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Efforts to examine coal and fly ash

Gajendra Kumar
Research Scholar Maharishi University of Information Technology Lucknow

Dr Rama Kant
Assistant Professor Maharishi University of Information Technology Lucknow

***Abstract*---**Fossil fuels have met a large portion of the world's ever-increasing energy demands as technology has progressed. Coal-burning in thermal power plants releases gaseous and particulate pollution into the environment, as explained in previously. During the coal-burning fuel cycle, many constituents are released into the atmosphere. India's thermal power plants account for 65 percent of installed capacity and 70 percent of the country's total energy output. The current installed capacity in India, including power utilities, is roughly 90,000 MW. More than 150 million tonnes of coal are currently consumed by thermal power plants in the United States. By 2001, the ratio of thermal power stations is predicted to rise to 75 percent. As a result of the recent liberalization, several thermal power projects are being planned. It is expected that these capabilities will be completely realized during the next five to 10 years. The ash content of Indian coals has been reported to range from 35% to 55%. In general, the ash component makes up about half of the entire weight. 75 thermal power plants in the country generate more than 60 million tonnes of fly ash per year. [2-3].

***Keywords*---**traces of components, sampling, fly ash etc.

Introduction

Investigations into traces of components

Adriano[4] looked into the benefits and drawbacks of fly ash as a fuel source, as well as the potential harm it could cause to wildlife and flora. While fly ash contains many helpful elements like calcium (Ca), magnesium (Mg), manganese (Fe), copper (Cu), zinc (B), sulfur (S), and phosphorus (P), it also contains considerable amounts of harmful metals (Cr, Pb, Hg, Ni, V, As and Ba). The concentration of trace elements and radioactivity in the ash can be extraordinarily high or extremely low depending on the location of the parent coal, the combustion circumstances, and the performance of the emission control equipment. Thermal power plants are recognized to pose health and

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environmental concerns due to the migration of trace elements included in fly ash. Fly ash is used in cement, concrete, ceramics, and various other items. For optimal plant growth, major and micronutrient components can be found. Research into fly ash's elemental makeup is essential since it can be both a health hazard and an industrial raw material.

In recent years, it has been increasingly relevant to examine the elemental composition of coal-derived material since it gives a more accurate picture of how thermal power plants deal with trace element reduction. Fly ash is the primary solid waste product produced by pulverized coal combustion in thermal power plants. The large amounts of substances released into the atmosphere due to coal combustion are pretty diverse (fig. 3.1). Low and high-Z element characterizations of coal and fly ash are essential for the thermal power plant to reduce its environmental impact. There are numerous applications for fly ash, from cement manufacturing to providing nutrients for healthy plant growth, that can benefit from these studies. [6].

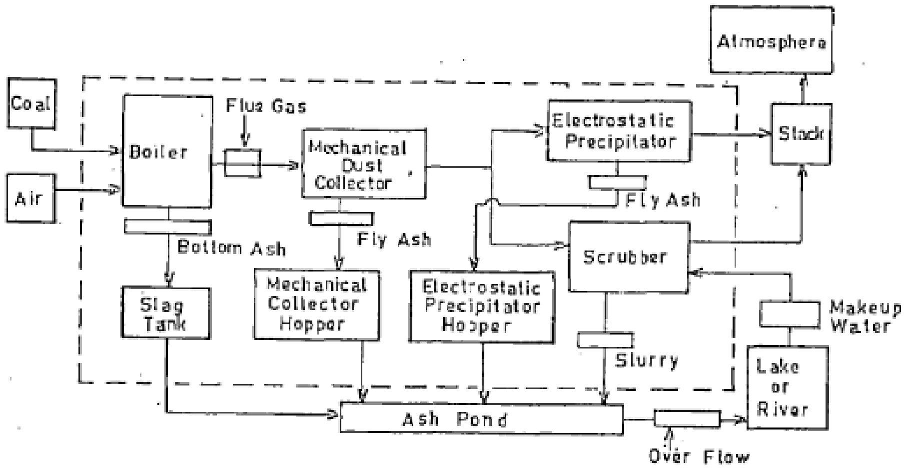

Fig. 3.1 A typical diagram of Thermal Power Plant

The investigation of trace components in coal fly ash has brought coal-fired power plants' pollution to the general public's attention in recent years. The amount of ash in Indian coal used in thermal power plants is substantial (up to 55 percent). However, this study is unusual because it uses PIGE and PIXE techniques to analyze coal and fly ash samples from the Orissa, India, industrial districts of Talcher and Angul to look for heavy metals. An explanation of sample preparation and analysis is given.

