading probability of uranium from its mine area to adjacent areas is increased if a river flows through the mine

region. The increased level of uranium in the surroundings generates an important issue regarding the risk which the contamination poses to human health. It may be mentioned here that ecological impact of radionuclides from uranium tailing dump in Ukraine and from leaching of contaminated water from an ore processing tailing pond near the town of Zhovti Vady into the river Dnipro have been assessed by Voitsekhovitch and his team[10].

One of the major Uranium mines of India is situated at Jaduguda in the Jharkhand state. Jaduguda region has high grade uranium ores which increases upto 0.20% of U_3O_8 (triuranium octaoxide)[11]. The acidity of the tailings or the waste materials is neutralized using lime. After neutralizing the acidity the materials are separated into coarse and fine particles. Uranium is then separated by chemical process. The coarse tailings are used to fill the mine cavities while the fine particles are discharged into the tailing pond after mixing with water[12]. Jaduguda mine has three tailing ponds (around 75 hectares), two of which are fully filled and one is presently running. Around 1.5 x 10^5 tonnes of waste materials are disposed of in the tailing ponds per year[13]. The mine cavities, tailing ponds and tailing dams are situated near the agricultural land of the adjoining villages[12]. In this site leaching of uranium is very much likely to be influenced by Subarnarekha River which flows near the mine area and merges into the Bay of Bengal. So, along the path of the river water, soil and associated materials may also be contaminated. Ailment pattern among the people in and around Jaduguda was shown in the report of Radiation and Tribal Health in Jaduguda where it was also mentioned that many of the sufferers believed that it was due to the radiation coming from Jaduguda uranium mine[12].

Some important works have been done on the assessment of radioactive pollution from waste dumps of mines in different parts of the world. Due to radium bearing water discharge into settling ponds and rivers from Polish coal mine in Poland, ^{226}Ra concentration were found to be few hundreds of Becquerel per kg[14]. Radium activity and radon exhalation rate from phosphate ore in Egyptian mines have been studied using SSNTD and Alpha Guard by Saad[15]. He found that the radium activity in phosphate samples varied from 1.8 to 361.3 kBqkg^{-1} and the radon exhalation rates in these samples varied from 0.020 to 4.125Bqm^{-2}h^{-1}. For two uranium production units of Brazil environmental waste management performance test was carried out by Fernandes and his team[16]. Wang and co-workers assessed the environmental impacts and the radiological risk due to U and Th leached from uranium mill tailing of Guangdong province in China[17]. Regarding the Jaduguda Uranium mine, assessment of radioactivity was performed by Tripathi and his group[18]. Here, the geometric mean activity of ^{222}Rn in air over the tailings ponds (I and II) were found to be 30 and 23 Bqm^{-3}, respectively. Radon exhalation rate and activity concentrations of rock samples collected from Jaduguda uranium mine have been measured by Mahur and co-workers[11]. Their measured concentrations in these samples varied from 123 ± 7 Bqkg^{-1} to 40,858 ± 174 Bqkg^{-1} for ^{238}U and 162 ± 11 Bqkg^{-1} to 9,024 ± 189 Bqkg^{-1} for ^{40}K. In the regions of Bagjata, Turamdih and Jaduguda, the concentration of naturally occurring radioactive materials (NORMs) in soil samples have been estimated by Tripathi and his team[13]. Here, the mean activity concentrations in this soil of Bagjata, Turamdih and Jaduguda regions were found to be 128.6, 95.7 and 49.2 Bqkg^{-1} for ^{238}U and 57.3, 78.4 and 68.9 Bqkg^{-1} for ^{232}Th, respectively. In 2014, Sethy and his co-workers measured the mean activity concentrations of ^{238}U, ^{226}Ra, $^{232+234}$Th and ^{210}Po in the soil samples collected from the uranium mineralized area of Jaduguda[19].

In an earlier study our group found elevated alpha radioactivity level in water of Subarnarekha River and tube well in-and-off zone of Jaduguda uranium mine[20]. In the study of Subarnarekha River basin, it is mentioned that the contamination of the sediments with metals at few locations of the river basin was attributed to mining, industries and other anthropogenic causes[23]. So, it would be very much relevant to measure the alpha activity level of soil, sand and gravels along the course of the river Subarnarekha. Presence of radionuclides in these materials may have serious consequences on human health because these materials are often used as building materials by the local people.

