REPORT NO. IAEA-R-2717-F

XA8413378

TITLE

Relative radiation hazards of coal based and nuclear power plants

FINAL REPORT FOR THE PERIOD

1980-12-01 - 1983-02-14

AUTHOR(S)

U.C.Mishra

INSTITUTE

Bhabha Atomic Research Centre
Air Monitoring Section
Trombay, Bombay
India

INTERNATIONAL ATOMIC ENERGY AGENCY

DATE April 1983

E-83048

IAEA Research Contract No. 2717/R-I/RB

Project title : Relative radiation hazards of coal based and nuclear power plants.

Investigators : Dr. U.C. Mishra, Chief Investigator
B.Y. Lalit and T.V. Ramachandran,
Air Monitoring Section, D.R.P.
Bhabha Atomic Research Centre,
Bombay - 400 085, INDIA.

FINAL REPORT

Coal, like most materials found in nature, contains trace quantities of the naturally occurring primordial radio-nuclides. The levels of these radioisotopes are usually low, and require very sensitive detector system for measurement.

Low concentrations of radioactivity in coal, however assumes importance when large quantities of coal are burnt in thermal power plants for electricity generation. Even though concentrations in coal may be low, some of the natural radionuclides get enriched in fly-ash. A study was undertaken to assess the radioisotope concentration in coal collected from different mines spread all over the country. Samples of coal, fly-ash, slag from some thermal power plants were also obtained and counted for their natural radioactivity content. Some of the measurements on these samples were done using the system developed with partial equipment support under this IAEA research contract. The summary of levels of natural radioactivity content in coal from various coal-fields in India is given in Table 1. Most of the power plants use coal produced in the vicinity of power plants. Hence, the release of radioactivity from such power station can be calculated, knowing its location, installed capacity and the ash content of coal and control measures taken for particulate emission.

Operation of nuclear power plants also releases some radioactivity to the environment. Recent cost-benefit methodology calls for comparative risks from different energy systems. Hence at many places, the relative radiation risk of thermal power plants and nuclear power plants are assessed. In this study, we have compared the thermal power plants at Nasik and Neyveli with nuclear power plants at Tarapur and Kota. Nasik and Neyveli power plants are of fairly modern design with efficient fly-ash control. Tarapur power station (TAPP) is BWR type and Rajasthan Atomic Power Plant (RAPP) at Kota is heavy water reactor, using natural uranium as its fuel. The results of the study of the thermal power plants at Nasik and Neyveli are given in Table 2. The radiation doses resulting from operation of these thermal and nuclear power plants to the population living in the 80 Km. radius of station are given in table 3 as per assumptions given in publications given in Annexure 2, (1) and (2). It is found from this table that computed radiation dose to the population from TAPP and RAPP are an order of magnitude lower than those for Nasik and Neyveli power plants.

A survey of the environmental gamma dose was carried out around Nasik and Neyveli thermal power stations and TAPP and RAPP nuclear power plants (3). This was done using locally fabricated survey meter having sensitivity of 0.1 µR/hour. Table 4 gives the results of this survey. At the time of survey, TAPP was operating at 75 MWe, RAPP at 220 MWe and Nasik and Neyveli power plants at 480 MWe and 600 MWe, respectively. Ash pond areas of thermal power plants gave relatively higher radiation doses of 22 µR/hr and 19 µR/hr for Nasik and Neyveli thermal power plants, respectively. The radiation doses in the environment of power stations of both types were comparable and were in the range of variations of natural background doses.

CONCLUSIONS

It is seen from this study that the radiation doses in the vicinity of thermal power plants are comparable to those for nuclear power plants in the vicinity of the power stations. All the doses are in the range of natural background radiation dose, the highest doses being about three times the average natural background dose of about 7 µR/hour. It is also shown in a paper presented at the 10th Indian Association for Radiation Protection conference held at Bombay during 1-4 March, 1983 (Annexure 2) that the collective dose commitments computed for 80 Km radius area of thermal power plants are an order of magnitude higher than those for BWR-type nuclear power plant.