Sampling

Samples of fly ash from Talcher's Thermal Power Plant and the Captive Power Plant of the National Aluminum Company (NALCO) in Angul were analyzed for both light and heavy components. These facilities use electrostatic precipitators to remove the fly ash created during the coal burning process and control the release of particulates into the atmosphere (with an efficiency of about 99 percent). They offer a wet ash disposal method for electrostatic precipitator residual ash. These boilers receive coal from the Talcher coalfield. These units consumed an average of 800 kg MW-1 h-1 coal [7]. Samples of Talcher's Thermal Power Plant's bituminous coal have also been collected.

Preparation of the specimen

According to Willis and colleagues[8], thick target samples can be more convenient and provide detection sensitivity comparable to thin pieces. With dense insulating fly ash, PIXE analysis presents many difficulties. Bremsstrahlung's background increases when these samples are subjected to charged particles. The increasing background radiation entirely obliterates many weaker X-ray lines in PIXE spectra. Several methods for extracting charge from thick insulating materials were summarised by Chaudhri et al.[9].

13mm diameter pellets were created by grinding and homogenizing the coal/fly ash sample with graphite powder (binder). The pieces were made as pelletsfthick targets) by adding graphite with equivalent weight to remove the charge-up effect. EPO and ENO coal fly ash standards were provided by the Czechoslovak Institute of Radioecology and Applied Nuclear Techniques (IRANT), produced in the same manner as samples. NIST was also responsible for its conception and development (NIST).

Targeted Inspection

For PIXE and PIGE measurements, the Institute of Physics' 3 MV horizontal pellet on accelerator facility has been employed. The target holder was mounted on an isolated stand-off, and electron suppression was held at a negative potential surrounding the target holder. The Si(Li) detector was positioned at a 90-degree angle to the beam to observe the targets in the target chamber. The objects were blasted with a 3 MeV proton beam with a 5-20 nA beam current. The integrated charges of thick samples were measured using a current integrator connected to a target holder. Before the X-rays entered the Si(Li) detector, there was a 1cm air gap between the target chamber and the sensor. An absorber of 75-200 /im thick mylar is in front of the detector to avoid detecting soft X-rays[10]. The HPGe sensor also detected gamma rays.

Fly ash samples taken from the Talcher Thermal Power Plant were analyzed at the EDXRF facility at MJP Rohilkhand University, as reported in Chapter 2, to compare our PIXE results. The spectral data were recorded using S8 multiparameter analyzers. The PIXE and PIGE spectra of fly ash samples from Talcher and Angul Thermal Power Plants are shown in Figures 3.2 to 3.5, respectively. A computer was used to analyze the spectral data further. The same sample was run three times to ensure consistent results. [11] These results were shown to be repeatable within a few percentage points of measurement error. EPO and ENO fly ash standards were irradiated using the same experimental protocols.

Spectral analysis

Chapter 2 of this publication described the PIXE spectrum of each thick target was analyzed using the GUPIX software. The matrix effect and self-absorption correction are both considered in the study. EPO and ENO fly ash criteria were examined. AS PREVIOUSLY MENTIONED, the GANAAS software[11] was used to analyze the PIGE spectra of thick objects. The PIGE measurements employed EPO fly ash as a comparison benchmark. Table 3.1 shows the results for the ENO fly ash standard. For the PIGE examination of coal samples, NIST coal was employed as a comparative standard.