For assessment of radioactivity in gravel, sand and soil samples, we have chosen nine different places along the course of river Subarnarekha starting from near Jaduguda and ending near its mouth. The places of samples collection are 3 - 50 km apart from one another depending on the accessibility of the site of collection of samples near the river. Alpha activities of the collected samples were measured using SSNTDs (LR-115). Our work is the first ever attempt to measure alpha radioactivity in soil, sand and gravels samples on river bank of Subarnarekha from near Jaduguda uranium mine area upto the river mouth at Bay of Bengal.

Materials and Methods

Description of study area: Jaduguda uranium mine (established in 1967) is situated at the heart of a tribal homeland. Jaduguda lies in the East Singbhum district of Jharkhand state of India. At Jaduguda mine, the concentration of uranium ore is 0.06%. The mine lies at 1600 ft to 2000 ft below the earth surface. The tailing dams of the mine have been constructed on the agricultural fields. Agricultural fields of Subarnarekha valley are contaminated by the air borne tailing dust particles[12]. Subarnarekha River which flows near the mine area is one of the major rivers in India, rising from the Chota Nagpur plateau in the state of Jharkhand. After passing through Jharkhand, the river enters the state of West Bengal, Orissa and empties into the Bay of Bengal. The path of the river along with the sampling sites is shown in Figure-1. We have collected gravel, sand and soil samples from Ghatsila (22°34′N and 86°28′E), Jamsola (22°13′N and 86°42′E), Gopiballavpur (22°13′N and 86°53′E), Harekrishnapur (near Rohini) (22°09′N

and 87°03′E), Kulboni (22°05′N and 87°08′E), Bhasraghat (22°03′N and 87°11′E), Balidangrighat (near Dantan) (21°56′N and 87°14′E), Sonakonia (21°51′N and 87°14′E) and Rajghat (21°45′N and 87°09′E) — along the flow direction of the river starting from the mine area to the river mouth. These locations are represented by the numbers 1, 2, 3, 4, 5, 6, 7, 8 and 9 respectively in Figure-1. The distances between the consecutive places are 44 km, 31 km, 26.5 km, 14 km, 3.6 km, 15.3 km, 10.5 km, and 15 km respectively starting from Ghatsila.

Sample collection and preparation: The study was carried out on the samples of gravel, soil and sand obtained from the bank of Subarnarekha River at 9 different places along the course of the river. The sample collection locations as shown in the Figure-1 are situated in three different districts, Purba Singbhum, Paschim Medinipur and Mayurbhanj of Jharkhand, West Bengal and Orissa state respectively. Soil and sand samples were collected from a depth of about 2 ft so as to get the natural soil and sand. The gravel samples were collected from the surface of the river bank. We collected three different types of gravel samples, two different types of soil and sand samples. The collected samples were fully dried by infrared (IR) lamp to remove absorbed moisture. The dried samples are then crushed into powdered form by using mortar and pestle, and then sieved[21].

Exposure and Etching of the samples: Alpha activity measurement was performed using LR-115 type II (12 µm cellulose nitrate on 100 µm polyester base) Solid State Nuclear Track Detector (SSNTD). Exposure was made using a pill box type container of depth 0.55 cm and diameter 2.9 cm. Fine powder of a sample was spread as a very thin layer at the inside bottom surface of the container. The plastic detector was put on the open surface of the container with the sensitive side of the detector facing the sample. Thus, the separation between the sample and the detector is 0.55 cm. The entire set up with the detector was then sealed and kept in a desiccator in a safe place as shown in Figure-2. Arrangement was such that all the α-particles detected must have come from the sample itself. Silica gel was kept in the desiccator for absorbing moisture[21]. Exposure was continued for 60 days in undisturbed condition. During this time a secular radioactive equilibrium is established between uranium, thorium and their corresponding daughter products. The detectors could record good number of α-particles resulting from the decay of the radionuclides and their daughters[22].

