Solution Approach to Some Coal Washing Issues in India  
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1. PREAMBLE

India’s energy sector is primarily dependent on coal which is the abundant indigenous resource. Presently about 55 percent of primary commercial energy supply and 70 percent of power generation is through coal. Such dependence on coal is going to continue in the foreseeable future. Unlike oil supply, of which 80% need is fulfilled through imports, the indigenous coal production meets more than 80% of country’s need. The imports are mainly for metallurgical coal and higher grades of non-coking coals, whose resources are scarce in the country. Currently, about 75% of domestic coal is used for power generation, 6% for cement industry, 5% for steel sector and 14% for other industries and consumers.

2. NEED FOR WASHING

Coal, the solid fossil fuel, occurs in nature in highly variable physical and chemical properties that affect its use. All industries viz. power, steel, sponge iron, cement etc., that use coal specify a range of quality requirements for their intended purpose. Coal consumers and producers try to match coal that most closely meets those quality requirements.

The most common and undesirable matter in coal is the noncombustible inorganic material termed as ash. The ash got associated with coal during its origin in geological past. The percentage of ash may get as high as 60%. Some ash also gets mixed with coal during its mining, subsequent handling and transport. In many countries it is customary that mining companies process the coal for ash reduction prior to selling it to consumers.

Coal washing or beneficiation is a process (with or without use of water) of mechanical separation of impurities (ash) from coal, making it suitable for particular use. Removal of sulphur is also an important aspect during washing process in some countries where sulphur in coal is comparatively high. Higher sulphur percentage makes coal unsuitable for metallurgical and some other industries as well as it harms environment when burnt with coal. Indian coals, except those of north eastern region generally contain low sulphur.

The early washeries in Europe and USA during 19th Century were setup with the objectives of mainly to get the increase of the selling price over and above the cost of washing or to permit the mining of a coal which on account of its large percentage of impurities could not be sold in the raw state.

Later, the consumers also realized other tangible and non-tangible benefits of washing especially, substantial reduction in transport and handling costs with lesser ash in coal, increase in end user plant capacity, reduced wear & tear at end user plant and the problems associated with handling of ash after burning coal. The washed coal with consistency in quality also created the numerous possibilities of blending.

Coming into the 2nd half of 20th Century, environmental concerns of transporting and using high ash coal also came into focus and legislations were framed to control and regulate it.

The views expressed here are those of the author and not necessarily reflect those of CMPDI.
3. BASIC PRINCIPLES OF WASHING

Nearly, all techniques of ash reduction or washing are based on differential specific gravities; that of pure coal being 1.3, of shale 1.8 and of stone >2.0. However, in actual conditions such pure cut off is not available, because as Run of Mine (ROM) we get shaley coal, carbonaceous shale, coal banded with shale or sand stones etc., materials which have specific gravities in between. In such conditions, and also because efficiency of washing process is never 100 %, segregation is not sharp and a part of one product gets misplaced into other stream and vice versa. Further, the differential sizes of constituents behave differently during gravity separation process, reducing the efficacy of washing. Ultra fines and fines are also difficult to wash and recover and some part of that is always lost.

The inherent ash of coal, too, up to certain extent could be liberated by crushing coal into smaller sizes. But if the ash is finely disseminated in coal matrix rather than coarsely, the desired level of liberation is not achieved even by crushing it into much finer sizes. Rather it involves infructuous cost and generation of undesirable fines. Further, mere liberation of ash does not serve the purpose. The objective remains to separate the two or three products i.e. clean coal with reduction in ash% as per the consumer requirement and other being middlings (used in power plants) as secondary product and rejects.

Washability curves drawn after analysis of coal in laboratories indicate that to reduce ash below a certain limit in clean coal, more carbon is lost alongwith the rejects. Further reduction of ash percentage in clean coal becomes prohibitive to make any economic sense, not only increasing cost of production of clean coal but also losing precious coal with rejects.