Table **3.1** : Results of analysis of ENO fly ash standard by PIGE and PIXE(concentrations in ppm unless otherwise specified)

Element	Measured	IRANT certified
Na(%)	0.52 ± 0.03	0.54 ± 0.02
Mg(%)	1.1 ± 0.21	1.2 ± 0.12
Al(%)	11.2 ± 0.6	10.9 ± 0.4
Si(%)	27.5 ± 2.1	26.4 ± 1.4
S	2360 ± 123.6	(2600)[a]
K(%)	1.84 ± 0.09	1.73 ± 0.05
Ca(%)	3.38 ± 0.1	3.34 ± 0.37
Ti(%)	0.46 ± 0.07	0.46 ± 0.03
V	166.4 ± 27.8	191 ± 12.0
Cr	112.5 ± 19.2	96.1 ± 8.0
Mn	592 ± 33.5	634 ± 27.3
Fe(%)	7.37 ± 0.3	7.46 ± 0.24
Ni	72.7 ± 10.3	77 ± 13.1
Cu	65.5 ± 5.8	61.0 ± 4.8
Zn	141.2 ± 17.9	149.0 ± 8.1
As	1711.5 ± 79.5	1790 ± 109.2
Se	12.0 ± 4.0	(10)[a]
Rb	135.7 ± 15.7	149 ± 8.1
Sr	262 ± 29.6	283 ± 20.9
Y	20.6 ± 4.5	(26.2)[a]
Zr	232 ± 37.3	222 ± 51.1
Mo	22.6 ± 7.1	(18.2)[a]
Pb	42.0 ± 5.2	41.7 ± 9.6

[a] These concentrations are listed but not certified by IRANT

Discussion of the Results

Coal and fly ash components have been analyzed using PIGE and PIXE methods. Non-destructive and multi-element, both of these techniques are available. Researchers have employed PIXE and PIGE analyses to determine the amounts of both light and heavy elements in coal and fly ash. [10] The approach outlined here can be used to create thick insulating fly ash samples for PIXE examination. These weaker lines are entirely obscured by the charge-up-induced Bremsstrahlung, as illustrated in the figures (3.2 and 3.3). The PIXE and PIGE techniques were tested against the ENO coal fly ash standard. Table 3.1's results reveal that the measured elemental concentrations agree with the certified values.

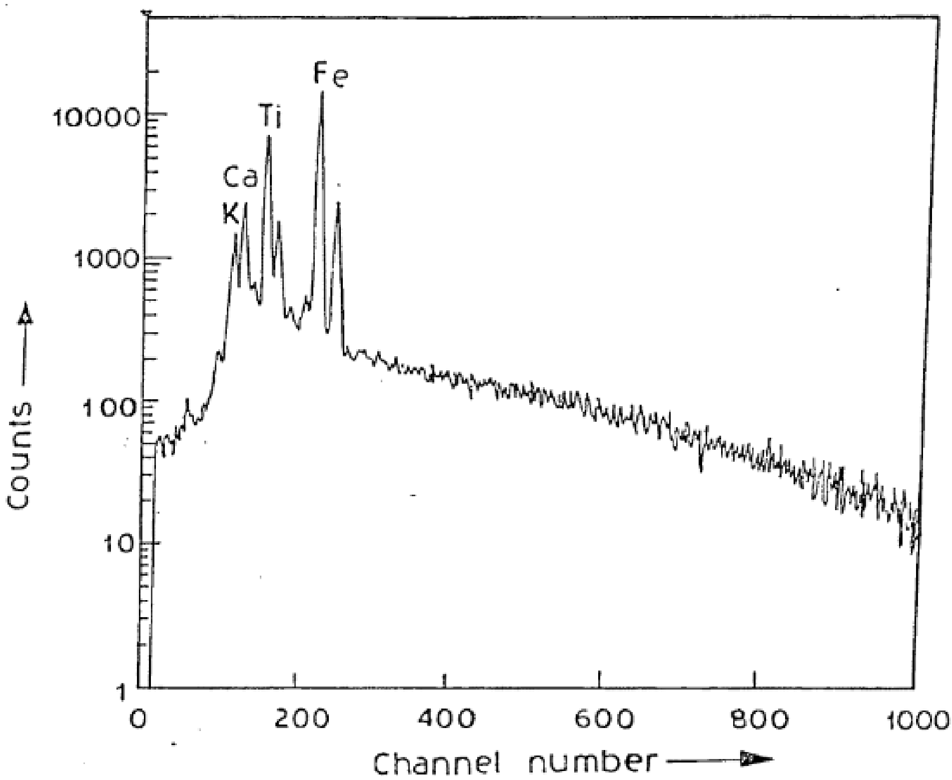

Fig. 3.2 PIXE spectrum of fly ash collected from Thermal Power Plant at Talcher(without graphite binder)

