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Natural radioactivity of ash and coal in major thermal power plants of West Bengal, India

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Natural radioactivity due to the presence of ^{238}U, ^{232}Th and ^{40}K in ash and coal in major thermal power plants of West Bengal, namely Kolaghat, Durgapur and Bandel, has been measured by a NaI (Tl)-based gamma ray spectrometer. The average activity concentrations of the radioelements ^{238}U, ^{232}Th and ^{40}K in the ashes of Kolaghat were found to be 111, 140 and 351 Bq/kg respectively, at Durgapur 97, 107 and 315 Bq/kg respectively, and at Bandel 106, 126 and 321 Bq/kg respectively. The absorbed gamma doses in air due to naturally occurring radionuclides in the ash from the power plants varied from 123 to 150 nGy h^{-1}, which are higher than three times the world average of about 43 nGy h^{-1}. The ash from power plants contains 2 to 3 times more natural radionuclides than that in feed coal. Ash samples have radium equivalent activity (Ra_{eq}) and external hazards index (H_{ex}) values closest to 370 Bq/kg and unity respectively, which have implications in terms of radiation hazard arising due to the use of these ash samples in building and construction.

Keywords: Ash, coal, radioactivity, thermal power plants.

COAL is an important source of power generation in India. The country has at present 90,000 MW of electricity generation, of which coal combustion contributes to more than 70% of the power generation. Hydroelectricity contributes to about 25% and the remaining is from nuclear power plants[1]. Combustion of coal results in generation of huge amounts of ash, which is a major environmental problem. This problem is particularly important for Indian power stations because most of them use poor quality coal with 55–60% ash content. This results in an average production of 100 million tons of ash per annum[2]. In the combustion process, most of the mineral matter in coal is converted into ash. Solid wastes produced from the coal-fired thermal power plants are mainly of two types, i.e. fly ash and bottom ash. Bottom ash is the coarse-grained fraction that is collected from the bottom of the boiler and is disposed by the wet disposal method in a slurry form to nearby waste-disposal sites (ash ponds). Owing to its relatively small size and hence large surface area, ash has a greater tendency to absorb trace elements that are transferred from coal to waste products during combustion[3]. Most of the toxic elements (As, Cd, Cr, Ni, Co, Cu and Sb) become enriched in the soil and groundwater through leaching form the bottom ash, causing soil and water pollution.

Coal, like most materials found in nature, contains trace quantities of naturally occurring radionuclides, ^{238}U, ^{232}Th and ^{40}K. Combustion of coal thus enhances natural radiation in the vicinity of the thermal power plants by release of these radionuclides and their daughters into the surrounding ecosystem. Unlike most of the nuclear and hydroelectric power stations, coal-fired power stations in India are generally located in areas which are thickly populated and, hence, the environmental impact experienced by the neighbouring population is significant. Apart from inhalation, an additional radiation hazard can be solid fallout resulting in elevated concentrations of natural radionuclides in the surface soils around the power

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plants[4]. The release of some of these residues to the environment, either directly through stack releases or indirectly from waste-storage areas, results in redistribution of natural radioactivity from deep under the earth to locations where it can modify ambient radiation fields and population exposure. Whether or not this redistribution constitutes a potential health problem has become a matter of public and scientific concern.

In India, most of the power plants operate in the vicinity of coal fields. Major coal fields of India are situated in the eastern region, in Bihar and West Bengal, which are densely populated. Natural radioactivity content of coal from these coal fields is also slightly higher than that from other coal fields of India[5]. Hence combustion of coal results in higher collective doses to the population in this part of the country. Thus special attention is to be given to the radiological impact of these power plants.

