ISSN 2250-3153

Distribution of Silica in different size fractions in Kusmunda, Korba Coal field

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Abstract- The huge amount of ash generated in our power plants can serve as important source for extraction of important ash constituents. Kusmunda area in Korba Coal field is an important source for power coals and therefore a bulk coal sample from the area has been studied in details as a test case for distribution of mineral matter in coal ash in different possible constituted dispatch material to power plants taking silica as a major and marker ash constituent. While, silica as percent of ash from samples under study remains within close limits, its retention in coarser constituted samples is found much higher than in corresponding finer coals.

Index Terms- Ash constituents, Silica

I. INTRODUCTION

Coal is a complex heterogeneous fossil fuel with its major utilization in power generation. So far, we have been more and more concerned with the calorific value of coal and all our designs were directed to the most possible efficient extraction of fuel value of the coal. We took care of mineral content of coals in as far as their role as diluents of calorific value and rate of heat release was concerned and if at all we thought of utilizing physical methods of coal beneficiation, our only aim was to get coal fractionated in to low and high ash fractions for their use in plants with different designs only. Now with more and more coal based power plants getting commissioned in our country, we will have to consider coal in its totality while extracting it for utilization. Apart from being a source of particulate and gaseous pollutant, coal combustion leaves a large residue of altered mineral residue, the ash, which can now no longer be treated as an industrial waste. This huge quantity of ash generation has attracted our attention due to associated ash handling and disposal problems only. Its disposal in large ash dams has been seriously affecting ground and water utility in adjacent areas. Many ash disposal projects/ programmes considered for safe disposal of ash including bricks making, land-filling, road-surfacing, lining of canals and soil nutrients and in cement industries etc, utilize less than 30 per cent of ash generated in the power plants in the region. To appreciate the bulk of ash production utilizing our high ash coals, let us consider total ash generated in a year when 10 million tones of coal is combusted in power plants in and around Korba, Bilaspur and Raigarh regions in a year when the amount of ash generated would be around 42 million tones of ash. This may be annual production target of some raw material in a small country. Again coal ash is known to contain almost all the elements of periodic table in oxide or other chemical forms, some in major proportions while others in trace or minor quantities. The major constituents of ash include silica SiO_2, alumina Al_2O_3, ferric oxide Fe_2O_3, lime CaO and magnesia MgO. Oxides of Titanium TiO_2 , Manganese Mn_3O_4, Phosphorous P_2O_5, Potassium K_2O and sodium. Na_2O are present in minor quantities while As, Zn, Sb, Bi, Hg, Ni, Cu, Co are present in trace quantities, some of these come out in gaseous form in flue gases. Thus considering the chemical constituents of ash, this bulk of industrial hazard can be gainfully exploited for its chemical values adding value to combustion of coal for power generation. To extract these constituents we need a composite chemical plan for isolation and separation. Again since we fractionate coals on the basis of size and/or density to make is suitably useful for a given plant appliance, we need to identify which fraction ash is more concentrated for a given ash constituent for its gainful isolation before the residual material is processed for remaining constituents in the composite plan.

The present studies are devoted to follow distribution pattern of silica, the most abundant constituent of coal ash on fractionating a bulk coal sample from Kusmunda Colliery, Korba Coalfield in different size fractions.

II. EXPERIMENTAL PARTICULARS

A run of mine coal sample has been drawn from the Kusmunda area, Korba Coal field. After proper mixing, coning and quartering a definite quantity of sample has been transported to CIMFR laboratory, Bilaspur. The bulk coal sample was made to pass through 100 mm screen, manually crushing any plus 100 mm material left on the screen. Subsequently the minus 100 mm material was put on 25mm screen and material retained on the screen was separated as 100-25 mm size fraction. Following the same scheme, remaining minus 25 mm material was passed through 13 mm screen to obtain 25-13 mm size fraction. Using 13mm, 6 mm, 3mm, and 0.5mm screens similarly 13-6mm, 6-3mm, 3-0.5mm and -0.5mm were separated. Individual size fractions were weighed and crushed to prepare x 72 mesh laboratory samples as per **BIS: 436, (Part 1/ Section 1) - 1964 and BIS: 436, (Part 2/ Section 2) - 1976** for characterization studies. Again by mixing proportionate weights of x 72 mesh laboratory samples an overall sample was obtained to represent the original bulk sample in quality and property parameters. Constituted broad size fractions were also prepared using proportionate weights of related size fractions. The samples were subjected to characterization studies including chemical analysis of coal ash.