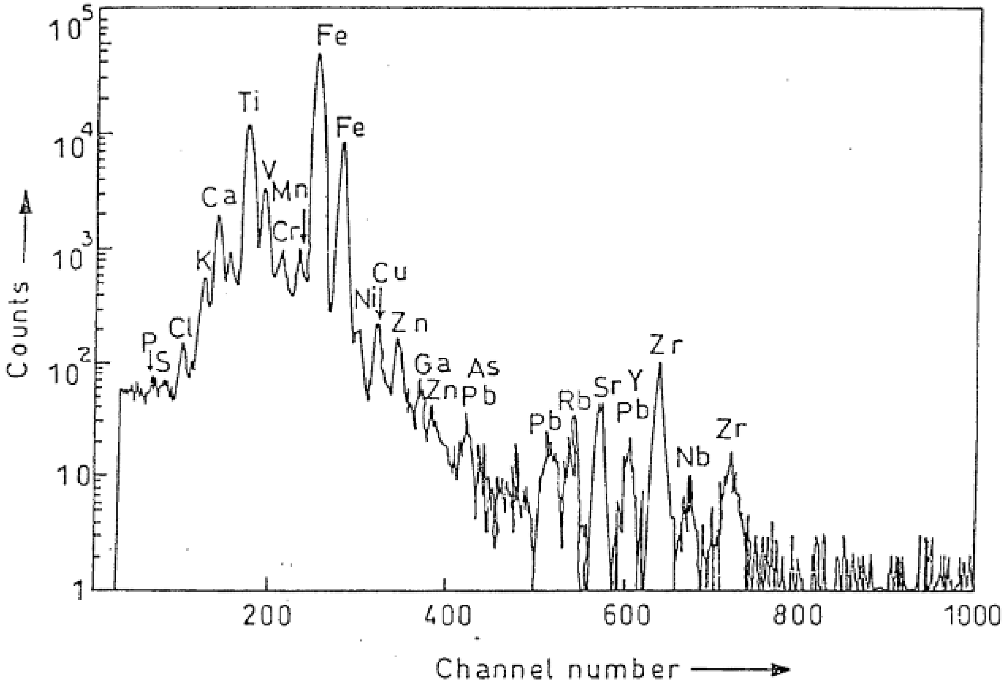

Fig. 3.3 PIXE spectrum of fly ash collected from Thermal Power Plant at Talcher(with graphite binder)

The teacher's thermal power plant's coal and fly ash samples are shown in Table 3.2. Sadasivan and colleagues found a high correlation between this ratio and the average of 128 for Indian coal fly ash [2]. Ash/coal ratios discovered in the literature are also listed in Table 3.2. We confirmed that the concentrations we measured are by previous estimates.

Table 3.2 : Average elemental composition of coal and fly ash from thermal power plant at Talcher(concentration in ppm unless otherwise specified)