4. WHY INDIAN COAL IS DIFFICULT TO WASH

The origin of Indian coal dates back to its geological past some 225 to 275 million years ago through “drift theory” (woody materials transported by water to a distance, carrying along other impurities after which coalification process took place), as a result of which the coal matter is finely disseminated with mineral matter causing deterioration in its quality during its formation stage itself. Coal of most of the other coal producing countries originated through “insitu theory” (coalification process took place at the same place where woody material grew and got buried) in which the deterioration of the quality was far less.

The inherent ash of Indian coal cannot be taken off easily because it is embedded in the coal matrix and thus results into more near gravity materials. The extraneous ash which gets mixed with coal, mostly during mining can be removed more easily.

5. COAL WASHING IN INDIA

5.1. COKING COAL WASHING

Coking coals are used for making coke for steel industry. The ash percentage in coal for making coke for use in blast furnace of steel plants should be within 18%. The higher ash adversely affects the productivity of blast furnace. It has been observed that 1% increase in the ash results in the reduction of the blast furnace productivity by 3-6%.
Prior to 1950, the requirement of coal for steel making in the country was very small and the required quantity and quality of coal was available directly from the mines. The method of mining was predominantly manual and handpicking to adhere to the quality requirement. With the expansion of steelmaking capacity, Tata Iron & Steel Company installed the first two coking coal washeries at West Bokaro in 1951 and at Jamadoba in 1952. With coming up of number of steel plants in public sector, the requirement of coal for steel making was increased in manifold and a number of new coking coal washeries came up over the years.

5.2. NON-COKING COAL WASHERY

The major consumer of non-coking coal till 1960 was Railways. In 1970s to boost up the industrial growth, Government decided to increase power generation capacity manifold. After the nationalisation of coal industries in mid 1970s, the expansion of coal industry was also taken up on massive scale due to rising demand from thermal power plants. With the heavy investments and coming up of large opencast mines, mining of low grade non-coking coal has become feasible with economies of scale, which was earlier neglected by the private operators prior to nationalization. Need for washing high ash coal was also felt by all stakeholders for its use in thermal power stations. However, Power Production Companies were yet to realise the full benefits of using washed coal and were reluctant to share the cost of washing.

In 1997 and 1998 Ministry of Environment & Forests (MOEF) issued two notifications prohibiting use of high ash coal in certain cases. These notifications brought environment concerns on forefront and were catalyst for speeding up installation of new washeries, both in public sector & private sector.

In the meantime, realising the importance of non-coking coal (NCC) washing, Coal India Limited (CIL) CIL began setting up NCC washeries and commissioned its first NCC washery integrated with Piparwar opencast mine project in 1997, North Karanpura coalfield with annual throughput capacity of 6.5 million tonnes per year. The second NCC washery, also integrated with mine was commissioned at Bina opencast mine project, Singrauli coalfield in 1999. Due to non-availability of suitable quality of coking coal, CIL also converted three nos. of earlier coking coal washeries i.e. Dugda I(BCCL), Gidi(CCL), Kargali(CCL), to non coking coal washeries during the period 1998-99.

To promote coal washing in private sector, Ministry of Coal issued Guidelines in September 2005 for setting up of coal washeries on Coal Company’s land by the coal consumer who has a Fuel Supply Agreement (FSA) or long term linkage with the coal producer or by any operator on his behalf for obtaining desired quality of washed coal and to meet the demand-supply gap of washed coal. In this case, Coal Company has to work as a facilitator.

Accordingly, Punjab State Electricity Board (PSEB), Singareni Collieries Company Limited (SCCL) and Andhra Pradesh Generation Corporation (APGENCO) have set up washeries by engaging washery operators.

CIL is also implementing a massive program for setting up of washeries on BOM concept.
6. ISSUES

6.1 COKING COAL WASHING

6.1.1 Lower Operating Efficiency of Old Coal WASHERIES
Some of the existing coking coal washeries of CIL (Patherdih, Bhojudih, Dugda II & Kathara) are more than 40 years old. They were basically designed for washing Washery Grade III coal having ash percentage up to 28%. Over the years, reserves of good quality coal have been depleted in the neighbouring mines resulting in radical deterioration in raw coal feed quality and characteristics. Several modification attempts were made and some are in progress to deal with the problem. Dismantling of these washeries in a phased manner and construction of new washery with State of Art Technology may be the only viable option. In this way the existing infrastructure facilities would be gainfully utilised and the uncertainties associated with the new location would be mitigated. The other old washeries whose capacity utilization is poor must also be suitably modified.