Recommendation :

The factors determining environmental exposures of general population from natural radioactivity release from coal-fired thermal power plants are

a) Natural radioactivity content of coal

b) Combustion temperatures which determine enrichment of natural radionuclides in fly ash.

c) Ash content of coal

d) Particulate emission controls at the power station

e) Local meteorological conditions

It was thought that since most of the coal used in Indian power plants has high ash content and particulate emission control systems are relatively inefficient, environmental releases could be high under the above conditions. However, low natural radioactivity content and favourable meteorological conditions seem to be primarily responsible for limiting environmental exposures. Still, even though not high, environmental radiation exposures from such stations have been found to give comparable measured and higher computed dose than those for nuclear power stations studied.

In the case of nuclear power stations, environmental radiation exposures are governed by

a) Type of reactor

b) Type of airborne emission control systems

c) Local meteorological factors.

Hence relative environmental exposure per unit of generated electrical power have lesser variability for nuclear power plants as the factors involved are fewer and in each factor (a & b) the range of variation is not very large. The last factor is common to both the types of power stations. Further, whereas for nuclear power plants, the main likely hazard is radiation exposure, for coal fired plants ~~there~~ several conventional pollutants are also involved. Hence total pollution potential of the two systems needs to be studied. On a global scale, many coal fired plants have been found to use coal with order of magnitude higher natural radioactivity (4) where environmental radiation exposures can be very much higher than background radiation exposures.

Further, a global study of the radiation exposures from coal fired power plants as well as environmental hazards due to conventional and radioactive pollution from both types of power stations and later from the entire fuel cycle in both cases will be extremely useful in recommending control measures. Such global studies can only be organized through coordinated research programmes to be arranged by agency like IAEA. It is thus strongly recommended that such programmes may be organised by the Agency as they will [illegible] be useful in recommending control measures to be adopted in each case, in view of anticipated large increase in both coal-based and nuclear power plants in decades to come. It will also provide quantitative information on how advantageous nuclear power stations are from environmental pollution consideration. Qualitatively, it can be predicted even now based on the available data. Such programmes initiated at this stage and suitably modified in light of available information from time to time will be a very useful exercise in the long run.

ACKNOWLEDGEMENTS

The investigators express their thanks to IAEA for the equipment made available under this Research contract (No. 2717/RB).

References :

1. UNSCEAR 1977, Sources & effects of ionizing radiation, Annex. B, Natural sources of radiation, United Nations, New York, 1977, pp. 35-114.

2. Hamilton, L.D. (1980), IAEA Bulletin, Vol. 22, No. 5/6, October 1980, 35-77, Comparative risks from different systems : Evolution of the methods of studies.

3. Gurg, R.P., Vyas, P.V., Sebastian, T. and Bhat, L.S. (1982). 1978-1979 Progress report of Environmental Survey Laboratory Rajasthan Atomic Power Station, Bhabha Atomic Research Centre, Bombay, India, 31 pages + 3 figures, BARC Report No. BARC/I-708.

4. Bauman, A., Horvat, D.J., Kovac, J. and Lokobauer, N. (1982) Technologically enhanced natural radioactivity in a coal fired power plant, Proc. of the Second Special Symposium on Natural Radiation Environment, Bombay , January 19-23, 1981, Wiley Eastern Ltd., New Delhi, pp. 401-429.

