MEETING REPORT

Coal science and technology*

A sharp revival in coal research has taken place since the mid-1970s. Successful application of fundamental science and characterization techniques to the development of eco-friendly coal technologies will determine in future, suitability of Indian coals as primary energy source in a sustainable manner. In recent years, due to shift in paradigm, further insights into structural features of different coal varieties have been gained using advanced physical and instrumental techniques. Furthermore, coal petrology is of special importance, as the macerals present in coal have an important bearing and indeed affect the coal conversion processes one way or the other. However, not much work has been done, especially on Indian coals known for their different ash contents and varying mineralogy, as to how petrographic characteristics of coal will affect the end-use applications.

Keeping in view the gaps and problems in coal science and technology in the present scenario, a national seminar (COAL 2003) was hosted by Central Fuel Research Institute (CFRI), Dhanbad. The seminar was aimed to review the present status of related methodologies and techniques and their applications to address basic and industrial problems related to coal science and technologies. COAL 2003 was to address the following issues: (i) Degradation in coal quality, (ii) need for a cheaper and efficient beneficiation strategy, (iii) global threat of competitiveness, (iv) need to study the burning characteristics, combustion behaviour and efficient burner design for power plants, (v) application of petrographic techniques with modern tools, such as fluorescence and image-processing techniques, (vi) studies related to coal bed methane (CBM) reserve estimation and its utilization, (vii) environmental challenges, etc.

Over 225 delegates, representing coal scientists, technologists, planners, academicians and researchers attended the seminar.

*A report on the National Seminar on Coal Science and Technology – Vision-2020 (COAL 2003) held at Dhanbad during 20–21 April 2003 and hosted by the Central Fuel Research Institute.

The Hon'ble Union Minister for Coal, Karia Munda, inaugurated the seminar. Kalyan Sen (Chairman, Organizing Committee and Director, CFRI), delivered the Welcome Address. He emphasized that with the dwindling of our limited reserves of coking coal and the availability of poor quality, non-coking high ash coals for the future and in the present context of globalization and competitiveness, futuristic, relevant and need-oriented R&D programmes have to be undertaken. To achieve generation of basic knowledge, innovation and advanced concepts in fuel S&T for economically efficient and environmentally safe energy management, and to develop newer innovative technologies, deeper insight into the structure of different ranks of coal is needed. He stressed that to take India out of the shackles of the 'energy-starved' nation and to make it an 'energy-efficient' and self-reliant nation, concerted multidisciplinary and multi-institutional R&D programmes have to be urgently taken up and developed.

The inauguration was followed by scientific presentations distributed in six technical sessions: (i) Exploration – coal and CBM; (ii) Coal characterization and petrography – basic and applied; (iii) Coal beneficiation; (iv) Environmental issues and waste management; (v) Coal utilization (carbonization and carbon artifacts) and processes (combustion, gasification and conversion); and (vi) Business session for industry participants. Leading experts and researchers in the respective fields shared their experiences and discussed recent trends and developments.

Exploration: Coal and CBM

In this session, four invited lectures were delivered. S. K. Acharyya reviewed the coal exploration status and strategy of the country and indicated that resource position and environmental issues demand a balanced mix of underground and opencast mining practices in future. Further, exploration efforts should be made for blendable coking coal and superior-grade coal, beyond the traditional domain of the Damodar Basin. He also provided comprehensive account on CBM potentiality and noticed that CBM plays being basin-specific.

Subrato Sinha showed that all the three basic tenets of the coal industry – exploration, exploitation and environmental management are inextricably linked up, and the pace of coal production has influenced the coal-mining methods. Lack of proper environmental management, especially in the context of large-scale opencast mining, has caused serious land damage and loss of biodiversity. He traced the historical landmarks in the coal industry through its colonial, post-nationalization and the post-globalization phases and suggested that community participation in all possible stages of the industry, along with a proper mix of underground and surface mining, may be the only way to conserve some of our invaluable coal resources for the future.

N. N. Gautam presented the objectives of a national (UNDP–GEF) pilot project entitled 'CBM recovery and commercial utilization'. The project, under implementation at two sites in the Jharia Coalfield, aims to strengthen and increase capacity-building activities of some Indian institutions, plan and prepare for all activities, design, drill and produce CBM in advance of mining, demonstrate utilization of the gas recovered for mine vehicle refuelling and power generation, and establish CBM clearing house at Ranchi. Mohit Banerjee opined that two basic questions are needed to be answered, before a CBM project can be carried out successfully – (i) what is the size of the resource, and (ii) what is the producibility?