Element	Concentration		Ash/coal	
	Coal	Fly ash	Present study	Range from literature[12]
Na	319.4 ± 20.7	910.7 ± 50.8	2.8	—
Mg(%)	0.12 ± 0.02	0.21 ± 0.02	1.7	—
Al (%)	1.12 ± 0.1	15.53 ± 0.9	13.9	10
Si(%)	3.43 ± 0.3	25.6 ± 1.9	7.5	5-10
S(%)	0.21 ± 0.03	0.15 ± 0.02	0.7	0.1-0.5
K(%)	0.15 ± 0.02	0.37 ± 0.03	2.5	2-6
Ca(%)	0.51 ± 0.04	0.24 ± 0.02	2.1	2-5
Ti(%)	0.11 ± 0.02	0.28 ± 0.03	2.6	3-6
V	11.7 ± 1.2	125.0 ± 11.7	14.9	8-20
Cr	9.0 ± 0.8	198.2 ± 25.9	22.0	15-40
Mn	64.9 ± 3.4	194.7 ± 17.9	3.1	—
Fe(%)	0.47 ± 0.04	1.9 ± 0.1	4.0	5-12
Ni	5.7 ± 0.7	60.1 ± 10.3	10.5	—
Cu	5.9 ± 1.1	83.5 ± 10.7	14.1	15-35
Zn	11.2 ± 0.9	117.2 ± 18.8	10.4	—
Ga	7.9 ± 0.8	32.4 ± 2.7	4.1	—
As	1.7 ± 0.2	9.3 ± 0.7	5.3	—
Se	1.1 ± 0.2	2.4 ± 0.3	2.2	—
Rb	4.8 ± 0.3	27.4 ± 4.3	5.8	2-8
Sr	39.6 ± 2.5	112.8 ± 16.2	2.8	2-6
Y	7.1 ± 0.5	28.6 ± 5.2	4.3	—
Zr	25.9 ± 2.2	363.6 ± 46.4	7.9	—
Pb	6.5 ± 0.7	15.9 ± 3.7	2.4	4-12

An ash sample from Talcher thermal power station was used in PIXE and EDXRF analyses to learn about the material's chemical composition. K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, and Pb were detected using PIXE and EDXRF. Overall, EDXRF and PIXE measurements agree well, showing that the experimental error is modest. When using the PIXE method, it was possible to measure S and Zr, but this was not possible when utilizing the EDXRF method.
Using fly ash samples from NALCO's CPP, Table 3.4 illustrates the elemental concentrations. The uncertainty in the integrated beam current, fitting errors,

and counting errors contributed to the measurement error, which is also shown in the table. Several other elements, such as magnesium, silicon, sulfur, calcium, titanium, and iron, were present in low concentrations in the soil sample.

Table 3.4 : Elemental distributions of fly ash from electrostatic precipitator of Captive Power Plant of NALCO at Angul (concentrations in ppm unless otherwise specified)

Element	Mean concentration
Na(%)	0.10 ± 0.01
Mg(%)	0.22 ± 0.04
Al(%)	16.1 ± 0.9
Si(%)	29.4 ± 2.2
S	1802.4 ± 117.3
K	6571.9 ± 154.0
Ca	5511.6 ± 465.8
Ti	12685.8 ± 663.3
V	244.6 ± 14.1
Cr	75.4 ± 6.3
Mn	246.5 ± 18.5
Fe	20841.5 ± 456.3
Ni	101.2 ± 10.2
Cu	101.7 ± 8.6
Zn	145.8 ± 10.5
As	3.2 ± 0.9
Rb	37.8 ± 3.3
Sr	170.2 ± 9.2
Zr	221.6 ± 17.7
Pb	14.8 ± 3.5

This study found that the bulk density of fly ash samples ranged from 1.14 g cm-3 to 1.25 g cm-3. According to Townsend and Hodgson[13], the bulk density of British coal ashes ranged from 0.99 to 1.73 g cm 3. We discovered that the bulk density of fly ash remained within the previously defined range. Low bulk density makes fly ash an excellent material for lightweight construction blocks like concrete. The risk of dust formation increases when dry fly ash is transported and kept in a dry state. The water extract from the experiment, which contained fly ash, had a pH range of 8.6 to 9.0, indicating an alkaline material.

According to a study, coal and fly ash samples from Orissa thermal power units provided information on enrichment occurrences for certain elements. Its speed and simplicity make it ideal for large-scale examinations of coal and fly ash samples using PIXE-PIGE. Findings from these studies will help determine the plant's environmental impact and the efficacy of its environmental control systems.

Radiation Research

Most natural materials, including coal, contain minute amounts of primordial radionuclides. A large portion of the radiation emitted by the environment comes from naturally radioactive elements (such as the U and Th series) and 40K. Large-scale coal combustion for power generation raises environmental concerns because of its high quantities of radionuclides in fly ash, which is discharged via the stack when the coal is burned in a power plant.