TABLE 1

Uranium, Thorium, Radium and Potassium content in Indian coal

Region	Radioactivity content pCi/g.			concn. in ppm	
	^{226}Ra	^{228}Th	^{40}K	^{238}U	^{232}Th
Southern Region					
Neyveli coal fields	0.2-4.8 (2.2)	0.9-1.6 (1.3)	3.7-6.8 (5.4)	0.5-14.1 (6.5)	8.2-14.5 (10.9)
Eastern coal fields					
West Bengal	0.4-2.0 (1.2)	0.9-2.5 (1.4)	3.6-7.7 (4.8)	1.2-5.9 (3.2)	8.2-22.7 (12.7)
Bokaro	0.4-2.2 (1.4)	0.8-2.2 (1.7)	4.2-4.4 (4.3)	1.2-6.5 (4.1)	7.3-20.0 (15.5)
Central coal fields					
Bihar	0.8-0.9 (0.9)	1.3-1.5 (1.4)	4.1-4.3 (4.2)	2.3-2.6 (2.5)	11.8-13.6 (12.7)
Madhya Pradesh	0.6-0.7 (0.7)	0.2-0.3 (0.3)	4.1-4.3 (4.2)	1.8-2.1 (2.1)	1.8-2.7 (2.7)
Uttar Pradesh	0.3-0.9 (0.7)	0.2-1.0 (0.6)	3.2-4.8 (3.7)	0.9-2.6 (2.1)	1.8-9.1 (5.5)
Orissa	0.7-0.9 (0.8)	1.5-1.9 (1.7)	2.2-4.6 (3.4)	2.1-2.6 (2.3)	13.6-17.3 (15.5)
Western coal fields					
Madhya Pradesh	0.2-1.2 (0.6)	0.3-1.2 (1.1)	0.5-7.7 (2.8)	0.6-3.5 (1.8)	2.7-10.9 (10.0)
Maharashtra	0.1-0.6 (0.4)	0.6-1.2 (0.7)	0.8-4.2 (1.9)	0.3-1.8 (1.2)	5.5-10.9 (6.4)
Nagpur	0.5-1.2 (0.8)	0.7-1.1 (1.1)	1.4-4.1 (2.7)	1.8-3.5 (2.3)	6.4-10.0 (10.0)

Numbers in parentheses give average values.

TABLE 2

Natural Radioactivity Content in Coal and Flyash Samples from Nasik and Neyveli Thermal Power Plants.

Name of the power plant & Installed capacity.	Date of sampling	Type of sample	Activity content in pCi/g.		
			^{226}Ra	^{228}Th	^{40}K
Nasik	Nov. 1978	Coal	1.2	0.8	3.1
480 MWe		Fly-ash	4.3	3.6	9.2
	July 1980	Coal	0.9	1.0	1.7
		Fly-ash	2.8	5.6	8.8
Neyveli	Aug. 1978	Coal	0.4	-	0.2
600 MWe		Fly-ash	23.4	2.9	-
Neyveli	Aug. 1980	Coal	0.5	1.0	0.4
600 MWe		Fly-ash	20.5	3.0	1.5
	Aug. 1981	Coal	0.7	1.0	4.1
		Fly-ash	20.6	3.0	0.0

TABLE 1

TABLE 3

Estimates of Collective Dose Commitments from Operations of Thermal Power Plant arising from Inhalation during the Cloud Passage and Dose Expected if the same Power is obtained from BWR type Nuclear Power Plant : (person-rem/year/MWe)

Name of the Power Station & capacity	Body tissue under considera-tion	Collective dose commitments arising from inhalation during the cloud passage.				
		Coal-based Thermal Power Plants[1]				Nuclear[2] Power Plant (BWR type)
		^{226}Ra	^{228}Ra	^{228}Th	Total	
Nasik	Lung	0.021	0.066	0.924	1.01	0.026
480 MWe	Bone Marrow	0.0004	0.0011	0.0792	0.08	0.026
	Bone Lining Cells	0.0031	0.0053	1.188	1.20	0.026
Neyveli	Lung	0.277	0.086	1.205	1.57	0.054
600 MWe	Bone Marrow	0.0055	0.0014	0.1033	0.11	0.054
	Bone Lining Cells.	0.0415	0.0069	1.5490	1.60	0.054