V. K. S. Visen *et al.* (Mineral Exploration Corporation Ltd. (MECL), Ranchi) presented a paper on advancement made in the bore-hole geophysical logging technology with the introduction of a digital logging system by MECL in the field of CBM exploration. Tiwari *et al.* (CFRI, Dhanbad) discussed the factors governing the activity and selectivity of the catalyst systems for conversion of methane to value-added chemicals. The conventional process for the conversion of CBM/natural gas to methanol and liquid hydrocarbons involves the reforming to

synthesis gas followed by catalytic conversion to methanol, which can further be transformed into a high octane gasoline through Mobil's methanol-to-gasoline technology.

V. A. Mendhe and A. K. Singh (Central Mining Research Institute (CMRI), Dhanbad), explained that gas contents vary both laterally and with depth in the Cambay Basin. Sorption capacity and gas content data suggested that samples are moderately saturated. Papers by B. C. Bhattacharya and D. Sarkar (Coal India Ltd) and G. R. Yenigalla (Singareni Collieries Company Ltd) enumerated the status of development of CBM in India in the background of the global scenario.

U. Chakrabarti and A. Roy (Geological Survey of India (GSI), Nagpur) concluded that there is no distinctive stratigraphic variation in the ash content between the coal seams of Sohagpur Gondwana Basin, indicating an overall similarity in depositional setting of coal beds through the Lower Permian Period. Singh *et al.* (CMRI) assessed the environmental impacts of coal mine fire in opencast workings of developed pillars and provided suitable suggestive measures for controlling and combating the intensity of the fire utilizing industrial wastes.

B. B. Sinha *et al.* (CFRI) presented the investigations carried out on a number of stacks prepared with different design parameters, like height, low angle slope, compaction with or without water, protection of stacks with inert materials (fly ash) for evaluating spontaneous combustion. A. K. Singh *et al.* (CFRI) made a thorough survey of the effect of mine fires in Jharia Coalfield and subsidence on economy and settlements and in depth analysis to suggest some remedial measures. U. K. Madan *et al.* (Indian Institute of Petroleum, Dehradun) while attempting abatement of fire hazards in underground coal-mines by the use of hydraulic fluids having fire resistant characteristics, described various types of FRHF, test conditions and procedures for their evaluation according the specification to avoid fire hazards in underground coal mines.

Coal characterization and petrography

In this session three invited lectures were delivered. Arabinda Ghosh described scope and capability of the assembled hardware – Auroview-2000, an optical image processing system developed to pursue petrographic analysis of coal. The software consists of two modules – analysis module (capable of producing modal % of macerals and minerals, besides measurement of rank (R_0) automatically or manually) and prediction module (capable of predicting ash and volatile matter % on dmmf-basis, and elemental carbon on pure coal basis). He opined that the overall performance of the system is satisfactory; however, development of a more user-friendly interface for commercializing the system is still lacking.

D. Chandra presented a comprehensive historical review of the basic work undertaken (by him during late 1950s and 60s) in the field of coal petrology. This included the relations between reflectance and carbon contents, optical properties and carbon contents of carbonized coals, and reflectance and temperature of carbonization; and results of experiments on oxidized and burnt-out coals. S. G. Chawdhuri highlighted the basic as well as applied aspects of coal petrography in general and its relation to coal characteristics and industrial behaviour with reference to coking and semi-coking Indian Gondwana coals.

H. K. Mishra and his team from the Central Mine Planning and Design Institute Ltd (Ranchi) presented a paper on characterization of Indian coal through petrographic image analysis technique, a system automated to accumulate petrographic data. They also discussed the application of petrographic study on coals of North Karanpura Coalfield and identified coals of good reactivity, suitable for combustion as well as for blends. Elaborate petrographical characterizations of coals were also presented from Kanhan Valley by M. P. Singh and R. R. Shukla (Banaras Hindu University, Varanasi), Ib-Valley by Sonali Guha and K. N. Singh (Vikram University, Ujjain), Talcher by A. K. Singh and M. P. Singh (BHU, Varanasi), West Daranggiri by S. Phukan and M. Ahmed (Gauhati University, Guwahati), and Makum by R. K. Sarmah (Dibrugarh University) and A. Ghosh (Jadavpur University) coalfields. B. K. Misra and B. D. Singh (Birbal Sahni Institute of Palaeobotany, Lucknow) reviewed the macerals of liptinite group in Indian coals and lignites and established that contrary to earlier view, they contain moderately to distinctly high amounts of these macerals.