The major thermal power plants of eastern India are those of Kolaghat, Durgapur and Bandel. They generate 1260, 350 and 530 MW of electricity respectively. The Kolaghat thermal power plant is located in Midnapur district, West Bengal (22°27′ to 22°25′N lat. and 87°50′ to 87°55′E long.), on the western side of River Rupnarayan. The thermal power plant consumes bituminous coal grade E and F. It has six units of 210 MW each and generates 1260 MW electricity. The Durgapur thermal power station is situated in Burdwan district (22°56′ to 23°53′N lat. and 86°48′ to 88°25′E long.), West Bengal on the northern bank of river Damodar within 160 km WNW of Kolkata. At present, the power station has two working units and generates 350 MW of electricity. The Bandel thermal power plant is situated in the Hooghly district (23°39′32″ to 23°01′20″N lat. and 87°30′15″ to 88°30′20″E long.), West Bengal and is at 50 km from Kolkata. These three power plants use Gondwana coals of low sulphur and high ash content. Hence combustion of coal in these power plants results in generation of huge amounts of ash, which is disposed-off in large ponds located close to the thermal power plants. The ash, after being dumped, is kept exposed to the sun and in the course of time gets dried and becomes hard and compact. Ash ponds are situated close to domestic areas. Hence the radiation emitted from them can affect the surrounding locality, on prolonged exposure.

The main objectives of the present work are:

(i) Radiometric study of coal and ash determine the concentrations of naturally occurring radionuclides (U, Th and K) in coal and ash and their enhancement from coal and ash, during combustion.
(ii) To determine the dose emitted from ash ponds in order to assess the radiological impact of ash disposal on the surrounding population, keeping in view the high population density in the neighbourhood of thermal power plants.
(iii) Comparative study of radioactivity in Kolaghat, Durgapur and Bandel thermal power plants.
(iv) Estimation of hazard index with implications to the preparation of fly ash admixture for cement, concrete and fly ash bricks.

The feed coal samples were collected from inside the power plants. Coal varieties, all of lower Gondwana age and mined in the four coal fields of Raniganj, Jharia, Giridih and Talchir, were mixed together and pulverized before being fed into the boilers. The entire mount of ash generated in the power plants was disposed-off in large ponds located near the power plant. In the present study ash samples were collected in plastic packets from the ash ponds and electrostatic precipitator. The collected samples were stored in polyethylene bags. The samples were dried for 24 h in an air-circulation oven at 110°C. About 100 g of each sample was packed in plastic containers and sealed for 15 days before radioactive determination of uranium and thorium to attain radioactive equilibrium with their daughter products and to prevent radon loss. After attainment of secular equilibrium between ^{232}Th, ^{238}U and their daughter products, the samples were subjected to gamma-ray spectrometric analysis. This was carried out at the Radiochemistry Division, Variable Energy Cyclotron Centre, BARC, Kolkata, using a 5″ × 4″ NaI (Tl) crystal detector coupled to a 5″ dia photomultiplier tube and the associated data acquisition and analysis system. The detector was used to estimation of ^{238}U, ^{232}Th and ^{40}K in soil, coal and ash samples collected from the study areas.

The energy resolution of the detector was 1.95 keV at 1332 keV of a ^{60}Co source and the efficiency of the detector was determined with a ^{152}Eu liquid source (Amersham, UK) of known activity. ^{152}Eu liquid sources have been widely used for calibration and efficiency determination[6] due to their wide range of energies (122, 244, 344, 411, 443, 779, 964, 1112 and 1408 keV) with emission abundances of 3–29%. The ^{152}Eu liquid source was thoroughly mixed with the normal silica sands, whose activity level was similar to the background radiation level. An ideal measuring geometry of a cylindrical source (homogeneously distributed activity with constant volume and distance) was placed coaxially with the detector for efficiency determination and the same procedure applied for sample measurements.