6.1.2 Problems in Beneficiation of Fines
Fine coal (-0.5 mm) treatment circuits with conventional flotation were installed in all coking coal washeries. Clean coal & tailings are the two products of these circuits. However, they have proven to be ineffective due to deterioration in quality of fines. Present system of dewatering of clean coal through disc /drum filter for dewatering/ reducing moisture is also not operating efficiently due to deterioration in quality of fines. Similarly, dewatering of tailings is also posing problems.

In view of the above, latest technologies in the field of fine coal beneficiation & dewatering are to be explored and implemented.

6.1.3 Recovery of Blocked Coking Coal Reserves
Kargali Coking Coal washery is in operation since 1958, and modifications were also done. The plant was converted to non-coking coal washery in 1999 utilising the existing infrastructure facilities. Kargali washery is located on coal bearing area blocking coking coal reserves underneath. Shifting of this washery to a non-coal bearing area will release blocked coking coal reserves.

6.1.4 Washing of Non Linked Washery Coking Coal
Availability of good quality (with low ash %) coking coal is scarce in the country. The crunch is being felt by the steel industries with the recent spurt in the international price. The practice till now was to take up washing of coal upto 35% ash content (Washery Grade IV) and coal with higher ash% was being linked / supplied to other consumers as the washing of such coal would have given a very low yield resulting into very high cost of clean coal. To conserve the scarce indigenous resource of coking coal, it has become imperative to also use such coals for the steel industry. Resources of such coals are estimated to be around 6.4 Billion tonnes. These coals are termed as Non Linked Washery (NLW) coal or Low Volatile high Rank (LVHR) coking coal and they generally occur in lower seams (combined seam V/ VI/ VII/ VIII and even seam IV, III, II) of Jharia Coalfield and Karo group of seams (IV to XI) in East Bokaro Coalfield.

The numerous laboratory tests and pilot scale studies have confirmed that these coals, after washing exhibit good caking properties and can be blended to produce blast furnace coke. Realising the
importance, Coal India Ltd. is already in the process to set up six (6) NLW coking coal washeries on BOM basis. These washeries will be three product washeries producing Clean Coal of 18% ash, Middlings of less than 40% ash and Rejects.

6.1.5 Revised Grading of Coking Coal
In the present system of grading of Coking coal, the band width of Washery Grade III coal is 24% to 28% ash and Washery Grade IV is 28% to 35% ash and the NLW coal having ash% greater than 35% are not graded as coking coal. With the advancement in coal washing technology such coal can also be washed to produce BF grade coking coal. It is proposed to revise the grading system of coking coal and bring the higher ash% coking coal also into the grading system. The band width, too, in the present system of grading is very large even when compared to that in grading non-coking coal. In the present system of grading of non-coking coal, the Gross Caloric Value (GCV) band is 300 K Cal/ kg and this corresponds to about 3 units of ash% band.

6.2 Washing of Non-coking Coal
About 90% of the planned additional power generation capacity is coal based. To cope up with the demand, coal washery of non-coking coal has become a major thrust area. The major issues are:

6.2.1 To avoid long distance transport of high ash coal for:
   i. Saving in cost of transportation
   ii. Saving energy consumed in transportation
   iii. Reduced Load on transportation network
   iv. Ensuring consistency in size and quality for the various end users
   v. Reducing wear & tear at user plants because of lesser handling
   vi. Higher efficiency and increase in capacity of end use plant due to burning of low ash coal
   vii. Reduced problem of reject ash handling & disposal and
   viii. Reduced impact on environment.

6.2.2 To ensure that minimum carbon or heat value is lost in Rejects, the washing process should be scientifically designed, implemented and controlled for optimum yield of clean coal. However, if the flow of carbon into the Rejects cannot be avoided, it should be utilized to generate power by utilizing FBC technology.