Coal contains radiation from the U, Th, and 40K classes. As a result, coal-burning is a source of artificial radioactivity[14]. An assessment of radiation levels from thermal power plant releases is needed to pinpoint the origin of exposures and doses in the environment and the human body resulting from these releases. Radiation from nearby nuclides emitting energetic beta particles and more penetrating gamma rays causes external exposure. Toxicological dosages of radionuclides can be absorbed by particular tissues when inhaled and swallowed due to their radioactive decay. Coal-fired thermal power stations have been the subject of numerous studies worldwide because of the possible radiological impact they could have on the environment.

According to several studies, coal-fired power stations have radiation risks that are on par with, if not worse, than nuclear power plants [15]. Plant development on changed soils may result in significant radioactive absorption due to various circumstances, including soil and pH type, plant species, and the radionuclides present in the fly ash. Therefore, research into radioactivity in fly-ash and its compounds is critical.

Backfill, bricks, foundations, and concrete mixes benefit from fly ash. Because fly ash contains significant levels of 226Ra and its decay products and is more excellent than typical exposures to external gamma radiation to the occupants, there is an elevated risk of bronchial cancer. Thermal power plants are increasingly using coal on a vast scale because of its naturally occurring radioactivity. The radioactivity of fly ash must be thoroughly investigated because it can be both harmful and beneficial. They may be helpful for pollution reduction, different fly-ash-related uses like the creation of cement or ceramics[4, 5], or as a source of essential macro-and micronutrients for plant growth[4].

The discharge of radioisotopes in gaseous and particle form from thermal power plants exposes residents living near coal-fired power plants to high radiation levels. UNSCEAR (1982) [18] detailed the cumulative dose responsibilities for a typical coal-fired power station. Similar effective dosage equivalent obligations were specified in UNSCEAR(1988)[19] for a specific "old5" coal-fired power station. In the coal-fired power plant model of the 1980s, 97.5 percent of the fly ash was kept (UNSCEAR, 1982). The stacks discharge (2.5 percent) into the environment. About 90% of the fly ash was retained in older coal-fired power plants, whereas 99.5 percent was retained in newer GPPs (UNSCEAR, 1988). (UNSCEAR, 1988). Fly ash was better reclaimed by modern GPPs (0.5 percent discharged).

(a) Sample collection and sample analysis:

A gamma spectrometer was used to check for radioactivity in coal and fly ash samples collected from Orissa's Talcher and Angul thermal power plants. To ensure radioactive balance with their daughters, 226Ra and 232Th were stored in airtight cylindrical plastic containers (6.5 cmf>x 7.5 cm height) for roughly a month. [21].

(b) Counting the samples:

Radioactivity can be measured using gamma-ray spectrometers, explained in detail in Chapter 2. The coaxial High Purity Germanium detector was found to have a resolution of 1.9 keV and a volume of 109.4 cm3 at 1.33 MeV. Shielding and direct contact with the sensor were used for counting purposes on the HPGe instrument. This instrument recorded the gamma radiation generated by the HPGe-detected specimens. For each test run, around 60000 samples were measured. For the Talcher Thermal Power Plant, the Talcher Thermal Power Plant, the Talcher Thermal Power Plant, and the Talcher Thermal Power Plant, The gamma-ray spectra were examined with the GANAAS software.

(c) Discussion of the findings:

Radioactive amounts in coal and fly ash from the Talcher Thermal Power Plant are listed in Table 3.5. Table 3.6 displays the radioactivity of fly ash from Angul's NALCO Captive Power Plant. Tables like this illustrate that fly ash has several times the radioactivity of coal. 226Ra radioactivity in Talcher thermal power plant coal was 35.8 Bq kg-1—similar to the previously reported 38.9 Bq kg-1 figure[22]. Fly ashes from Talcher and NALCO power plants contained lower concentrations of 226Ra than fly ashes from Neyveli (India) and Northern Greece, where the reported values were 177.5-596.4 Bq kg-1 in fly ashes (lignite burnt) and 366 Bq kg-1 in fly ashes (lignite roasted). 358.9 Bq kg-1 40K and 226Ra concentrations are equivalent to those discovered in fly ashes from the USSR with values of 42.5, 70.3, and 358.9 Bq kg-1, respectively. Many applications for fly ash, such as cement production, fly ash-based bricks, and as a source of nutrients for healthy plant growth, could benefit from developing a pollution abatement approach based on this research.