For the characterization studies methodologies as contained in Indian Standard specifications **BIS: 1350 Part I, 1984 second revision,** have been followed. Chemical analysis of coal was done following specifications as contained in **BIS 1355-1984** and using analytical grade reagents. .

III. Results and Discussion

Results of characterization studies have been presented in the table below**.** The moisture in coal being dependent on ambient laboratory conditions, the results have been recast on dry basis to avoid any variation on account of weather conditions or otherwise.

Table: 1 Characterization study of different size fractions and bulk samples.

Size fraction	Weight %	Dry Ash %	Ash as % of mass of size consist	Ash as part of total ash in bulk coal
100-25 mm	54.9	40.4	22.18	61.10 %
25-13 mm	8.8	35.3	3.10	8.54 %
13- 6 mm	13.1	32.4	4.24	11.68 %
6- 3 mm	6.2	26.4	1.64	4.52 %
3- 0.5mm	10.1	26.3	2.66	7.33 %
- 0.5mm	6.9	35.9	2.48	6.83 %
Bulk coal	100.0	36.3	36.30	100 %

From Table – 1, the results of characterization studies reveal that out of 100 tonnes of coal produced, 100-25mm size contributed to 54.9 tonnes, 25-13mm size to 8.8 tonnes, 13-6mm size to 13.1 tonnes, 6-3mm size to 6.2 tonnes, 3-0.5mm size to 10.1 tonnes and the rest 6.9 tonnes were contributed by –0.5mm size materials.

The 100-25mm size fraction analyses 40.4 ash $_{dry,}$ this is higher than analyzed by any other size material as also the bulk coal sample. The fraction retains 22.18 part of the total bulk coal ash amounting to 61.1 per cent of the total ash

The 25-13 mm size material analyses 35.3 per cent ash, near similar to ash (35.9 %) found for minus 0.5 mm size fraction. This represents 3.10 part or 8.54 per cent of the total ash in the bulk coal sample.

The ash in 6-3mm and 3-0.5mm size fractions has been found to be lowest with 26.4 and 26.3 per cent respectively representing 1.64 and 2.66 part or 4.52 and 7.33 per cent of total coal ash.

The 13-6 mm size fraction analyses 32.4 per cent ash forming 4.24 parts or 11.68 per cent of the bulk coal ash. The minus 0.5 mm fines have retained 2.48 parts amounting to 6.83 per cent of the bulk coal ash.

Thus from 100-25mm size to 3-0.5mm size, ash percentage is found decreasing while in -0.5mm, the finest size coals, the ash percentage is increased by about 10 units from that for 3-0.5mm size. In bulk coal, the ash percent is 36.3 which is nearer to the ash of -0.5mm fines.

The coal ash for individual size consists as also the constituted bulk coal samples were subjected to ash analysis. The results in respect of silica content in these samples have been summarized below in terms of per cent of ash,

Table 2: Silica distribution in different size fractions, Kusmunda Coals, Korba CF

Size fraction (mm)	Wt%	Ash $_{Dry}$ %	SiO2%
100-25	54.9	40.4	64.20
25-13	8.8	35.3	63.54
13-6	13.1	32.4	63.47
6-3	6.2	26.4	62.80
3-0.5	10.1	26.3	62.57
-0.5	6.9	35.9	63.33
Bulk sample	100.	36.3	63.81

It is seen that silica per cent for ash samples of different size fractions as also the bulk coal ash varies within a narrow range of 1.63 units.

The 6-3 mm and 3-0.5 mm fractions analyze 62.80 and 62.57 per cent silica while the 100-25 mm large coal ash analyzes 64.26 per cent silica.

Table 3 below presents retention of silica in different size fractions in terms of mass.

Table: 3 Distribution of Silica (SiO2) in different size fractions.