Natural radionuclides of relevance to this work are mainly γ-ray emitting nuclei in the decay series of ^{232}Th and ^{238}U, and ^{40}K. While ^{40}K can be measured by its own γ-rays, ^{232}Th and ^{238}U are not γ-ray emitters. However, it is possible to measure γ-rays of their decay products. Decay products for ^{238}U (^{214}Pb: 295 and 352 keV; and ^{214}Bi: 609 keV) and ^{232}Th (^{228}Ac: 209, 338, and 911 keV; ^{212}Pb: 239 keV; ^{212}Bi: 727 keV; and ^{208}Tl: 583 keV) were used by assuming the decay series to be in secular equilibrium[6]. Weighted averages of several decay products were used to estimate activity concentrations of ^{238}U and ^{232}Th. The natural abundance of ^{235}U is only 0.72% of the total uranium content and hence was not considered in the present study. Although activity concentrations of ^{40}K were measured by its own γ-rays (1460.8 keV), ^{228}Ac, a daughter nuclide of ^{232}Th, producing 1459.2 keV γ-rays, interferes with 1460.8 keV of ^{40}K. Thus, when the Th content is high, it becomes difficult to determine the ^{40}K content accurately. The activity concentrations were calculated from the intensity of each γ-line taking into account the mass of the sample, branching ratios of the γ-decay, duration of counting and efficiency of the detector. One ppm of Th and U corresponds to 4.04 and 12.36 Bq/kg respectively, whereas 1% of K_2O corresponds to 252 Bq/kg of ^{40}K. Activity concentrations, calculated from the intensity of several γ-rays emitted by a nuclide, are grouped together to produce a weighted average activity per nuclide. Errors arise due to a number of factors like volume of the sample, efficiency calibration, peak area determination and random uncertainties associated with background and sample counts. All these errors were estimated to be of the order of 8–10% for the ^{232}Th and ^{238}U decay-series radionuclides. The error for ^{40}K is larger (more than 20%) due to contamination of its γ-ray line (1460.8 keV) by that of ^{228}Ac (1459.2 keV). For estimation of K, U and Th, the corresponding energies, i.e. 1.46, 1.76 and 2.62 MeV are used.

The absorbed gamma dose rate in air 1 m above the ground surface for uniform distribution of radionuclides (^{232}Th, ^{238}U and ^{40}K) was computed on the basis of guidelines provided by UNSCEAR[7,8]. The conversion factors used to compute absorbed gamma dose rate (D) in air per unit activity concentration in (1 Bq kg^{-1}) sand correspond to 0.621 nGy h^{-1} for ^{232}Th, 0.462 nGy h^{-1} for ^{238}U, and 0.0417 nGy h^{-1} for ^{40}K respectively.

$$D = [0.604C_{Th} + 0.462C_U + 0.0417C_K] \text{ nGy h}^{-1}, \quad (1)$$

where C_{Th}, C_U and C_K are the average activity concentrations of ^{232}Th, ^{238}U and ^{40}K in Bq kg^{-1} respectively. Radioactivity and absorbed dose rates in air from ash ponds are given in Tables 1–3.

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose rates (0.7 Sv Gy^{-1}) and outdoor occupancy factor (0.2) proposed by UNSCEAR[8] were used.

$$\text{Effective dose rate (mSv y}^{-1}) = \text{Absorbed dose rate in air (nGy h}^{-1}) \times 8760 \text{ h} \times 0.2 \times 0.7 \text{ Sv Gy}^{-1} \times 10^{-6}, \quad (2)$$

The results of annual external effective dose rates from ash ponds are also given in Tables 1–3.

Hamilton[9] defined an index called the 'radium equivalent activity' to obtain the sum of activities for comparison of the specific radioactivities of materials containing different radionuclides like Ra, Th and K. Krisiuk *et al.*[10] and Stranden[11] estimated that 370 Bq kg^{-1} (10 pCi/g) of ^{226}Ra, 260 Bq kg^{-1} (7 pCi/g) of ^{232}Th and 4810 Bq kg^{-1} (130 pCi/g) of ^{40}K produce the same gamma-ray dose rate. Thus the radium equivalent activities (Ra_{eq}) are estimated using the equation:

$$Ra_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077), \quad (3)$$

where A_{Ra}, A_{Th} and A_K are the activities in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K respectively.