TABLE 2

TABLE 4

Typical Radiation Doses Observed at Some Power Plants in India

Details of Power Station	Sampling Location	Radial distance from Centre & direction Km	Dose rate μR/hr	Details of Power Station	Sampling Location	Radial distance from Centre & direction	Dose rate μR/hr
Nasik TPS 480 MWe Stack ht. 80 M	Power Stn.	-	7.0	Neyveli TPS 600 MWe Stack ht. 20 M, 60 M	Power Stn.	-	9.6
	Ash pond-I	3 NE	19.5		Ash Pond-I	2.5 EW	19.0
	Ash pond-II	1.2 N	11.8		Ash Pond-I	1.5 S	11.7
	River Bank	1 NE	20.1		High dump yard	1.5 W	11.7
	Coal handling area	1 S	12.0		Entrance Gate	0.5 NE	8.2
	Chemistry Lab.	0.5 NE	4.5		Fly-ash yard	-	8.5
	Guest House	2 SW	6.5		Water treatment Lab.	0.5	6.2
	Pump House	1.5 N	10.5		Ash pond	2 WS	15.7
	Nasik Rly. Stn.	6 SW	7.0		Soil	2.0 Ave.	13.5
Tarapur NPS 75 MWe Stack ht. 110 M.	Prefre Main gate	1.6	25.0	Kota N.P.S. 220 MWe Stack ht. 100 M. (Ref. 3)	RAC Camp		15.0
	Micrometeo-rology Lab.	1.6	7.4		Phasel colony	5 NW	10.0
	Tarapur	3 NEE	4.7		RPS Colony	6 W	10.0
	Chinchni	5 NEE	5.0		Saddle Dam	3 SW	10.6
	Poparon Temple	3.5 SSE	18.8		Bhainsroad garh	12 NNW	14.6
	Boisar	10 SE	5.2		Rawatbhata fish farm	6 W	9.5
	Power Stn.	-	18.6		Aklingpura	15 SE	12.9
	TAPS Colony	4 SE	7.8		Gandhi Sagar	20 S	9.4

Annexure I

Performance of Compton Suppressed Low-Level Gamma-ray spectrometer fabricated under IAEA Research contract no. 2717/R-1/RB

SYSTEM :

A compton suppressed gamma spectrometer system was fabricated and commissioned in the Air Monitoring Section, Bhabha Atomic Research Centre, Bombay-400 085, India for measurement of natural radioactivity in coal and fly ash samples. IAEA had supplied analog-to-digital converter and plastic scintillator during the first year of the contract. A 10 cm dia x 10 cm thick NaI (Tl) integral assembly was supplied during the second year of the contract.