Size fraction	Wt (in tonnes)	Silica in tonnes	Silica as % of mass of size consist	Silica as part of silica in bulk coal
100-25 mm	54.9	14.24	25.93	61.48 %
25- 13mm	8.8	1.97	22.43	8.51 %
13-6mm	13.1	2.69	20.56	11.61 %
6-3mm	6.2	1.03	16.57	4.45 %
3-0.5mm	10.1	1.66	16.46	7.16 %
-0.5mm	6.9	1.57	22.72	6.78 %
Bulk coal	100.0	23.16	23.16	100 %

From Table 3 it can be seen that 100 tonnes of the bulk coal contains 23.16 tonnes silica in its ash. Of this 14.24 tonnes silica is present in 100-25mm, 1.97 tonnes silica in 25-13mm, 2.69

tonnes in 13-6mm, 1.66 tonnes in 3-0.5mm and 1.57 tonnes silica is present in -0.5mm size material.

It is discernible that the silica contained in individual size consists is essentially related to weight contribution of these size fractions in the bulk coal sample and their ash percentage. As the 100-25mm size consist represents 54.9 per cent of the bulk coal sample and has higher ash content as well, the quantum of silica produced on its combustion is also pretty high. It is found to be 14.24 tonnes from combustion of 54.9 tonnes of the size consist. This represents 61.48 per cent of total silica of the bulk coal sample and 25.93 per cent of the weight of size consist burnt.

The 25-13 mm material represents 8.8 per cent of the bulk coal and analyses 35.3 per cent ash. 8.8 tonnes of this material on combustion would generate 1.97 tonnes of silica which is 8.51 per cent of total silica of the bulk coal sample and 22.43 per cent of the mass of the size consist.

The 13-6 mm size material forms 13.1 per cent of the bulk coal and analyses 32.4 per cent ash. The silica produced on combustion of 13.1 tonnes of this material would be 2.69 tonnes representing 11.61 per cent of total silica of bulk coal sample and 20.56 per cent mass of the size consist.

The 6-3 mm size consist represents 6.2 per cent of the bulk coal sample and is found to analyze 26.4 per cent ash., the silica produced on its combustion would be 1.03 tonnes This represents 4.45 per cent of total silica of the bulk coal sample and 16.57 per cent of the size consist burnt.

The 3-0.5 mm size consist represents 10.1 per cent of the bulk coal sample and analyses 26.3 per cent ash. Silica produced would be 1.66 tonnes from combustion of 10.1 tonnes of the size consist. This would be 7.16 per cent of total silica of the bulk coal sample and 16.46 per cent of the size consist burnt

The minus 0.5 mm fines representing 6.9 per cent of the bulk coal sample analyses 36.3 per cent ash. 1.57 tonnes of silica would be produced from combustion of 6.9 tonnes of the size consist. This represents 6.78 per cent of total silica of the bulk coal sample and 22.72 per cent of the size consist burnt.

Thus the lower size fractions are found to retain comparatively lower proportions of total silica. Again except the lower ash fractions (6-3 mm and 3-0.5 mm) produce 16.57-16.46 per cent of the mass burnt, for all other size consists including the bulk coal silica produced on combustion is between 20.56 and 25.93 per cent of the mass of coal burnt.

IV. Distribution of Silica in Constituted Coal Samples

In order to obtain coal dispatches for specific industries, it is generally advisable to screen the total coal produce of the mine on one or two screens only. The effect of this exercise can be theoretically perceived on reconstituted samples as discussed below.

By mixing of proportionate weights of different size fractions, some new constituted samples have been obtained as +25mm and -25mm, +13mm and -13mm, +6mm and -6mm, +3mm and -3mm, and +0.5mm and-0.5 mm size. These samples were subjected to characterization studies and ash analysis to follow distribution pattern of silica. The results are presented in Table 4 and 5.

Table 4: Results of Characterizations of Constituted samples, Kusmunda Coals

Size fraction(mm)	Wt%	Ash dry%	SiO_2%
+25mm	54.9	40.4	64.20.
-25mm	45.1	31.3	63.19
+13mm	63.7	39.7	64.10
-13mm	36.3	30.3	63.19
+6mm	76.8	38.4	64.09
-6mm	23.2	29.2	62.88
+3mm	83.0	37.5	64.03
-3mm	17.0	30.2	62.91
+0.5mm	93.1	36.3	64.03
-0.5mm	6.9	35.9	63.38
100-0mm	100	36.3	63.87

The results immediately show that the coarser size consists +25 and +13 mm material analyses ash in the range of 40 per cent and represent major chunk of coal production at 54.9 and 63.7 per cent level. The + 6, +3 and +0.5 mm material also analyzes higher ash in the range of 36.3-38.4 per cent.