To limit the radiation dose from building materials to 150 mrad/yr, a model developed by Krisiuk *et al.*[10] in the Soviet Union and proposed recently to serve as a criterion in the Federal Republic of Germany[12] is

$$\frac{A_{Ra}}{370} + \frac{A_{Th}}{260} + \frac{A_K}{4810} \leq 1. \quad (4)$$

Equation (4) considers the external hazards index (H_{ex}) due to γ-rays. The formula corresponds to a maximum Ra_{eq} of 370 Bq/kg and maximum H_{ex} of unity for building and construction materials. The results of radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) from ash are also given in Tables 1–3.

Radiometric analysis of ash samples from power stations at Kolaghat, Durgapur and Bandel are shown in Tables 1–3. The activity concentrations of ^{232}Th ranged from 126 to 146 Bq kg^{-1} with an average of 140 Bq kg^{-1} in Kolaghat ash; from 96 to 120 Bq kg^{-1} with an average of 107 Bq kg^{-1} in the Durgapur ash, and from 62 to 139 Bq kg^{-1} with an average 106 Bq kg^{-1} in the Bandel ash. ^{238}U ranges from 98 to 119 Bq kg^{-1}, 85 to 102 Bq kg^{-1}, and 78 to 183 Bq kg^{-1} in ash from Kolaghat, Durgapur and Bandel thermal power plants respectively. The average activity concentrations of ^{238}U at Kolaghat, Durgapur and Bandel for power plant ashes are 111, 97 and 126 Bq kg^{-1} respectively. The activity concentrations of ^{40}K ranged from 266 to 415 Bq kg^{-1} with an average of 351 Bq kg^{-1} in Kolaghat ash; from 267 to 364 Bq kg^{-1} with an average of 315 Bq kg^{-1} in Durgapur ash, and from 174 to 417 Bq kg^{-1} with an average of 321 Bq kg^{-1} in Bandel ash. Thus it is seen that the ashes of Kolaghat thermal power plant are enriched in the radionuclide of ^{232}Th compared to those of Durgapur and Bandel stations. The ashes of Bandel thermal power plant are enriched in the radionuclide of ^{238}U compared to those of Durgapur and Kolaghat stations. The activity concentrations of ^{40}K are more in the ashes of Kolaghat and Bandel stations than those of Durgapur. Among these, the highest activity concentration of ^{40}K is in the ashes of Kolaghat thermal power plant. The ashes of the power plants are enriched in the radionuclide ^{232}Th compared to that of ^{238}U. Earlier studies[13] had reported that the feed coal of these power plants also show high concentration of ^{232}Th compared to that of ^{238}U. The activity concentrations of radionuclides

Table 1. Radioactivity in ash, dose rate emitted from ash ponds, annual external effective dose rate (mSv y^{-1}), radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) from ash of Kolaghat thermal power plant

Sample no.	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Dose rate (nGy h^{-1})	Annual external effective dose rate (mSv y^{-1})	Ra_{eq} (Bq kg^{-1})	H_{ex} (Bq kg^{-1})
KAP1	117.4	145.8	403.0	159.1	0.195	357	0.96
KAP2	119.8	146.7	279.0	155.6	0.191	351	0.95
KAP3	114.9	144.2	282.1	151.9	0.186	343	0.92
KAP4	117.4	143.0	266.6	151.8	0.186	342	0.92
KAP5	98.9	141.8	372.0	146.8	0.180	330	0.89
KAP6	110.0	146.7	272.8	150.8	0.185	341	0.92
KAP7	117.5	136.2	372.0	152.1	0.187	341	0.92
KAP8	108.0	136.4	372.0	147.8	0.181	332	0.89
KAP9	113.7	126.1	359.6	143.7	0.176	322	0.87
KAP10	108.4	138.7	384.4	149.9	0.184	336	0.91
KAP11	107.2	139.7	368.9	149.3	0.183	335	0.90
KAP12	107.5	146.3	415.4	155.3	0.191	348	0.94
KAP13	113.9	141.4	403.0	154.9	0.190	347	0.94
KAP14	105.2	129.7	359.6	141.9	0.174	318	0.86
Mean	111.4	140.2	350.7	150.8	0.185	339	0.91