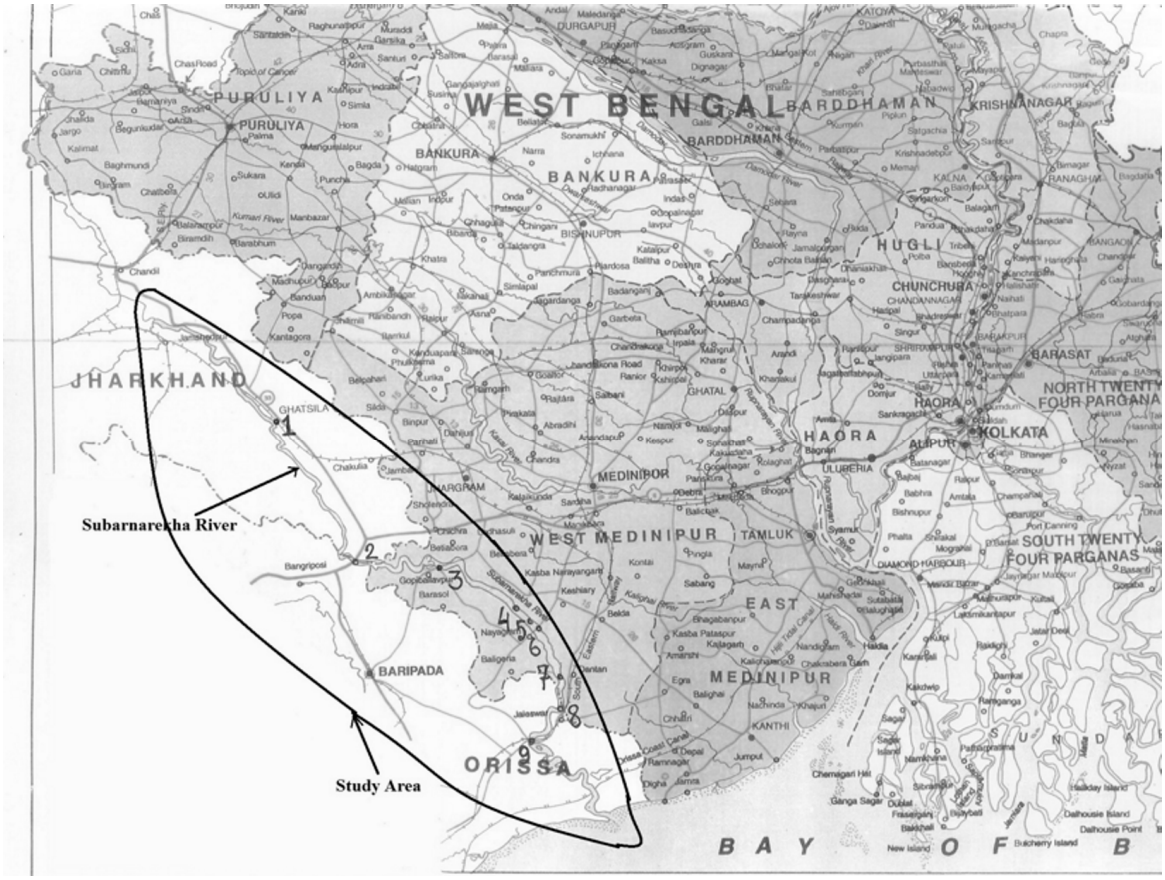

Figure-1
Locations of sampling sites along the river path

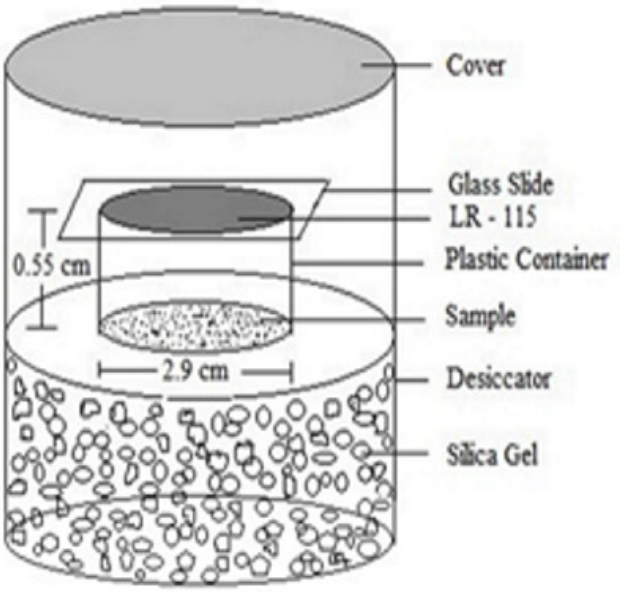

Figure-2
Experimental set up for exposure of LR-115 film to the sample

After exposure, track etching was carried out using a 2.5 N NaOH solution at 60°C temperature in an etching bath for 2 hours[22]. Temperature of the solution was never allowed to vary ± 0.1°C.