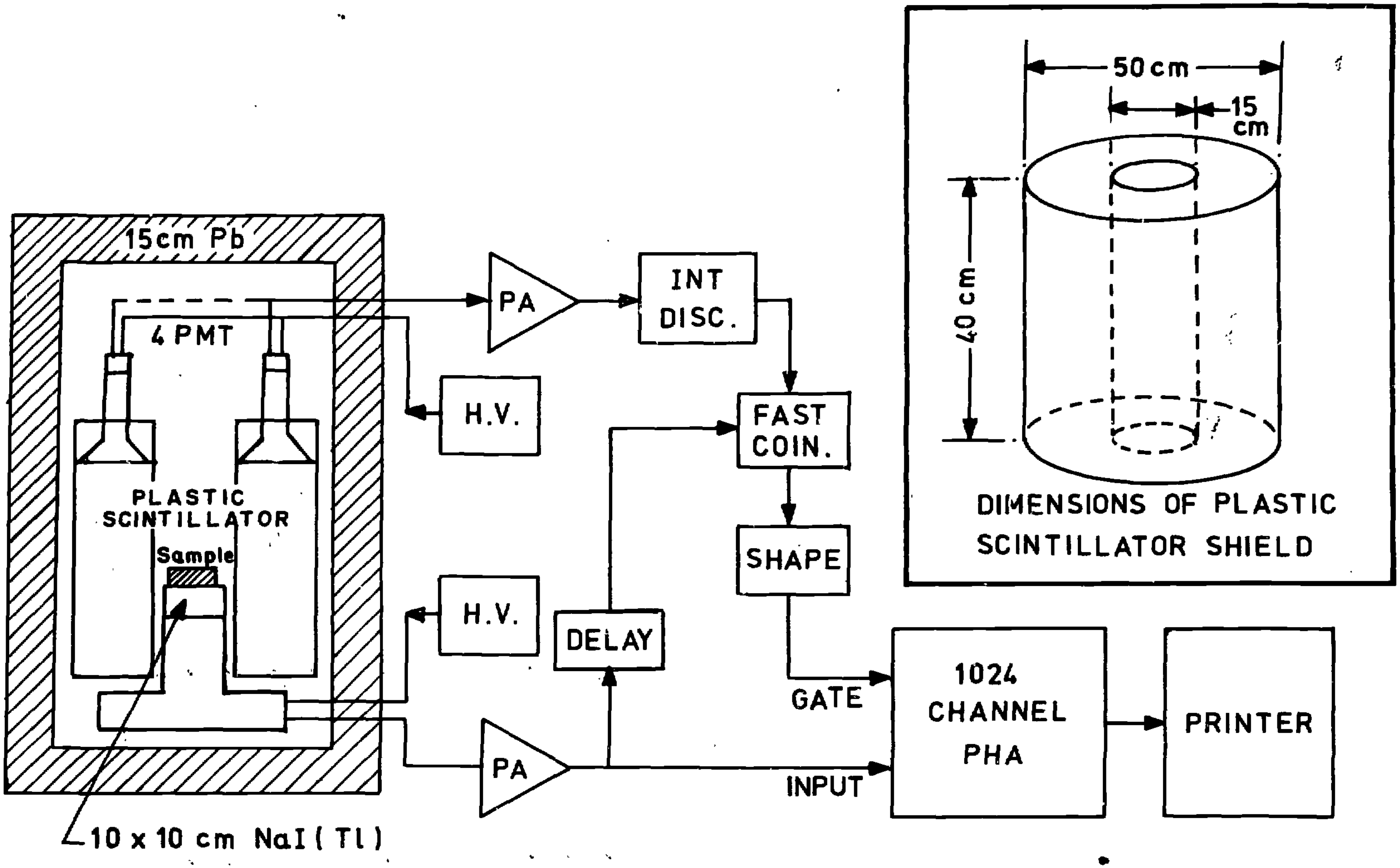
A 1024 channel analyser employing 8 K Canbera ADC was fabricated in the section and anticoincidence shield employing plastic scintillator coupled to four EMI 9709 photomultipliers was also completed during the first year. The complete low-level spectrometer with 7.5 cm dia x 7.5 cm height NaI (Tl) integral assembly as sample counter kept inside the plastic scintillator anticoincidence was also tested. The complete detector assembly was kept in 15 cm thick lead shield. The interface electronics was also procured and assembled locally. However, it was felt that the detection sensitivity of the system can be further improved by replacing 7.5 cm x 7.5 cm NaI (Tl) with 10 cm x 10 cm NaI (Tl) as sample counter and hence this detector was requested from IAEA during the second year of the contract. The detector was recently received and coupled and in the Table given at the end, performance of the system in terms of background reduction, compton suppression and minimum detectable activity are given.

It is evident from the tables that the system as a whole is now adequate for measurement of natural radioisotopes in coal, fly-ash and other environmental samples at ambient concentrations in normal environments. The system is suitable for monitoring long-lived gamma emitting radioactive fallout nuclides in environmental samples as well. The block diagram of the system is also given at the end. Thus a useful facility has been established for long term environmental studies due to partical equipment support from IAEA under the research contract.

TABLE

System Performance for Plastic Scintillator Anticoincidence Gamma-ray Spectrometer

Details under consideration	Mode of operation	0.91 MeV peak for ^{228}Th	1.76 MeV peak for ^{226}Ra
Background	Normal	18.3 cpm	5.8 cpm
	Suppressed	7.3 cpm	2.6 cpm
	Improvement factor	2.5	2.2
Compton region	Normal	413 cpm	760 cpm
	Anticoincidence	109 cpm	292 cpm
	Improvement factor	3.8	2.6
Efficiency	Normal	10.7 %	3.5 %
	Anticoincidence	9.7 %	3.3 %
Min. Detectable Activity (100 min) 3σ in Bkg.	Normal	13.5 pCi	54.7 pCi
	Anticoincidence	9.4 pCi	38.8 pCi



BLOCK DIAGRAM OF LOW-LEVEL GAMMA SPECTROMETER.