Table 2. Radioactivity in ash, dose rate emitted from ash ponds, annual external effective dose rate (mSv y^{-1}), radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) from ash of Durgapur thermal power plant

Sample no.	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Dose rate (nGy h^{-1})	Annual external effective dose rate (mSv y^{-1})	Ra_{eq} (Bq kg^{-1})	H_{ex} (Bq kg^{-1})
DAP1	96.6	109.1	300.7	123.1	0.142	276	0.74
DAP2	93.1	105.3	280.1	118.3	0.142	265	0.71
DAP3	96.5	109.3	290.4	122.7	0.145	275	0.74
DAP4	94.1	101.0	267.3	115.7	0.159	259	0.70
DAP5	85.4	107.6	272.4	115.8	0.146	260	0.70
DAP6	96.5	98.1	354.7	118.6	0.157	264	0.71
DAP7	100.4	113.9	344.4	129.5	0.150	290	0.78
DAP8	95.6	103.8	287.8	118.8	0.157	266	0.72
DAP9	100.4	110.0	364.9	128.1	0.143	286	0.77
DAP10	99.6	104.0	326.4	122.4	0.158	273	0.74
DAP11	101.7	112.0	321.3	128.0	0.161	287	0.77
DAP12	99.3	96.0	313.5	116.9	0.156	261	0.70
DAP13	102.9	112.0	334.1	129.1	0.142	289	0.78
DAP14	96.7	120.0	336.7	131.2	0.142	294	0.79
DAP15	100.4	110.3	341.8	127.3	0.145	284	0.77
Mean	97.3	107.5	315.8	123.0	0.150	275	0.74

are high compared to those in fly ash from thermal power stations in other parts of India, as shown in Table 4.

Uranium is present in the carbonaceous components of sedimentary rocks and accumulates in coal during the process of coalification. It is mainly present in the organic fraction in coal due to sorptive uptake onto the organic fraction during the early stages of peat accumulation and burial[14], whereas thorium is present in inorganic phases. The area around the ash ponds of Kolaghat, Durgapur and Bandel is dominantly composed of laterites with clay at the top. It is known that clays are great repositories of trace elements. In the three cases, the ashes on drying get mixed with the clay and constitute the topsoil of the area. Hence, the radionuclides are adsorbed onto the top clayey layer. Uranium gets leached out by the percolating rain-water and sub-surface run-off, while thorium is adsorbed onto the top layer. For this reason the ash when sampled and measured gives high concentration of thorium compared to that of uranium.

From the activity concentrations of ^{232}Th, ^{238}U and ^{40}K of bulk ash samples, the gamma-absorbed dose rates in air were computed and the results are presented in Tables 1–3. The calculated annual external effective dose rates (mSv y^{-1}) in air varied from 0.174 to 1.95 with an average value 0.185 in Kolaghat; 0.142 to 0.161 with an average value 0.150 in Durgapur and 0.107 to 0.200 with an average value 0.167 in Bandel (Tables 1–3). Thorium in the ash contributes more to the dose rate due to its high concen-

Table 3. Radioactivity in ash, dose rate emitted from ash ponds, annual external effective dose rate (mSv y^{-1}), radium equivalent activity (Ra_{eq}) and external hazard index (H_{ex}) from ash of Bandel thermal power plant

Sample no.	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Dose rate (nGy h^{-1})	Annual external effective dose rate (mSv y^{-1})	Ra_{eq} (Bq kg^{-1})	H_{ex} (Bq kg^{-1})
BAP1	116.6	139.9	327.7	152.0	0.186	342	0.92
BAP2	128.4	123.9	296.9	146.6	0.180	328	0.89
BAP3	133.4	111.6	332.8	142.9	0.175	319	0.86
BAP4	78.5	62.8	307.2	87.0	0.107	192	0.52
BAP5	183.4	118.2	174.1	163.4	0.200	366	0.99
BAP6	130.2	94.8	417.3	134.8	0.165	298	0.80
BAP7	118.3	92.6	396.8	127.1	0.156	281	0.76
Mean	126.9	106.3	321.8	136.3	0.167	304	0.82