Measurement of alpha activity: The etched films were washed thoroughly in distilled water for about 30 minutes and finally dried in a dust free chamber. The α-tracks formed on the films were viewed under an optical Microscope. The number of α-tracks in the films was counted using 10X objective in conjunction with 10X ocular lens. The background was estimated by using a few unexposed LR-115 films. It was found that the value of the track density varied from 6 to 8 no. of α-tracks.cm^{-2}. So, we took the average value of background count as 7 no. of α – tracks.cm^{-2}. This background count was subtracted from the measured α-track density (N) to get the effective no. of α-tracks.cm^{-2} (ρ = N-7).

In order to estimate the α-activity of the samples, the detector was calibrated by irradiating it to a known radioactive source $^{252}Cf_{98}$ which is an α-emitter. Exposure was given under similar condition as stated before for 3 minutes. Calculation shows that each α-tracks.cm^{-2}.min^{-1} in the detector corresponds to activity of 2.67 Bq.

Alpha activity in Bqkg^{-1} of a sample may be estimated from the following relation:

$$Activity = \frac{10^6\,\rho c}{mt}$$

Where, 'ρ' is the no. of α-tracks.cm^{-2}; c = 2.67 Bq, the activity corresponding to each α-tracks.cm^{-2}.min^{-1} in the detectors, called the calibration factor; 'm' is the sample mass in mg, and 't' is the exposure time in minute.

Alpha activities of all the collected gravel, soil and sand samples were measured using the above relation.

Results and Discussion

The details regarding the alpha activity measurement in the samples of gravel collected from the specified sites along the path of Subarnarekha River are represented in Table-1 for details see Appendix-A.

It is observed that alpha activity of the gravel samples at any particular location varies widely. At the 1st site (Ghatsila) nine samples have alpha activity less than 500 Bqkg^{-1} with minimum of 60 Bqkg^{-1} (White - 1), four samples have activity greater than 500 Bqkg^{-1} and two of them have activity greater than 1000 Bqkg^{-1} with maximum of 1150 Bqkg^{-1} (Brown - 2). At the next site (Jamsola) out of seven samples one sample has activity greater than kBqkg^{-1} (1167 Bqkg^{-1}, Brown -1) and two other samples have activity greater than 500 Bqkg^{-1}. Here, also the minimum activity occurs for White sample (White - 1, 66 Bqkg^{-1}). At Gopiballavpur site one sample has activity more than 1000 Bqkg^{-1} (1108 Bqkg^{-1}, Brown -3) and four other samples have activity greater than 500 Bqkg^{-1} which varies from 728 Bqkg^{-1} to 965 Bqkg^{-1}. Seven samples have activity less than 500 Bqkg^{-1} with minimum for White - 2 (78 Bqkg^{-1}). At the fourth location (Harekrishnapur near Rohini) we see that one sample has activity more than 1000 Bqkg^{-1} (1062 Bqkg^{-1}, Brown -2). Here, equal no. (Three) of samples have activities greater than 500 Bqkg^{-1} and less than 500 Bqkg^{-1}. Black -1 has minimum activity of 138 Bqkg^{-1}. At Kulboni site minimum is 80 Bqkg^{-1} for White – 1 sample whereas maximum is 1141 Bqkg^{-1} for Brown -1 sample. Here, three samples have activity more than 500 Bqkg^{-1} including one having activity above kBqkg^{-1} and six samples have activity less than 500 Bqkg^{-1}. At the Bhasraghat site activity of 500 Bqkg^{-1} or more occurs for three samples with maximum value of 702 Bqkg^{-1} (Brown -3) and six samples have activity below 500 Bqkg^{-1}, minimum being 55 Bqkg^{-1} (White - 1). All the eight samples of Balidangrighat near Dantan site have activity less than 500 Bqkg^{-1} with maximum value of 472 Bqkg^{-1} (Brown -1) and minimum of 78 Bqkg^{-1} (White - 1). At the last two sites, two and four samples have activity more than 500 Bqkg^{-1}. White - 1 (90 Bqkg^{-1}) and White - 2 (121 Bqkg^{-1}) samples have minimum activity at both these sites respectively. At Sonakonia site highest activity is 1434 Bqkg^{-1} (Brown -1) and that at Rajghat site is 2116 Bqkg^{-1} (Brown -3). These two samples have the highest activity among all the gravel samples. It is found that all the sites minimum activity occurs for White gravels (except at Harekrishnapur near Rohini) whereas maximum activity occurs for Brown gravels samples. The overall minimum and maximum activity of the gravel samples are found as 55 Bqkg^{-1} (White) and 2116 Bqkg^{-1} (Brown) respectively.