The paper by N. K. Ghosh and K. N. Ghosh (Steel Authority of India Ltd (SAIL), Ranchi) indicated that quantity and degree of anisotropic carbon in the coke is responsible for its cold and hot strength, besides reactivity to CO_2. P. Sarkar *et al.* (CFRI) discussed the burning characteristics of Indian coal and its relation with petrographic characteristics. They concluded with the illustrated thermograms that coals of different petrographic composition behave differently under the same experimental condition of combustion.

A. K. Varma *et al.* (Indian School of Mines (ISM), Dhanbad), while discussing petrographic controls of coal combustion found that combustion efficiency decreases with increase in the rank. High-density chars are derived predominantly from the microlithotypes vitrinertite-I and inertite and, low-density chars are derived from vitrinertite-V and vitrite. A. K. Singh *et al.* (CFRI) emphasized that the study on the petrography of devolatilized coals and natural cokes of Jharia Coalfield is helpful to devise a new microstructural classification system for the natural cokes and its future industrial utilization.

S. K. Misra *et al.* (Regional Research Laboratory (RRL), Bhubaneshwar) discussed mineral petrography of Talcher coals, Orissa and its significance. Many trace elements present in coal undergo major change during combustion of the coal and lead to environmental pollution. This aspect from certain coalfields was covered by J. K. Mohanty *et al.* (RRL, Bhubaneshwar), S. Mukherjee and P. C. Borthakur (RRL, Jorhat), and Sonali Guha and K. N. Singh (Ujjain).

Coal beneficiation

In this session four invited lectures were arranged. R. K. Sachdev stressed the need for making regulations regarding safe use of coal, caring for the environment. He discussed some of the unresolved issues that need to be seriously addressed regarding washing of coal for power plants – making land available at the pit head, availability of railway siding facility, supply of raw coal on long-term basis under a proper 'fuel supply agreement', disposal of washery rejects in mined out areas, etc. He opined that unless these basic requirements are provided by the coal companies, the power plants are in a position to induce private washery developers to make investments under the

build–own–operate model, which is considered to be the most workable arrangement under the present circumstances, when coal companies have decided not to invest on coal washeries.

V. N. Misra reviewed the state-of-the-art of utilizing non-coking Indian coals in metallurgical industries and the prospects of beneficiation of these coals by advanced techniques to yield high-quality clean coal. S. Chattopadhyay expressed views regarding fly ash produced from improper beneficiated power-plant coal. B. N. Upadhyay expressed the need for modernization of coal washeries in India.

P. S. R. Reddy *et al.* (RRL, Bhubaneshwar) presented the prospects of dry beneficiation of non-coking coal, with suggestions to improve performance. P. C. Borthakur *et al.* (RRL, Jorhat) suggested removal of ash and sulphur from Makum (Assam) coals by wet-grinding of the coal in water medium alone or in the presence of a small dose of an anionic polyelectrolyte. P. Gogoi *et al.* (RRL, Jorhat) suggested removal of high sulphur from northeastern Indian coals using the oxidative desulphurization process.

L. Besra *et al.* (RRL, Bhubaneshwar) have evaluated how flocculation can be controlled from washery wastewater. They mentioned that regression equations have been developed as a function of flocculant dosage, settling time and time of stirring. In a talk on the effect of wetting and conditioning time on flotation of a low-volatile medium coking coal, M. Z. Ahmad and S. Bhattacharya (ISM) indicated that shorter the wetting and conditioning time, better were the flotation results.

S. K. Biswal *et al.* (RRL, Bhubaneshwar) suggested techniques of beneficiation of non-coking coal fines from Sponge Iron Plant using Flotation Column. S. V. Bagul *et al.* (CFRI, Nagpur) discussed the beneficiation possibility of non-coking coals below 34% of ash level to explore the possibility of reduction in ash content and to determine maximum yield of clean coal at this level of ash from the washability data of coals. The paper on flotation of non-coking coal using non-conventional collectors by B. Das *et al.* (RRL, Bhubaneshwar) attempted two oils (polang and mahua) as collectors on Talcher coals, and found potential to impart frothing effect and coat sufficiently on the surface of the coal particles. They have further indicated that these oils can be used as the flotation collector after due modification of the surface.