Table 4. Comparison of mean activity coefficients of radionuclides (U, Th and K) and absorbed dose rates from ashes of Kolaghat, Durgapur and Bandel compared with other thermal power plants in India

Thermal power station (India)	Activity (Bq kg^{-1}) ^{226}Ra	^{228}Ac	^{40}K	Absorbed dose rates (nGt h^{-1})	Reference
Allahabad (Uttar Pradesh)	78.4	89.1	362.7	107.59	2
Angul (Orissa)	78.5	86.5	278.1	102.38	2
Badarpur (Delhi)	75.5	88.1	286.4	102.50	2
Chandrapur (Madhya Pradesh)	58.2	89.2	301.2	96.46	2
Raichur (Karnataka)	83.1	102.5	334.1	117.27	2
Talchir (Orissa)	79.2	96.3	291.6	109.73	2
Bokaro (Bihar)	70.3	118.4	252.0	118.91	5
Ramagundam (Andhra Pradesh)	59.2	95.1	507.0	109.38	5
Neyvelli (Tamil Nadu)	64	126.9	370.0	126.76	5
Amarkantak (Madhya Pradesh)	49.2	106.2	329.3	105.04	5
Nasik (Maharashtra)	126.9	138.0	279.0	157.18	5
Nellore (Andhra Pradesh)	64	126.9	370.0	126.76	5
Farakka (West Bengal)	84.1	98.8	297.1	113.71	2
Bakreshwar (West Bengal)	76.3	87.5	288.1	102.52	2
Kolaghat (West Bengal)	111.4	140.2	350.7	150.8	Present work
Durgapur (West Bengal)	97.3	107.5	315.8	123.0	Present work
Bandel (West Bengal)	126.9	106.3	321.8	136.3	Present work

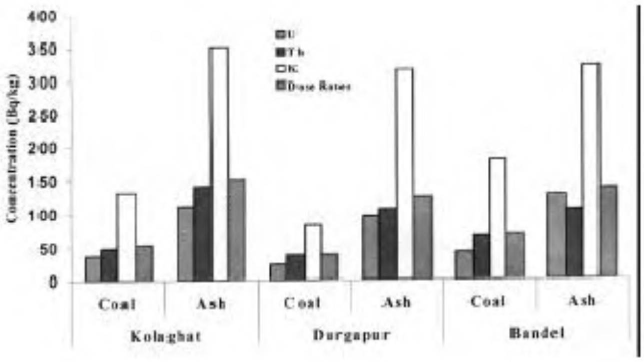

Figure 1. Mean radioactivity in coal used and in ash from Kolaghat, Durgapur and Bandel thermal power plants.

tration in the ash. According to UNSCEAR[7,8], the mean natural radionuclide concentration in coal is 35 Bq kg^{-1} (range: 17–60) for ^{238}U, 30 Bq kg^{-1} (range: 1–64) for ^{232}Th and 400 Bq kg^{-1} (range: 140–850) for ^{40}K. The radionuclide concentration of ^{238}U, ^{232}Th and ^{40}K in feed coal samples from Kolaghat, Durgapur and Bandel thermal power plants is 37, 48 and 130 Bq kg^{-1} respectively; 24, 38 and 82 Bq kg^{-1} respectively; 42, 65 and 179 Bq kg^{-1} respectively. The feed coal in power plants contains 2 to 3 times less natural radionuclides than ash (Figure 1).