Table-1
Details of the measurement of alpha radioactivity in gravel samples

Location	Gravel sample			
Site No. and Name	**Sample Type**	**Alpha activity ($Bqkg^{-1}$)**	**Minimum alpha activity ($Bqkg^{-1}$)**	**Maximum alpha activity ($Bqkg^{-1}$)**
1. Ghatsila	White - 1 White - 2 White - 3 White - 4 White - 5 White - 6 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Brown - 5 Black - 1 Black - 2	60 68 106 284 97 185 521 1150 1084 647 471 90 105	60 White - 1	1150 Brown - 2
2. Jamsola	White - 1 White - 2 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Black - 1	66 252 1167 811 529 195 117	66 White - 1	1167 Brown - 1
3. Gopiballavpur	White - 1 White - 2 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Brown - 5 Brown - 6 Brown - 7 Brown - 8 Black - 1 Black - 2	97 78 398 921 1108 728 748 965 377 258 365 170	78 White - 2	1108 Brown - 3
4. Harekrishnapur (near Rohini)	White - 1 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Black - 1	226 720 1062 711 453 138	138 Black - 1	1062 Brown - 2
5. Kulboni	White - 1 White - 2 White - 3 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Black - 1 Black - 2	80 147 155 1141 865 824 347 91 99	80 White - 1	1141 Brown - 1
6. Bhasraghat	White - 1 White - 2 Brown -1 Brown - 2 Brown - 3 Brown - 4 Black - 1 Black - 2 Black - 3	55 135 585 535 702 338 415 104 128	55 White - 1	702 Brown - 3
7. Balidangrighat (near Dantan)	White - 1 White - 2 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Black - 1 Black - 2	78 192 472 406 378 368 128 176	78 White - 1	472 Brown - 1
8. Sonakonia	White - 1 White - 2 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Brown - 5 Brown - 6 Black - 1 Black - 2	90 162 1434 881 358 494 445 464 102 132	90 White - 1	1434 Brown - 1
9. Rajghat	White - 1 White - 2 White - 3 Brown - 1 Brown - 2 Brown - 3 Brown - 4 Brown - 5 Brown - 6 Black - 1	128 121 295 1196 1036 2116 723 474 329 185	121 White - 2	2116 Brown - 3

Table-1
Appendix-A

Location	Gravel sample					
Site No. and Name	**Sample Type**	**ρ (Track.cm^{-2})**	**Sample mass m (mg)**	**Alpha activity (Bqkg^{-1})**	**Minimum alpha activity (Bqkg^{-1})**	**Maximum alpha activity (Bqkg^{-1})**
1. Ghatsila	White - 1	29	15	60	60 White - 1	1150 Brown - 2
	White - 2	33	15	68		
	White - 3	48	14	106		
	White - 4	138	15	284		
	White - 5	44	14	97		
	White - 6	90	15	185		
	Brown - 1	219	13	521		
	Brown - 2	521	14	1150		
	Brown - 3	526	15	1084		
	Brown - 4	314	15	647		
	Brown - 5	198	13	471		
	Black - 1	38	13	90		
	Black - 2	51	15	105		
2. Jamsola	White - 1	32	15	66	66 White - 1	1167 Brown - 1
	White - 2	114	14	252		
	Brown - 1	491	13	1167		
	Brown - 2	341	13	811		
	Brown - 3	257	15	529		
	Brown - 4	82	13	195		
	Black - 1	53	14	117		
3. Gopiballavpur	White - 1	44	14	97	78 White - 2	1108 Brown - 3
	White - 2	33	13	78		
	Brown - 1	193	15	398		
	Brown - 2	447	15	921		
	Brown - 3	538	15	1108		
	Brown - 4	330	14	728		
	Brown - 5	339	14	748		
	Brown - 6	437	14	965		
	Brown - 7	183	15	377		
	Brown - 8	125	15	258		
	Black - 1	177	15	365		
	Black - 2	77	14	170		
4. Harekrishnapur (near Rohini)	White - 1	95	13	226	138 Black - 1	1062 Brown - 2
	Brown - 1	326	14	720		
	Brown - 2	481	14	1062		
	Brown - 3	345	15	711		
	Brown - 4	220	15	453		
	Black - 1	58	13	138		
5. Kulboni	White - 1	39	15	80	80 White - 1	1141 Brown - 1
	White - 2	62	13	147		
	White - 3	75	15	155		
	Brown - 1	554	15	1141		
	Brown - 2	420	15	865		
	Brown - 3	400	15	824		
	Brown - 4	157	14	347		
	Black - 1	41	14	91		
	Black - 2	48	15	99		