G. C. Srivastava and P. K. De (Bharat Coking Coal Ltd (BCCL)) highlighted the benefits of using beneficiated power coals in thermal power plants along with a case study for converting a coking coal washery into non-coking coal washery. P. Yerriswamy *et al.* (RRL, Bhopal) presented the results of Tri-Flo Separator treatment for Indian coking coals, which can achieve about 90% organic efficiency. K. Sen *et al.* (CFRI) discussed the impact assessment of coal quality for clean power generation and stressed the need for assessment of the environmental situation.

Environmental issues and waste management

Two invited lectures were delivered in this session. T. N. Singh reviewed the fire history in coal mines, mostly in coking coal seams, of Jharia Coalfield. The fires are concentrated in the northeasterly, highly populated portion of the field along the rim. He emphasized that nearly 6.19 km^2 residential area (with 12,450 houses/huts) required immediate rehabilitation. The impact of fire is being realized in the form of environmental pollution in addition to burning of valuable coking coal – a national asset with no substitute in India. P. K. Mishra discussed the problem of water pollution in coal mine areas and drew attention to an urgent need for abatement of water pollution as well as recycling of polluted water. He reasoned that wetlands can be exploited to check water pollution in the coal belt.

P. K. Singh *et al.* (CMRI) presented environmental issues related to coal-mining activities and also strategies adopted for environmental management. D. Shome and A. Ghosh (Kolkata) reported on the impact of coal mining on wastewater chemistry and state-of-the-art from North and South Karanpura coalfields. They showed that the concentration of toxic inorganics is much below the tolerance limit advocated by WHO. B. K. Saikia *et al.* (RRL, Jorhat), while discussing the release of trace and heavy metals from sub-bituminous northeast Indian coals, visualized that the presence of these elements in high-sulphur coals is found to exceed the recommended water quality levels. S. Kumar *et al.* (CMRI) explained how groundwater and water table get affected due to mining and suggested reuse of groundwater from the mine after proper treatment.

H. P. Deka Boruah *et al.* (RRL, Jorhat) explored the feasibility of legume cultivation on soil affected by effluents from coal mines in northeast India. Seed bacterization with some selected strains showed a decrease in toxic effect of coal-mine pollutants on French bean. A. K. Bharati *et al.* (CFRI) discussed the restoration of overburden dumps through the plantation of efficient photosynthetic/soil-conserving plant species and other suitable amendments. They observed that after plantation of selected species, the mine refuse has significantly improved with respect to physico-chemical/biological parameters, together with >90% survival rate of the plants.

Jha *et al.* (CFRI) indicated that ash-filled low-lying areas can be suitably reclaimed biologically (for social forestry purpose, apart from mitigation of CO_2 emitted from Thermal Power Plant), and ash leachates can be used for irrigation purpose. Tripathi *et al.* (CFRI) discussed the experimental results of microbial solubilization of Neyveli lignite into humic acid (quite effective in improving the properties of soil) at ambient temperature and pressure.

S. K. Roy *et al.* (CFRI) discussed the role of thermal power plants/automobiles, etc. in the increase of oxides of nitrogen. They suggested that oxides can be minimized by modification of the combustion process and by selective non-catalytic reduction and selective catalytic reduction technologies (i.e. ammonia slip system). A. K. Singh *et al.* (CMRI) studied the application of natural geotextiles and vegetative reclamation as an effective method for erosion control, stabilization and vegetation of mine overburden dumps. In another paper, Singh evaluated the controlling factors and impact of coal mining and allied industry on the water and sediment quality in the Damodar river basin, through heavy metal and trace elements discharge.

Carbonization and carbon artifacts/coal combustion, gasification and conversion

In this session four invited lectures were delivered. G. S. Natrajan highlighted the

role of granular activated carbon in wastewater treatment, drinking water improvement, and in the recovery of precious organic and inorganic materials from aqueous streams, generally from industrial streams. M. P. Singh dealt with the fundamentals of pulverized fuel combustion char morphologies and their relationship with the petrographic constituents of coal. He also projected the application of char morphology in assessing the reactivity of coal and the thermal efficiency of boilers.