All the finer sizes, the -25, -13, -6, and -3 mm size consists analyze nearly 10 units lower in ash as compared to their coarser sizes. The +0.5 and -0.5 mm material, however, have practically similar ash , closer to the bulk coal but still about 4 units lower that the +25 and +13 mm material.

The silica per cent in all the plus or coarser size constituted samples has been around 64 % of ash, nearly 1 unit higher than the finer constituted samples.

Table: 5 Distribution of Silica (SiO_2) in different constituted size fractions.

Size fraction	**Wt % (in tonnes)**	**Silica in tonnes**	**Silica as % of mass of size consist**	**Silica as part of silica in bulk coal**
+25 mm	54.9	14.24	25.93	61.49
- 25mm	45.1	8.92	19.78	38.51
+13 mm	63.7	16.21	25.45	70.00
-13 mm	36.3	6.95	19.15	30.00
+ 6 mm	76.8	18.91	24.62	81.65
- 6 mm	23.2	4.25	18.31	18.35
+ 3 mm	83.0	19.93	24.01	86.05
- 3 mm	17.0	3.23	19.0	13.95
+ 0.5 mm	93.1	21.59	23.19	93.22
- 0.5 mm	6.9	1.57	22.75	6.78

As we include more and finer sizes in the constituted samples, the amount of silica generated on combustion of the constituted sample goes on increasing. Thus on combustion of 54.9 tonnes of +25 mm material, silica generated would amount to 14.24 tonnes, this is 61.49 part of the silica in the bulk coal sample and forms 25.94 per cent of the mass of size consist combusted. Corresponding – 25 mm material retains 8.92 tonnes of silica which would be 38.51 parts of total silica in bulk coal

and 19.78 per cent of the mass of the size consist. Similarly, + 13 mm material retains 16.21 tonnes of silica which constitutes 70.0 per cent of total silica of the bulk coal and 25.45 per cent of the mass of size consist. The – 13 mm constituted sample retains 6.95 tonnes of silica forming 30% of the total silica of the bulk sample and 19.15 per cent by weight of the size consist. The + 6mm constituted sample has retained 18.91tonnes of silica constituting 81.65 parts of silica in the bulk coal. This is 24.62 percent of the mass of the size consist.

The silica retained in – 6 mm material is 4.25 tonnes, which would be 18.35 parts of the total silica in bulk coal sample and 18.31 per cent of the mass of the size consist. Similarly +3 mm material retains 19.93 tonnes of silica representing 86.05 parts of silica in the bulk coal sample and forming 24.01 per cent by weight of the size consist. The + 0.5 mm constituted sample retains 21.59 tonnes of silica which would be 93.22 parts of the silica in the bulk coal and forms 23.19 per cent mass of the size consist. The remaining – 0.5 mm fines have 1.57 tonnes of silica representing 6.78 parts of the bulk coal silica and 22.75 per cent of mass of the size consist.

From quality results of different size fractions and constituted samples it is seen that the + 25 mm coarse coal and - 0.5 mm fines have pretty high ash and their inclusion in constituted samples has adversely affected the quality of such coals. While the quantum of + 25 mm coals requires improvement of its quality by addition of lower ash finer sizes, the effect of addition of 6.9 tonnes of - 0.5 fines in the coarser material would reduce the ash burden in resultant excluding -0.5 mm finer constituted samples without having any adverse effect on the coarser coals. The results of the exercise have been compiled in tables below.