E-5044-E-83048

Annexure 1

RADIOLOGICAL RISK ASSESSMENT OF THERMAL POWER PLANTS IN EASTERN ZONE OF INDIA

B.Y. Lalit, T.V. Ramachandran and U.C. Mishra

Air Monitoring Section
Bhabha Atomic Research Centre
Bombay-400 085, INDIA

Paper presented at X Annual Conference of India Association for Radiation Protection on "Radiation Risk Assessment : Present and Future Considerations", held at Bhabha Atomic Research Centre, Bombay 400 085 during March 1-4, 1983.

India has to largely depend on its more than 85770 million tonnes (MT) of recoverable coal reserves for her future energy needs (India, 1981). The annual requirement of coal by 2000 AD is expected to go beyond 425 MT compared to a production of 113 MT in 1980-81. The total installed power generating capacity in India was about 29000 MWe in March 1980. Thermal power stations generate about 16500 MWe, amounting to 57% of total generating capacity. In eastern region considered here, 3855 MWe is generated by thermal power stations amounting to about 81% of total power produced in the region (India, 1981). Most of these power stations consume coal as fuel. Use of coal in thermal power stations give rise to environmental gaseous and particulate pollution. Important pollutants include sulphur dioxide gas, particulate matter and a large number of other pollutants which have long term effects on vegetation, fish and animal life, human beings and even structures. It also results in the release of large amounts of carbon dioxide which builds up levels of carbon dioxide in the environment. Coal also contains natural radioactivity due to uranium and thorium series and potassium-40 and its combustion disperses these natural radionuclides over large areas in the vicinity of thermal power stations. Unlike most of the nuclear and hydro power stations, coal fired thermal power stations are located in areas which are thickly populated and as such the environmental impact is experience by the population. In this paper environmental impact of thermal power stations in eastern region has been estimated only with regard to natural radioactivity present in coal. Comparison has been made with the expected environmental radiation exposures from a nuclear power stations of similar size. As will be seen from the results, the coal produced in the eastern region has somewhat higher natural radioactivity levels and as such the collective dose commitments has been found to be higher than the nuclear power stations, the estimates of which have been given using data given by Hamiton (1980). It may be mentioned here that burning of coal results in concentrations of some of the natural radionuclides in the fly ash which when deposited over the soil gives rise to enhanced natural radiation exposures even in cases where natural radioactivity of coal is comparable to the local soil values. In India, particulate pollution as well as natural radioactivity deposition is higher than some of the western countries mainly because of high ash content of the coal and relatively poor fly ash control measures.

Coal, Fly ash, slag and soil samples from Bokaro, Durgapur, Bandel, Patrau and Talchar thermal power plants were analysed for their radioactivity content using low level gamma-ray spectrometer (Mishra et al., 1981). Coal brought to pulverised form is stored in airtight containers for a minimum period of one month to allow daughter products to come into radioactive equilibrium with ^{226}Ra and ^{228}Th and then counted for its radioactivity content (Lalit et al. 1980). The results of these measurements are given in Table 1 for radium-226, thorium-228 and potassium-40. The table also includes the results of radioactivity content of soils from nearby regions (Mishra et al., 1971).

For calculating the release of radioactivity through the stacks of these power stations, it is assumed that the coal contains 30% ash and the utilities have 95% fly-ash control (usually it is worse) to abate particulate pollution. It is further assumed that 15 tonnes of coal per day is required to generate 1 MWe electricity and the power plant operates for 180 days in a year on an average. The discharged products from the power stations get dispersed into the atmosphere through winds over several kilometers. It is assumed that practically all the activity gets dispersed and deposited within a circle of 80 km radius around the utility. The total population living in this area is estimated using average population density statistics from 1981 census for the states under consideration (India 1981). The necessary details for these power stations such as power generation capacity, location, population density and total population in the 80 km radius around the power plant are also given in table 1.

