# Characterization of Al, Si and Mg in coal residues by Proton Induced Gamma Ray Emission Technique

Shashank Singh[1], Mumtaz Oswal[1, 4], Sk Wasim Raja[3], Shivcharan Verma[1], B.R. Behera[1], A. Kumar[1], R. Acharya[3], S. Santra[2] and K. P. Singh[1]*

*[1]Physics Department, Panjab University, Chandigarh-160014, INDIA*
*[2]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
*[3]Radio Chemistry Devision, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
*[4]Physics Department, Dev Samaj College for Women, Sector 45/B Chandigarh-160047*
*. * email: singhkp@pu.ac.in*

## Introduction

Coal is used for one third of the whole energy production all over the world and makes up to 40% of the electricity generation. It also plays a dominant role in industries such as iron and steel [1]. Nearly 80% of the total electricity generated in India is from coal. But from the recent few years the production and consumption of coal is reduced worldwide. This shift largely reflects structural factors: the growing accessibility and competitiveness of natural gas and renewable energy resources, united with the government and societal pressure to shift towards clean, green and low carbon generating fuels [2]. No doubt coal is very important fuel for human being but after combustion process coal leaves a large amount of coal residue and its utilization is an important area of study. The residue contains a wide range of elements including many toxic elements. For suitable use of coal residues elemental characterization is needed.

Particle induced gamma ray emission (PIGE) is a nondestructive nuclear analytical technique which is suitable for detection and measurement of concentration of low Z elements. In PIGE, the target nuclei present in the sample are irradiated with suitable energetic charged particles to excite. These nuclei are excited through (p,p'γ), (p,nγ) or (p,αγ) reactions. The emitted gamma rays after de-excitation of nuclei are detected and counted for identification of the elements and their concentration in the sample.

## Sample Collection and target preparation

Coal fly ash and coal pond ash samples were collected from six thermal power plants of Punjab and Haryana region. The targets of NIST reference material coal bituminous 1632a, coal sub-bituminous 1633, coal fly ash 1635 were prepared at FOTIA Lab (BARC) as standard samples. All targets were made in lithium and cellulose matrix. First sample was dried in air after that 250 mg of sample was homogeneously mixed with 10 mg of $Li_2CO_3$ and 490 mg of cellulose. The mixture was then pressed into pellets of diameter 20-mm using a hydraulic press.

## Experimental Details

The experiment was carried out in Folded Tandem Ion Accelerator Lab, BARC, Mumbai. The thick target of samples and reference material were mounted on a steel ladder in a scattering chamber. The scattering chamber was having vacuum of the order of $10^{-6}$ Torr. The proton beam of 3 MeV energy with current ~10 nA was used to bombard the targets.

The target ladder was placed at 45° to the beam direction. HPGe detector was placed at 90° with respect to the beam direction at a fixed distance of 7 cm from the target ladder. A gold foil of thickness 9.1 mg/cm$^2$ was placed just before the target ladder. A SSB detector was placed at 165° in the backward direction to measure the count rate of backward scattered protons from gold foil. Typical RBS spectra obtained from SSB detector is shown in Fig.1. Gamma-rays spectrum was measured using a

30% relative efficiency HPGe detector coupled to a PC based 8k MCA. The obtained spectrum was analyzed using peak-fit software called Pulse Height Analysis software (PHAST) for peak area determination.

## Data analysis and results

The concentration of a particular element x in the sample is calculated using the formula

$$Cx, sam = Cx, std * \frac{Rcn, sam}{Rcn, std}$$

where Cx,std is the concentration of element x in the standard sample. Rcn,sam and Rcn,std represents charge normalized peak area of the specific peak for sample and standard respectively. The charge normalization was done using RBS technique.

**Table1:** Results of elemental concentration

| Sample | Al in ppm | Mg in ppm | Si in ppm |
|---|---|---|---|
| **G** Fly ash | 130188.4 | 3816.90 | 252993.988 |
| **G** Pond Ash | 83031.67 | 0 | 140859.392 |
| **L** Fly Ash | 127699.94 | 3805.54 | 254626.86 |
| **L** Pond Ash | 124485.68 | 2063.27 | 260961.23 |
| **R** Fly Ash | 155271.5 | 2653.83 | 150056.39 |
| **R** Pond Ash | 137391.4 | 4882.80 | 98829.76 |
| **Y** Fly Ash | 97472.52 | 2054.60 | 150280.28 |
| **Y** Pond Ash | 177607.7 | 576.31 | 106575.93 |
| **H** Fly Ash | 125195.8 | 6018.26 | 243897.78 |
| **H** Pond Ash | 133730.4 | 0 | 0 |
| **P** Fly Ash | 121197.5 | 4169.16 | 240090.75 |
| **P** Pond Ash | 104248.4 | 3696.02 | 112373.38 |

Where:

**G:** Guru Nanak Dev Thermal Plant (Bhatinda) Punjab, **L:** Guru Hargobind Thermal Power Plant, Lehera Mohabbat (Bhatinda) Punjab, **R:** Rajpura Thermal Power Plants (Patiala) Punjab, **Y:** Deenbandhu Chhotu Ram Thermal Power Station (Yamunangar) Haryana, **H:** Rajiv Gandhi Thermal Power Station (Hissar) Haryana, **P:** Panipat Thermal Power Station (Panipat) Haryana

## Conclusion

The PIGE investigation was carried out for fly ash and pond ash samples. From this study, it is found that elements Al and Si are present in these samples as major trace elements, whereas, Mg is present as sub trace element. Al concentration, beyond the certain limit is very toxic. The EPA has recommended a Secondary Maximum Contaminant Level (SMCL) of 0.05–0.2 mg/L for aluminum in drinking water [3] and also OSHA set a legal limit of 15 $mg/m^3$ (total dust) and 5 $mg/m^3$ (respirable fraction) aluminum in dusts averaged over an 8-hour work day [3]. However, silicon has less health hazards but excess inhalation of silicon causes some lungs disorders. Mg is not a toxic element usually.

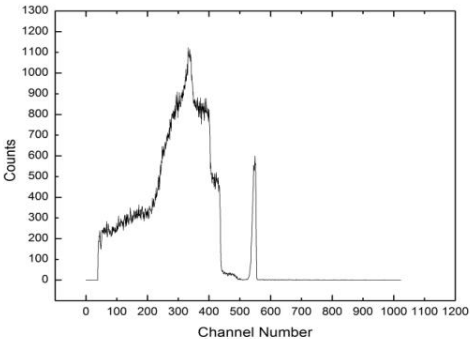


**Fig. 1** Rutherford Backscattering peak of proton from $^{197}$Au

With the use of proper treatment techniques coal ashes can be used in industry, infrastructure, agriculture and in many more other fields [4]. This increased utilization can combat environmental problems associated with fly ash generation.

## References


[1] https://www.iea.org
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