Table 6: Results of Characterization of Constituted samples, Kusmunda Coals,

Size fraction(mm)	Wt%	Ash dry%	SiO_2%
+25 incl. (-0.5)	61.8	39.9	64.32
-25 excl. (-0.5)	38.2	30.4	63.29
+13 incl. (-0.5)	70.6	39.4	63.92
- 13 excl. (-0.5)	29.4	29	63.10
+ 6 incl. (-0.5)	83.7	38.3	63.85
- 6 excl. (-0.5)	16.3	26.2	63.0
Bulk Sample	100	36.3	63.87

It is seen that the higher constituted samples on inclusion of – 0.5 mm fines still maintain their ash levels near similar to what they had when the - 0.5 fines were not added. However, the corresponding finer constituted samples have rather improved in quality with decrease in their ash by 1 to 3 units. The silica as per cent of ash is slightly higher in the coarser or plus constituted samples as compared to the corresponding finer minus constituted samples.

Table: 7 Distribution of Silica (SiO_2) in different reconstituted size fractions.

Size fraction	Wt % (in tones)	Silica in tonnes	Silica as % of mass of size consist	Silica as part of silica in bulk coal
(+25 incl.-0.5mm)	61.8	15.81	25.58	68.26
(-25excl.-0.5mm)	38.2	7.25	19.24	31.74
(+13 incl.-0.5mm)	70.6	17.78	25.18	76.77
(-13 excl.-0.5mm)	29.4	5.38	18.30	23.23
(+ 6 incl.-0.5mm)	83.7	20.47	24.26	88.39
(- 6 excl.-0.5mm)	16.3	2.69	16.50	11.61
(+3 incl.-0.5mm)	89.9	21.50	23.92	92.83
(-3 excl.-0.5mm)	10.1	1.66	16.44	7.17

As the -0.5mm size is included in coarser size, the contribution of silica is increased in plus sizes while decreased in minus sizes. In (+25 incl. -0.5mm) size, 15.81 tonnes silica is present leaving 7.35 tonnes silica retained in (-25 mm excl. -0.5mm) size. This represents 68.26 part of total silica of the bulk coal and 25.58 per cent weight of the size consist. In the same pattern, (+13 incl.-0.5mm) size is found to contain 17.78 tonnes of silica representing 76.77 per cent of the bulk coal silica and 25.18 per cent of the mass of the size consist. The (+6 incl. -0.5mm) mm material retains 20.47 tonnes of silica forming 88.39 part of the total silica of the bulk sample and 24.46 per cent mass of the size consists. The (+3 incl. -0.5mm) has retained 21.50 tonnes of total silica representing and 92.83 parts of silica in bulk coal and 23.92 per cent of the mass of the size consist.

The finer minus constituted samples excluding the contribution of – 0.5 mm fines have retained comparatively lower silica in their ash. . In (-25 excl -0.5mm) size, 7.35 tonnes silica is present This represents 31.74 parts of total silica of the bulk coal and 19.24 per cent weight of the size consist. Similarly the (-13 excl.-0.5mm) size constituted sample is found to contain 5.38 tonnes of silica representing 23.23 per cent of the bulk coal silica and 18.30 per cent of the mass of the size consist. The (-6 incl. -0.5mm) mm material retains 2.69 tonnes of silica forming 11.61 parts of the total silica of the bulk sample and 16.5 per cent mass of the size consists. The (-3 excl. -0.5mm)sample has retained 1.66 tonnes of total silica representing 7.17 parts of silica in bulk coal and 16.44 per cent of the mass of the size consist.

Summary

The Indian coals, due to their drift origin have been responsible for generation of extremely large quantities of ash in major power plants of the country. Since coal ash is known to contain a number of major and minor ash constituents of commercial significance the huge tonnage of ash generated in our plants can be treated as source material for some commercially important constituents. In the light of this the present studies were under taken on a bulk coal sample from Kusmunda mine, Korba Coalfield in Korba District of Chhattisgarh**.**

To evaluate the movement and distribution pattern of silica with different sizes and size fractions and bulk coal sample from Kusmunda area, Korba Coal Field has been taken for study.

Different size fractions were obtained following standard specifications and after recording their weights, laboratory samples were prepared BIS: 436, (Part 1/ Section 1) - 1964 and BIS: 436, (Part 2/ Section 2) – 1976 for characterization studies and chemical analysis of ash.

Characterization studies have been done as per BIS: 1350 Part I, 1984 (2^{nd} revision). The chemical analysis of ash has been done as per BIS: 1355- 1984.