In considering the radiation health hazard from the operation of thermal power plants, inhalation exposure is considered as important health hazard because fly ash is insoluble and the radium inhaled through fly ash would be present in higher concentrations in the lungs than in other soft tissues. Air-borne release is thus considered as the main pathway through which the population living around coal fired power stations is exposed to enhanced levels of natural radioactivity. The collective radiation dose commitments, due to inhalation during the passage of clouds, to population living in the 80 km radius area have been estimated using the assumptions given in UNSCEAR (1977) regarding average dilution factor and variation of the concentrations as a function of distance with correction for population density given in table 1. The collective dose commitments due to atmospheric releases on the above assumptions are given in table 2 for lung, bone marrow and bone lining cells.

It is seen from the table 1, the levels of natural radionuclides are rising in the soils of plant environments studied. They are 3-4 times more than those found in normal soils in W. Bengal and Bihar, except for ^{40}K. The activity concentration of ^{40}K in fly ash is about the same as in soil. Hence there is no significant difference in soil levels of ^{40}K in thermal plant environment and other eastern region soils. Thus one sees that the levels of ^{226}Ra, ^{228}Th and ^{228}Ra are increasing in soils around these thermal power plants. This deposited activity will give additional dose to the population in the immediate vicinity of the power plants. The absorbed dose rate in air at 1 metre above the ground has been calculated using dose rate factors given in UNSCEAR (1977).

Since natural radioactivity released by coal fired thermal power stations is only one of the environmental hazard, the over all hazards associated with use of coal in thermal power stations in India is very much higher, due to particulate and gaseous pollution created by them. Since there appears to be no alternative to the large scale use of coal in India for the next couple of decades atleast, it is imperitive that fly ash control measures have to be very much improved and use of low ash content coal has to be increased. In addition, wherever possible, such power stations should be located away from thickly populated areas. A comprehensive study of the environmental hazards of thermal power stations should also include environmental pollution associated with coal mining, transportation and use on disposal of large quantities of fly ash produced by such stations. Similarly, for comparison with nuclear power stations, the entire fuel cycle for nuclear power stations is also to be taken into account. Attempt is being made in this direction and results will be reported in near future.

Acknowledgements :

Authors express their sincere thanks to the authorities of various thermal power stations for providing the samples of coal, fly-ash, slag and soil for analysis. Measurements on the samples were made using the anticoincidence type low-level gamma-ray spectrometer fabricated through the assistance of IAEA research contract No. RC/2717/RI/RB.

REFERENCES

HAMILTON, L.D. (1980), IAEA Bulletin, Vol. 22, No. 5-6, October 1980, 35-77.

INDIA 1981. A reference annual 1981, Chapter 1, Land and people, Publications Division, Government of India, New Delhi, 1-11.

Ibid, Chapter 17, Energy, 267-287.

Ibid, Chapter 18, Industry, 288-330.

LALIT, B.Y. and RAMACHANDRAN, T.V. (1980), Natural Radioactivity in Indian food-stuffs, Proc. of Natural Radiation Environment III, Edited by; J.A.S. Adms & W.M. Lowder, Rice University, Houston, Texas, 800-809.

MISHRA, U.C. and SADASIVAN, S. (1971), Journ. of Sci. & Ind. Res. 30, No. 2, 59-62.

MISHRA, U.C., LALIT, S.Y., SHUKLA, V.K. and RAMACHANDRAN, T.V. (1981) Standardized low-level measurements methods for environmental studies, proc. of IAEA Symp. on "Methods of Low Level Counting and Spectromety", Berlin (West), 6-10 April 1981, IAEA, Vienna, 189-199.

UNSCEAR (1977), Sources and effects of Ionizing Radiation, Annex B: Natural Sources of Radiation, United Nations, New York. 35-114.