6. Bhasraghat	White - 1	23	13	55	55 White - 1	702 Brown - 3
	White - 2	61	14	135		
	Brown -1	265	14	585		
	Brown - 2	225	13	535		
	Brown - 3	318	14	702		
	Brown - 4	142	13	338		
	Black - 1	188	14	415		
	Black - 2	47	14	104		
	Black - 3	62	15	128		
7. Balidangrighat (near Dantan)	White - 1	33	13	78	78 White - 1	472 Brown - 1
	White - 2	93	15	192		
	Brown - 1	214	14	472		
	Brown - 2	197	15	406		
	Brown - 3	159	13	378		
	Brown - 4	155	13	368		
	Black - 1	54	13	128		
	Black - 2	74	13	176		
8. Sonakonia	White - 1	38	13	90	90 White - 1	1434 Brown - 1
	White - 2	68	13	162		
	Brown - 1	696	15	1434		
	Brown - 2	399	14	881		
	Brown - 3	174	15	358		
	Brown - 4	240	15	494		
	Brown - 5	187	13	445		
	Brown - 6	225	15	464		
	Black - 1	46	14	102		
	Black - 2	64	15	132		
9. Rajghat	White - 1	62	15	128	121 White - 2	2116 Brown - 3
	White - 2	51	13	121		
	White - 3	143	15	295		
	Brown - 1	503	13	1196		
	Brown - 2	436	13	1036		
	Brown - 3	1027	15	2116		
	Brown - 4	351	15	723		
	Brown - 5	230	15	474		
	Brown - 6	149	14	329		
	Black - 1	90	15	185		

Table-2 Appendix-B contains the details of the relevant parameters associated with the alpha activity measurement in the samples of sand and soil. The Table shows that alpha activities of sand and soil samples at any particular location do not vary much. Soil activity varies from 979 $Bqkg^{-1}$ to 1924 $Bqkg^{-1}$ and sand activity varies from 933 $Bqkg^{-1}$ to 2075 $Bqkg^{-1}$. Considering all types of samples it is found that in majority of the sites soil samples show highest alpha activity among all types of materials. Clay and clay sand samples always have high activity value compared to the activity of the other types of soil and sand samples at the same location.

To study the variation of alpha activity of the soil and sand samples as we move from location to location along the Subarnarekha River, site-wise average activities have been calculated and represented in Table-3. As the alpha activity of the gravel samples varies to a large extent at each location, we do not determine the average value and perform any further analysis of the data. It is revealed by the analysis that the average alpha activity of both soil and sand samples falls as we go away from the mine area along the river upto Bhasraghat with one exception for soil as well as for sand. Relatively high value of soil activity at the Jamsola (2^{nd} location) may be attributed to the fact that here Clay type of soil which always has comparatively high value of activity is the only available sample type. On the other hand, activity of sand becomes relatives high at the 3^{rd} location (Gopiballavpur), because here the collected Clay sand type of sand sample has so high value of activity compared to others that the average is influenced by this high value. So exceptions are basically manifestations of low statistics. After Bhasraghat (which is about 135 km away from the 1^{st} site at Ghatsila) variation of average activity is not so consistent, especially for soil samples.