Ra_{eq} is related to the external gamma dose and internal dose due to radon and its daughters. The maximum value of Ra_{eq} in building materials must be less than 370 Bq kg^{-1} for safe use and the maximum value of H_{ex} allowed is unity corresponding to the upper limit of Ra_{eq} (370 Bq kg^{-1}). The mean radium equivalent activity (Ra_{eq}), mean external hazard index (H_{ex}) and range of radium equivalent and external hazard of samples in major thermal power plants of West Bengal are calculated based on eqs (3) and (4) and are given in Tables 1–3. The calculated values of Ra_{eq} ranges from 318 to 357 Bq kg^{-1}, with average of 339 Bq kg^{-1} is Kolaghat ash; 259 to 294 Bq kg^{-1} with

Table 5. Comparison of radium equivalent (Ra_{eq}; Bq kg^{-1}) in construction material from various regions of the world

	Radium equivalent Ra_{eq} (Bq kg^{-1})		Material			
	Sand	Portland cement	Fly ash	Slag	Clay brick	Reference
India	170.8	104.7	109.2	189.8	151.7	16
Australia	70.3	114.7	355.2	340.4	218.3	17
Finland	177.6	99.9		214.6	240.5	18
Germany	59.2	70.3	451.4	421.8	207.2	12, 18
Norway		7.4			27.4	11
Sweden		140.6			351.5	18
UK	18.5	59.2			170.2	9, 19
Kolaghat				339	157.06	Present work
Durgapur				275		Present work
Bandel				304		Present work

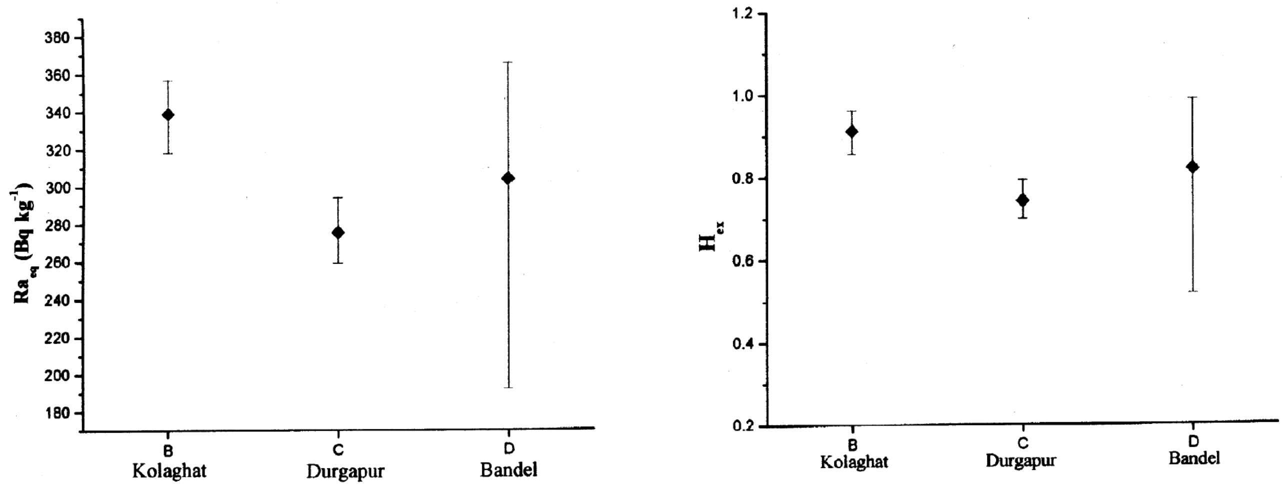

Figure 2. Comparison of mean Ra_{eq} and H_{ex} of ash in major thermal power plants of West Bengal, India.

average of 275 Bq kg^{-1} in Durgapur ash, and 192 to 366 Bq kg^{-1} with average of 304 Bq kg^{-1} in Bandel ash.

The calculated values of H_{ex} range from 0.86 to 0.96 Bq kg^{-1} with average of 0.91 Bq kg^{-1} in Kolaghat; 0.709 to 0.79 Bq kg^{-1} with average of 0.74 Bq kg^{-1} in Durgapur, and 0.52 to 0.99 Bq kg^{-1} with average of 0.82 Bq kg^{-1} in Bandel (Table 5). Maximum ash samples have radium equivalent activity (Ra_{eq}) and external hazards index (H_{ex}) values close to 370 Bq/kg and unity respectively (Figure 2).