The isolated size factions differ in their mass representation in the bulk coal, the 100-25 mm coarser size forming the major chunk representing 54.9 per cent of the mass of coal production.

The bulk coal sample analyzed 36.3 per cent ash. Of different size fractions, the 100-25mm size material analyzed 40.4 per cent ash suggesting shade higher concentration of ash forming mineral in the coarser coals. The 6-3mm and 3-0.5mm sizes have analyzed nearly 10 units lower ash than the bulk sample.

The 13-6mm material has analyzed 32.4 per cent ash while 25-13 mm material and minus 0.5mm fines have ash near similar to the bulk coal.

Silica as per cent of ash has been nearly same and varies within 2 units amongst different size fractions.

In terms of silica retained in different size fractions as part of total silica in the bulk coal sample, and as per cent of mass of the size consist, the distribution pattern changes according to the weights and ash content of the size consists..

The total silica in the present bulk coal sample from Kusmunda area is 23.16 tonnes. Of this, 14.24 tonnes silica is present in 100-25mm, 1.97 tonnes silica in 25-13mm, 2.69 tonnes in 13-6mm, 1.66 tonnes in 3-0.5mm and 1.57tonnes silica is present in -0.5mm size materials. These form 61.48, 8.51, 11.61, 4.45, 7.16 and 6.78 per cent of the total silica. In terms of the mass of the size consist, these amounts to 25.94, 22.39, 20.53, 16.61, 16.44 and 22.75 per cent of the mass.

In commercial practice, coals are screened on one or two screens only to obtain desired quality production for coal utilization. The conditions can be simulated in the laboratory by mixing proportionate weights of specific size fractions to constitute required quality product.

Distribution of ash and silica in such constituted samples shows that on inclusion of finer sizes, their cumulative silica concentrations increases from 61.49 to 93.22 per cent of the total silica in higher sizes and decreases in sizes from 38.51 to 6.78 per cent.. Out of 23.16 tonnes of total silica in the bulk coal sample, the +25mm size contains 14.24 tonnes and -25mm size contains 8.92 tonnes silica. This constitutes 61.49 and 38.51 per cent of the total silica respectively and represents 25.93 and 19.78 per cent mass of the size consists. In the +13mm, +6mm, +3mm, and +0.5mm size constituted samples , 16.21 tonnes, 18.90 tonnes, 19.93 tonnes and 21.59 tonnes silica has respectively been retained while the corresponding -13mm, -6mm, -3mm and -0.5mm size consists have 6.95, 4.26, 3.23 and 1.57 tonnes silica respectively.

The minus 0.5 has comparatively higher ash and therefore contributes larger dosage of silica in the finer (minus size) reconstituted samples. On inclusion of the -0.5 mm fines with coarser reconstituted samples, the quality of the product will not be affected adversely while the finer reconstituted samples will show sizeable improvement in their quality.

Thus when -0.5mm material is mixed in different coarser reconstituted samples, the silica contribution would be 15.81, 17.78, 20.47 and 21.50 tonnes respectively in +25 mm, +13mm, +6 mm and + 3mm constituted samples.

The corresponding -25, -13, -6 and -3 mm size consists on removal of the –0.5 mm fines show improvement with 7.35, 5.38, 2.69 and 1.66 tonnes of silica retained in them. The retentions of total silica increases from 68.26 parts to 92.83 parts of silica in the bulk coal for the coarser size samples while for the finer size reconstituted samples the retention decreases from 31.74 to 7.17 parts for corresponding reconstituted samples.

V. Conclusion

By the results, Silica has been concentrated the maximum 14.24 tonnes or 61.48 % in 100-25mm or +25mm size with 54.9 % yield and 15.81 tones or 68.26 % in (+25 incl.-0.5mm) size with 61.8 % yield out of 23.16 tonnes the total Silica present in bulk coal. This size may be used as a source for the separation of Silica.

Acknowledgement

We are thankful to Mr. B. L. Shah ex-OIC, CFRI (earlier CIMFR), Mr. A. K. Chattopadhyay, OIC and Dr. A. K. Sharma, Senior scientific Officer, CIMFR Bilaspur Unit for their valuable co-operations and suggestions for preparation of this paper.

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