6.2.3 Possibility of deep washing of certain non-coking coals
Certain type of non-coking coals could be washed to produce a small fraction of clean coal with ash content of 15-18%. Such clean coal could be used in suitable blends with coking coal for their eventual use in steel making. This would result in some saving in the requirement of coking coal and its import.

6.2.4 Washing of high ash non-coking (>46% Ash) poses typical problem of generating very high % of rejects generation with residual heat value. It has come out through various laboratory studies and tests that reduction in ash unit of more than 10%, generates rejects in excess of 40% with residual GCV of around 2000 kcal/kg. Use of such large quantity of coal in FBC power may not be a desirable option.
It may be a better idea to go for lesser reduction in ash % so that the ash % in rejects is above 65% for better conservation of a valuable resource in the Country. The percentage of ash in clean coal in such cases may be above 34%.

7. Solution Approach

A. Coking coal washing

i) The old washeries should be renovated to utilize their capacity to the maximum extent.

ii) Grading for washery grade coal should be revised to include coking coals which are presently termed as NLW coal as follows:

<table>
<thead>
<tr>
<th>Existing Grades</th>
<th>Ash Content as per Existing Grades</th>
<th>Proposed Grades</th>
<th>Proposed Ash Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Grade-I</td>
<td>- 15%</td>
<td>Steel Grade-I</td>
<td>- 15%</td>
</tr>
<tr>
<td>Steel grade-II</td>
<td>+ 15% - 18%</td>
<td>Steel grade-II</td>
<td>15% - 18%</td>
</tr>
<tr>
<td>Washery Grade-I</td>
<td>+18% - 21%</td>
<td>Washery Grade-I</td>
<td>+18% - 21%</td>
</tr>
<tr>
<td>Washery Grade-II</td>
<td>+ 21% - 24%</td>
<td>Washery Grade-II</td>
<td>+ 21% - 24%</td>
</tr>
<tr>
<td>Washery Grade-III</td>
<td>+ 24% - 28%</td>
<td>Washery Grade-III</td>
<td>+ 24% - 28%</td>
</tr>
<tr>
<td>Washery Grade-IV</td>
<td>+ 28% - 35%</td>
<td>Washery Grade-IV a</td>
<td>+ 28% - 32%</td>
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<td></td>
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<td>Washery Grade-IV b</td>
<td>+ 32% - 36%</td>
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<td></td>
<td></td>
<td>Washery Grade-IV c</td>
<td>+ 36% - 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Washery Grade-IV d</td>
<td>+ 40% - 44%</td>
</tr>
</tbody>
</table>

iii) Use of high ash coking coal which is presently referred as NLW coal in power industry should be stopped in phased manner such that NLW Coal is not directly linked to power sector by 2020.

iv) Construction of new washeries for washing of NLW coal should be taken up to meet the deadline of 2020.

v) New NLW coal mine projects should be linked to steel plants for clean coal after washing.

vi) Design of NLW washery should be such that it produces three products viz., 18.0± 0.5 ash% clean coal for metallurgical purpose, middling of less than 40 ash% for power sectors as per the prevailing practice for coking coal washeries, and rejects.

B. Non Coking Coal Washing

i) Coal having GCV less than 4600 kcal per kg should not be transported to consumers located at a distance of more than 1000 km.

ii) Coal having GCV less than 4300 kcal per kg should not be transported to consumers located at a distance of more than 500 km.

iii) Coal having GCV less than 4000 kcal per kg should not be transported to consumers located at a distance of more than 250 km.
iv) All new mines of more than 2.5 Mty capacity which are not linked to pithead power plants should be designed with an integrated washery with state of the art technology.

v) The rejects having GCV of more than 1500 kcal should be used in FBC power plants for generation of Power.

vi) For washing very high ash coal (>46%) non-coking coal circuit should be so designed that ash% in rejects remains above 65%.

vii) All consumers/coal producers should take necessary steps for enhancement of washing capacity, so that above norms are complied.