Table-2
Details of the measurement of alpha radioactivity in soil and sand samples

Location	**Soil sample**		**Sand sample**	
Site No. and Name	*Sample Type*	*Alpha activity ($Bqkg^{-1}$)*	*Sample Type*	*Alpha activity ($Bqkg^{-1}$)*
1. Ghatsila	Soil 1 Soil 2 Clay	1437 1281 1924	Sand 1 Sand 2 Clay - Sand	1234 1230 1419
2. Jamsola	Clay	1823	Sand 1 Clay -Sand	1195 1339
3. Gopiballavpur	Soil 1 Soil 2 Clay	1304 1226 1493	Sand 1 Sand 2 Clay -Sand	1146 1150 2075
4. Harekrishnapur (near Rohini)	Soil 1 Soil 2	1181 1162	Sand 1 Sand 2	1104 1106
5. Kulboni	Soil 1 Soil 2	1042 1060	Sand 1 Sand 2	1088 1069
6. Bhasraghat	Soil 1 Soil 2	1015 1005	Sand 1 Sand 2	1008 958
7. Balidangrighat (near Dantan)	Soil 1 Soil 2	1276 1262	Sand 1 Sand 2	1234 1172
8. Sonakonia	Soil 1 Soil 2 Clay	1060 1154 1067	Sand 1 Sand 2 Clay -Sand	1053 933 1156
9. Rajghat	Soil 1 Soil 2	1160 979	Sand 1 Sand 2	1045 996

Table-2
Appendix-B

Location	**Soil sample**				**Sand sample**			
Site No. and Name	**Sample Type**	**ρ (Tracks.cm^{-2})**	**Sample mass m (mg)**	**Alpha activity (Bqkg^{-1})**	**Sample Type**	**ρ (Tracks.cm^{-2})**	**Sample mass m (mg)**	**Alpha activity (Bqkg^{-1})**
1. Ghatsila	Soil 1 Soil 2 Clay	651 539 934	14 13 15	1437 1281 1924	Sand 1 Sand 2 Clay - Sand	559 597 689	14 15 15	1234 1230 1419
2. Jamsola	Clay	826	14	1823	Sand 1 Clay - Sand	580 650	15 15	1195 1339
3. Gopiballavpur	Soil 1 Soil 2 Clay	633 595 628	15 15 13	1304 1226 1493	Sand 1 Sand 2 Clay - Sand	482 558 940	13 15 14	1146 1150 2075
4. Harekrishnapur (near Rohini)	Soil 1 Soil 2	497 489	13 13	1181 1162	Sand 1 Sand 2	500 537	14 15	1104 1106
5. Kulboni	Soil 1 Soil 2	506 446	15 13	1042 1060	Sand 1 Sand 2	493 519	14 15	1088 1069
6. Bhasraghat	Soil 1 Soil 2	427 488	13 15	1015 1005	Sand 1 Sand 2	424 403	13 13	1008 958
7. Balidangrighat (near Dantan)	Soil 1 Soil 2	578 531	14 13	1276 1262	Sand 1 Sand 2	559 569	14 15	1234 1172
8. Sonakonia	Soil 1 Soil 2 Clay	480 523 518	14 14 15	1060 1154 1067	Sand 1 Sand 2 Clay - Sand	511 453 561	15 15 15	1053 933 1156
9. Rajghat	Soil 1 Soil 2	488 475	13 15	1160 979	Sand 1 Sand 2	507 451	15 14	1045 996

Table-3
Variation of average alpha activity of different type of materials from location to location

Site No. and Name	Average alpha activity ($Bqkg^{-1}$)	
	Soil	**Sand**
1. Ghatsila	1547	1294
2. Jamsola	1823	1267
3. Gopiballavpur	1341	1457
4. Harekrishnapur (near Rohini)	1172	1105
5. Kulboni	1051	1079
6. Bhasraghat	1010	983
7. Balidangrighat (near Dantan)	1269	1203
8. Sonakonia	1094	1047
9. Rajghat	1070	1021

Conclusion

From our present study we can conclude the followings: Average alpha activity of the soil and sand samples decreases as we go away from the mine area along the river Subarnarekha. There are some exceptions as we go far away from the mine area.

The above feature of variation of alpha activity of soil and sand samples is similar to the variation of activity of the river water as reported in our earlier work[20].

In case of gravel samples variation pattern of alpha activity from location to location cannot be determined properly as activity of different samples varies widely in any particular location.

The observations suggest that the radioactivity of the soil and sand samples is correlated to the activity of the river water. Uranium leaches into the river water from the mine area and flows with the river. Soil and sand samples might get contaminated from this water.

Origin of alpha-activity of the gravel samples seems to be not associated with the activity of the river water. Their activity is likely to be dependent on their constituents and the local environment.

In many gravel, soil and sand samples specially Brown gravels, Clay and Clay sand samples activity is high enough which demands more awareness of the common people and proper initiative of the local authority as these materials are often used as building materials and thus are capable of causing major health hazards.

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