The dose emitted from ash ponds of power plants of Kolaghat, Durgapur and Bandel is higher than three times the world average of 43 nGy h^{-1}. The ash from power plants contains 2 to 3 times more natural radionuclide than feed coal. Thus there is significant amount of health risk to the population living in the surrounding areas. The radium equivalent activity (Ra_{eq}) and external hazards index (H_{ex}) values are closest to 370 Bq/kg and unity respectively. Thus the concentration of natural radionuclides in ash used as additives in building materials should be monitored carefully[15].

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Secretion of a potent antibiotic by salt-tolerant and alkaliphilic actinomycete *Streptomyces sannanensis* strain RJT-1

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An alkaliphilic actinomycete, *Streptomyces sannanensis* strain RJT-1 was isolated from the alkaline soil of Saurashtra University Campus, Rajkot. The isolate exhibited optimal growth at 5% (w/v) NaCl and pH 9. It was Gram-positive, having filamentous, long thread-like structure and started sporulation after 3 days of incubation. It was capable of producing antibiotic against Gram-positive bacteria, while Gram-negative organisms were not affected. Starch agar was the preferred medium for antibiotic production. Optimum salt and pH for antibiotic production were 3% (w/v) NaCl and 9 respectively. Studies on the nutritional factors showed that the highest antibacterial activity was obtained when glucose and lactose at 1% (w/v) were used as carbon sources. *S. sannanensis* strain RJT-1 displayed higher antibiotic production with inorganic nitrogen sources such as urea, $(NH_4)_2SO_4$ and NH_4NO_3 compared to organic nitrogen supplements. So far only few alkaliphilic actinomycetes have been explored for their antimicrobial potential.

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MICROBES from extreme environments have attracted considerable attention in recent years. This is primarily due to the secret that they hold about the molecular evolution of life and stability of the macromolecules. Majority of the studies on extremophilic organisms, however, have been confined to extremophilic bacteria and actinomycetes are relatively less explored group. A novel, alkaliphilic actinomycetes *Nocardiopsis alkaliphila* sp. nov. was reported[1] to grow optimally at pH 9.5–10. *Nacardiopsis metallicus*[2] exhibited growth in the pH range 7–10.5, whereas in *Bogoriella caseilytica*[3], a new alkaliphilic actinomycete, optimum growth occurred at pH values 9–10. It is widely accepted that alkaliphilic actinomycetes will provide a valuable resource for novel products of industrial interest, including enzymes and antimicrobial agents[4,5]. Pyrocoll, an antibiotic, antiparasitic and antitumour compound was recently detected in novel alkaliphilic *Streptomyces* strain[6]. A new antitherapeutic antibiotic, fattiviracin was detected in *Streptomyces microflavus*[7]. Moreover, few marine actinomycetes have also been recently reported for their antimicrobial activity[8–10]. Some novel antitumour antibiotics, such as chinikomycin and lajollamycin were detected in marine *Streptomyces* spp.[11,12]. These recent examples from the literature highlight the fact that despite extensive exploration of the actinomycetes for their antimicrobial products in the past, the search for novel molecules having unique therapeutic properties continues to be an active area of research. In this context, studies on extremophilic actinomycetes would be a valuable addition. The present communication deals with the isolation and characterization of an alkaliphilic and salt-tolerant actinomycetes, identified as *Streptomyces sannanensis* strain RJT-1. The study focuses on the production of an antibiotic from this organism as a function of salt and pH.

An alkaliphilic strain was isolated from the alkaline soil, collected from the Saurashtra University Campus, Rajkot. Ten grams of alkaline soil was mixed with 1.0 g of $CaCl_2$ and incubated at 45°C. After 7 days, 1 g of the treated soil was added to 25 ml of sterile Actinomyces broth (Hi Media Ltd) containing 5% w/v NaCl. The final pH of the medium was adjusted to 9 by adding separately sterilized 20% Na_2CO_3. The inoculated broth was incubated at 28°C