K. Basu discussed processes of gasification and combustion, i.e. integrated gasification combined cycle and fluidized-bed combustion, which can utilize coals with higher efficiency and better environmental performance than conventional power plants. S. R. Gun emphasized the role of coal-liquefaction technology for supplementing oil needs in the country.

A. Parti and H. K. Chati (SAIL, Ranchi) coined a new performance parameter *Y*-to-*V* ratio (ratio of yield of primary by-product to volatile matter content) to quantify the performance of coke ovens and coal chemical plants on a macro level. S. Phukan and M. Ahmed (Guwahati) presented results on low-temperature carbonization of West Daranggiri coal to determine coke, tar, liquor, ammonia and gas yields. A. K. Sharma *et al.* (CFRI) suggested a substitute (high temperature coke-breeze) of standard silica sand, useful in caking-index determination. A. Gupta *et al.* (SAIL) presented a coal-blending model (CBM–RDCIS), which gives a least-cost coal blend, after considering various constraints like coal availability, minimum and maximum permitted coal uses, etc. P. P. Kumar *et al.* (Jindal Vijayanagar Steel Ltd, Bellary) defined the COREX process in which non-coking coals are used for heat generation, production of reduction gases and to maintain adequate bed-permeability.

K. K. Singh *et al.* (Tata Steel, Jamshedpur), while studying the effect of carbonization time on properties of coke, observed that increased carbonization time results in all-round improvement in coke characteristics. M. S. Sengupta *et al.* (SAIL, Ranchi) suggested selective crushing technology and blending of coal for steel plants. M. K. Sharma *et al.* (SAIL) suggested that use of 0.03% select transformer oil in the form of oil–water emulsion resulted in increase in bulk density of coal blend at the Bhilai Steel Plant. Improvement in bulk density with the use of diesel oil was found to be on the higher side. T. K. Mukherjee and A. Parti (SAIL) observed that during thermal analysis, coke gasification is rapid in flowing O_2 than in CO_2 atmosphere.

R. C. Borah and P. G. Rao (RRL, Jorhat) presented a mathematical model on coal devolatilization to predict and compute devolatilization time in a fluidized bed combustor. J. Roy *et al.* (CFRI) presented a method for the measurement of simulated adsorption–desorption of gases on active carbon/modified active carbon used in coal gas separation, by pressure swing adsorption technique.

S. Singh and M. K. N. Yenkie (CFRI, Nagpur) showed that the source material used for preparation of granular activated carbon (GAC) has significant effect on coal pore structure and adsorption capacity. D. Satapathy *et al.* (CFRI, Nagpur) discussed the scavenging of precious metal ions (nickel and copper) onto GAC from aqueous solutions. S. Alam *et al.* (of Hazaribagh with CFRI team) proposed a probable mechanism for low-temperature, cobalt-catalysed, water-vapour gasification of low-rank coals.

S. Biswas *et al.* (CFRI) presented a newly designed and constructed pulverized coal combustion facility – Drop Tube Furnace, which can provide information on combustion characteristics, carbon burnout, fly ash and bottom-ash properties. N. Choudhury *et al.* (CFRI) concluded that vitrite, inertite, vitrinertite-I and carbargillite microlithotypes produce chars of characteristic morphology. J. Mukherjee and G. Ghosh (CFRI) discussed the quantity of hydrogen in the volatile matter of a coal and indicated that coal which can eliminate 95% of its hydrogen during a thermal shock, has been categorized as the best flame-producing coal.

H. C. Das *et al.* (Oil India Ltd (OIL), Duliajan) discussed liquefaction of Assam coal, highlighting the process, quality of products and OIL's present plan to carry out coal-only processing study. G. S. Salvapathi and K. V. Ramanamurthy (Indian Institute of Chemical Technology, Hyderabad) evaluated the potential aromatic nature of Singareni coals to obtain value-added chemicals by fingerprinting. M. Nath and M. Ahmed (Gauhati University) explained the utilization prospects of Bapung coal, Meghalaya and found it suitable for steam-raising and gasification.

The seminar covered almost all aspects of Indian coal science, technology and planning. However, we still feel that to improve our understanding of the nature, formation (origin), quality (maceral composition–organic microconstituents), grade (rank or maturity) and other physico-chemical properties for the judicious and sustainable utilization of this solid fossil fuel and its associated methane gas (CBM), long-term experimental, analytical and observational investigations (with multidisciplinary approach) using conventional and most modern techniques are imperative.

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