Table 3.5 : Radioactivity content in coal and fly ash from thermal power plant Talcher(activity in Bq kg^{-1})

Radionuclide	Average activity	
	Coal	Fly ash
^{226}Ra	35.8 ± 6.4	104.1 ± 16.9
^{232}Th	74.1 ± 8.7	169.2 ± 15.1
^{40}K	85.6 ± 9.2	228.7 ± 19.2

A look into the 226Ra emissions from Talcher Angul's coal-fired power plants may be seen in Table 3.7. An estimated 5000 MBq GW-1 year"1 of atmospheric dis-charge is produced by traditional coal-fired power plants, but only 250 MBq GW-1 year"1 is produced by modern coal-fired power plants, according to UNSCEAR (1988). Talcher and Angul's 22eRa atmospheric discharge was anticipated to be 1200 and 824 MBq GW"1 year"1 respectively, which was approximately 5 and 3 times higher than a modern power plant (UNSCEAR, 2008).

Table 3.6 : Radioactivity content in fly ash collected from Captive Power Plant of NALCO at Angul(activity in Bq kg^{-1})

Radionuclide	Mean activity
^{226}Ra	84.9 ± 14.3
^{232}Th	183.8 ± 17.6
^{40}K	193.5 ± 17.9

Table **3.7** : Estimates of collective effective dose equivalent commitment to lung tissues per unit power generated resulting from atmospheric release of ^{226}Ra from coal-fired power plants at Talcher-Angul area year^{-1})

CPP	^{226}Ra release (MBq GW^{-1} year^{-1})	Inhalation during the passage of the cluod (10^{-3} manSv GW^{-1} year^{-1})	Internal irradiation due to the activity deposited (10^{-3} manSv GW^{-1} year^{-1})
Talcher	1200	5.1	4.7
Angul	824	4.1	3.8
UNSCEAR (1988)	5000[a]	13.0	30.0
	250[b]	0.7	1.5

[a]Old type
[b]Modern type

Additionally, Table 3.7 provides estimates of the total practical dose equivalent commitment. Both Talcher and Angul in India have emitted 226Ra into the atmosphere, resulting in lung tissue dosage equivalents 5.9 and 5.1 times more than that found in UNSCEAR(1988) for a modern coal-fired plant of the same design. This was expected because more 226Ra was released for every kilowatt. Because of cloud inhalation and internal irradiation from activity deposits, residents living near coal-fired power plants are at risk of radiation exposure.

References

[1] Abo El-Seoud M.; El-Motaium R.A.; Mufeed I. Batareh and Kreuzig R. (2014). Impact of gamma radiation on the degradability of polynuclear aromatic hydrocarbons in Egyptian sewage sludge. Fresenius Environmental Bulletin Vol.13, No.l pp. 52-55

[2] Ahlstrom S.B. (2005). Irradiation of municipal sludge for agricultural use. Radn. Phys, and Chem. J. 25:1-10

[3] Alcock R.E., McGrath S.P. and Jones K.C. (2005). The influence of multiple sewage sludge amendments on the PCB content of an agricultural soil over time. Environ. Toxicol.Chem. 14:553-560

[4] Badawy S.H. and El-Motaium R.A. (2009). Effect of irradiated and non-irradiated sewage sludge application on some nutrients heavy metals content of soils and tomato plants. Proceeding of the Is' Congress on: Recent Technology in Agriculture. Bull. Fac. Agric, Cairo University, Special Edition, Vol. IV, pp. 728-744

[5] Bevenue A- and Beckman H. (2007). Pentachlorophenol: A discussion of its properties and its occurrence as a residue in human and animal tissues. Res. Rev. 19 pp.83-134

[6] Brandon J.R. (1979). Pathogen reduction in sludge by irradiation. Sandia irradiator for dried sewage solids, Seminar Proceedings and Dedication, October 18-19, 1978, Albuquerque, New Mexico, Sandia Laboratory Energy Report. Sandia, 79-0182. Applied Biology and Isotope Utilization Division, Sandia National Laboratory (2009) 37-47