C. GENERAL

Central Govt. issued Gazette Notification on 30th December 2011 for switching over to GCV based Grading and pricing system for non-coking coals. This would call for revision of all quality requirements of various consumers having FSA. Accordingly, washery design should also take into account quality parameters of input and output/products.

i) Ownership of raw coal, washed coal, middlings, rejects and slurry, if any, will be of the linked consumer or any operator having long-term FSA. Linked consumer(s) is required to take approval of Government for disposal of rejects.

ii) Linked consumers having arrangement for washing coal through any washery operator, should monitor (quality & quantity) the raw coal supplied from the mines and fed to washery (quality & quantity), yield% of washed coal, efficiency of washing circuit, reject (quality & quantity) and its handling/disposal system. Consumers are also required to examine the availability of infrastructure facilities in respect of raw coal storage, washed coal storage, reject handling facility. Status of Statutory clearances should also be ascertained.

iii) Washeries should be designed to preferably integrate with the mine or located close to it. Otherwise only crushed coal (-200mm/100mm) from linked mines are to be supplied to the Washeries.

iv) Sites for new washeries should be selected considering the extent of coal bearing area and possibility of future mineability.

v) Action should be initiated to release the coal blocked beneath existing washeries or other infrastructure.

vi) New washeries should be planned with maximum utilization of available land keeping in view minimum half-day storage for raw coal and one day storage of saleable products (clean coal & middling), closed water circuit operation with emergency slime ponds only and adhering to all environmental aspects. Further reduction in land requirement may be explored with introduction of state-of-the-art technology and plant layout etc.
vii) Standard design of annual throughput capacity of 2.5/5.0/10.0 Million tonnes should be preferred.

viii) For Coking coal washing 1 Mty washeries can also be considered as per need.

ix) To cater to small mines of lesser capacity of coal, a centralised washery could be planned.

x) Coal transportation by road, either from linked-mines or dispatch of products to loading centre, is to be best avoided wherever possible. All new washeries are to be envisaged with belt conveyor systems for all such transportations, unless otherwise constrained due to geographical terrain or unmanageable factors.

xi) To increase the utility of Railways facilities, fast loading systems @ 3600 tph are to be introduced wherever possible. This would avoid wharf wall loading and re-handling of saleable products.

xii) Most of the water requirement is to be met by re-use of plant water through closed-water circuit. However, for make-up water, independent perennial source of water is required for operation & maintenance of a washery. Utilization of available mine water should preferably be explored for the purpose, with due regard to conservation of scarce water resource.

xiii) Power is another important infrastructure facility essential for setting up of washery and operation. Independent feeder and reliable supply of power from sub-station may be envisaged for the washery to realise maximum output from the washery.

xiv) Coal beneficiation practice is a highly specialized subject. Regular training of manpower is needed to keep pace with the global advancement in washing and allied technology by incorporation of innovative and environment-friendly technologies in CIL washeries.

xv) Various tests carried out on certain type of non-coking coals have shown encouraging results for use of low ash washed non-coking coal with 15-18 ash% as blends for making Blast Furnace coke. Such coal could be used in suitable blends with coking coal for steel making. This would result in some saving in the requirement of coking coal and its import. However, this needs techno-economic study

xvi) Technologies in vogue for coal beneficiation are wet ones as they offer better efficiency and minimum misplacement of clean coal (i.e. minimum loss of carbon in reject). At some places, local authorities imposed moratorium to draw water from the natural streams for industrial use. Also, water conservation is required to be given due importance. Of late, there has been considerable development in dry coal beneficiation technology. There is need for R&D trials to assess suitability of different available technology(s) for dry beneficiation of coal so that commercial scale adoption can be decided based on their relative merits and demerits on case-to-case basis. **Dry coal beneficiation** should also be looked as a suitable option to the extent possible keeping in view the scarcity of water.
xvii) Effluent treatment plants are to be installed as far as applicable in existing washeries to ensure zero discharge water system in the circuit.

xviii) To work out a right strategy and promote best utilisation of resource it is necessary that all data remain available with a centralised agency/ institution. The washery operators may be asked to furnish the data every month as well as annually regarding source-wise receipt of coal, dispatch of coal, details of consumer, and quality parameters of coal supplied to the consumer. For this some Amendments could be done in Coal Conservation & Development of Mines Act (CCDA), 1974 / CCDA Rules, 1975, which already has certain provisions in this regard for effective acceptance & compliance.