TABLE 1

NATURALLY OCCURING RADIONUCLIDES IN COAL, FLY ASH, SLAG AND SOIL SAMPLES FROM THERMAL POWER PLANTS

Power Station Location	Power capacity (MWe)	Population Density Persons/km^2	Type of Sample	Activity in Bq/Kg		
				Ra-226	Ra-228	K-40
BANDEL	350.0	614	Coal	18.5	29.6	81.4
W. Bengal			Ash	110.0	173.9	521.7
		1.235×10^7	Slag	181.3	233.1	573.5
			Soil	55.5	111.0	625.3
Calcutta			Soil	20.4	24.1	666.0
BOKARO	248.0	402	Coal	40.7	55.5	118.4
Bihar			Ash	70.3	118.4	251.6
		8.083×10^6	Slag	155.4	66.6	388.5
Ranchi			Soil	24.8	22.3	1060
DURGAPUR	290.0	614	Coal	33.3	66.6	388.5
W. Bengal			Ash	92.5	129.5	325.6
		1.235×10^7	Slag	44.4	74.0	273.8
			Soil	66.6	92.5	640.1
Kharagpur			Soil	15.2	18.6	72.6
PATRATU	510.0	402	Coal	22.2	37.0	107.3
Bihar			Ash	81.4	177.6	444.0
		8.083×10^6	Slag	25.9	37.0	262.7
			Soil	29.6	59.2	77.7
Ranchi			Soil	24.8	22.3	1060
TALCHER	255.0	169	Coal	29.6	62.9	77.7
Orissa			Ash	81.4	155.7	181.3
			Slag	88.8	151.7	207.2
		3.340×10^6	Soil	44.4	133.2	521.7

TABLE 2

ESTIMATES OF COLLECTIVE DOSE COMMITMENTS FROM OPERATIONS OF THERMAL POWER PLANTS IN EASTERN REGION ARISING FROM INHALATION DURING THE CLOUD PASSAGE

Name of the Power station and capacity	Body tissue under consideration	Collective dose commitments arising from inhalation during the cloud passage in person - Sv/year				Nuclear Power Plant	Natural Back-ground dose Person-SV / Year
		^{226}Ra	^{228}Ra	^{228}Th	Total		
		Coal-based Thermal Power Plant				Total	
Bandel 350 MWe	Lung	0.22	0.85	11.93	13.0	0.33	1.36×10^4
	Bone Marrow	0.0042	0.014	1.02	1.04	0.33	1.14×10^4
	Bone Lining cells	0.03	0.0[illegible]	15.3	15.4	0.33	1.06×10^4
Bokaro 248 MWe	Lung	0.063	0.27	3.75	4.08	0.15	0.89×10^4
	Bone Marrow	0.001	0.0043	0.32	0.33	0.15	0.74×10^4
	Bone Lining Cells	0.009	0.022	4.82	5.19	0.15	0.70×10^4
Durgapur 290 MWe	Lung	0.15	0.53	7.36	8.04	0.27	1.36×10^4
	Bone Marrow	0.0024	0.0084	0.631	0.64	0.27	1.14×10^4
	Bone Lining Cells	0.022	0.042	9.47	9.53	0.27	1.06×10^4
Patrau 510 MWe	Lung	0.151	0.83	11.57	12.55	0.32	0.89×10^4
	Bone Marrow	0.0024	0.0133	0.99	1.01	0.32	0.74×10^4
	Bone Lining Cells	0.022	0.066	14.87	14.96	0.32	0.70×10^4
Talcher 255 MWe	Lung	0.032	0.16	2.15	2.34	0.07	0.37×10^4
	Bone Marrow	0.00052	0.0024	0.184	0.19	0.07	0.31×10^4
	Bone Lining Cells	0.0047	0.0123	2.77	2.79	0.07	0.29×10^4

TABLE 3

ABSORBED DOSE RATES IN AIR AT 1 METER ABOVE GROUND SURFACE FROM RADIONUCLIDE PRESENT IN SOIL IN VICINITY OF THERMAL POWER PLANTS.

Location of TPS	mSv/year	Nearby Place in the state	mSv/year	Expected Dose Rate from NPS of same size mSv/year
Bandel	1.09	Calcutta	0.47	0.0016
Bokaro	1.14	Ranchi	0.62	0.0011
Durgapur	1.03	Kharagpur	0.19	0.0013
Patrau	0.48	Ranchi	0.62	0.0024
Talcher	1.14	Ave. for Eastern Region Soil	0.43	0.0012
		World soil Average :	0.39	