[7] Buhler D.R., Rassmusson M.E. and Nakaue H.S. (2003). Occurrence of hexachlorobenzene and pentachlorophenol in sewage sludge and water. Environ. Sci. Technol. 7, pp. 929-934

[8] Bryan E.H.; Dick R.I.; Swinwood J.F.; Kruger P.; Carlson D.A.; Hare G. and Waite T, (2002). Radiation energy treatment of water, wastewater and sludge. A State-of-the An report by the Task committee on Radiation Energy Treatment, Air and Radiation Management Committee, Environmental Engineering Division, American Society of Civil Engineers, American Society of Engineers, New York (1992) 51 pp

[9] Capizzi S., Chevallier A. and Schwartzbrod J. (2009). Destruction of Ascaris ova by accelerated electron. Radiation Physics and Chemistry Vol. 56, pp 591-595

[10] Chaney R.L. (2000). Health risks associated with toxic metals in municipal sludge. In sludge health risks of land application. Ann.Arbor Sci. Publ., Ann Arbor.MI

[11] Chang A.C. (2007). Land application of sewage sludge: pathogen issues. 1AEATECDQC-971: 183-190

[12] Chappell W.R., Beck B.D., Brown K.G., Chaney R., Richard Coihem C, Irgolic K.J., North D.W., Thornton I. and Tsongas T.A. (2007). Inorganic Arsenic; A need and an opportunity to improve risk assessment. Environmental Health Perspectives. Vol. 105, No. 10 pp. 1060-1067

[13] Cirelli D. (2008). Patterns of pentachlorophenol usage in the United States of Americaan overview.p. 13-18. In K.R, Rao (ed.) Pentachlorophenol. Plenum, New York

[14] Clesceri L.S.; Greenberg A.E.; Eaton A.D. (2008). Standard methods for the examination of water and wastewater, 20* Edition. APHA, AWWA & WEF, Washington, D.C. USA

[15] Cooper W.J.; Nickelsen M.G.; Tobien T. and Mincher B.I. (2011). The electron beam process for waste treatment. In: hazardous and radioactive waste treatment technologies Handbook, Chapter 5.5.1, Chang Ho Oh, Ed. CRC Press LLC, Boca Raton, FL, pp. 5.5-1-15

[16] El-Motaium R.A. (2011). Contribution of sewage sludge to phosphorus nutrition of tomato plants:Using 32P as tracer. Arab J- Nuclear Sci. and Application, Vol. 34 No.2 pp.235241

[17] El-Motaium R.A. (2011). Bioavailability of nitrogen from sewage sludge using 1SN labeled ammonium sulphate. Isotope and Radiation Research Vol. 33, No. 2 pp.267-280

[18] El-Motaium R.A. and Badawy S.H. (2011). Heavy metals (Cd, Co, Ni and Pb) accumulation in tomato plants and soils amended with irradiated and non-irradiated sewage sludge. Egyptian J. Soil Sci. Vol. 42, No. 3. pp. 521-543

[19] El-Motaium R.A.; Ezzat H.E.M. and El-Batanony M. (2010). Radiation Technology: a means of sewage water and sludge disinfection treatment in Egypt. The Egyptian J. Medical Microbiology, Vol. 9 No. 2 pp. 387-392

[20] El-Motaium R.A.; El-Ammari M.F. and Sabry A. (2015). Improving sewage wastewater characteristics using radiation treatment. Isotope and Radiation Research Bulletin, Vol. 37. No.l, pp.253-262, ISSN 0021-1907

[21] Kustina, K.T., Dewi, G.A.A.O., Prena, G.D., Suryasa, W. (2019). Branchless banking, third-party funds, and profitability evidence reference to banking sector in indonesia. *Journal of Advanced Research in Dynamical and Control Systems, 11*(2), 290-299.

[22] Nyandra, M., Kartiko, B.H., Susanto, P.C., Supriyati, A., Suryasa, W. (2018). Education and training improve quality of life and decrease depression score in elderly population. *Eurasian Journal of Analytical Chemistry*, *13*(2), 371-377.