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TRANSACTIONS

A Technical Publication of
The Mining, Geological and Metallurgical Institute of India

MGMI
Established 1906

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THE MINING, GEOLOGICAL AND METALLURGICAL INSTITUTE OF INDIA
Inaugurated 1906 - incorporated 1909 - as the Mining and Geological Institute of India, the word Metallurgical was included in the title in 1937.

Honorary Editor
BC Bhattacharya

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Foreword

TECHNICAL PAPERS

FOREWORD

In quest for development and prosperity, human civilisation has reached a crossroad whence we are uncertain to find our future course of action. Mining activity - essential for the prosperity of a nation, is always blamed for environmental degradation or disaster. Investigations & researches are going on all the time to choose the correct path of progress.

A small sample of the efforts of the esteemed members of the MGMI, as inspired by our President in his address, is presented in this humble publication. As tradition, Holland Memorial Lecture and the Foundation Day Lecture delivered by invited renowned personalities on two different occasions have also been included for the members to enjoy reading. Besides, the Transactions contain four technical papers presented by MGMI Member authors in two Ordinary General Meetings (OGMs), discussed and finally accepted for publication in the Transactions of the year.

In the Presidential Address, Shri AN Sahay observed that there is no substitute of fossil fuel in our country at least for next couple of decades. Even then the coal sector is not getting its due recognition for the hard job it is doing. On the contrary, it is being criticised for the negative impact like land degradation, environmental degradation and displacement of people. He rightly advised that the knowledgeable members of the MGMI should highlight the efforts being made by the coal sector for sustainable growth mitigating the above constraints judicially in totality. The President further suggested that mining of coal should be planned for higher depths as deep as 1200m and Coal blocks should be allocated keeping in mind the vertical expansion concept utilising global technology available for extraction at higher depth. This will need lesser land with lesser disturbance to the ecology as well as lesser displacement of people.

Prof H Gupta's illuminating Holland Memorial Lecture was a wonderful treatise on Artificial Water Reservoir induced seismicity with special emphasis on Koyna Dam (Satara district of Maharashtra), in the Western ghats region of India.

Prof VP Dimri, in his Foundation Day Lecture, suggested means of reducing global warming by injecting CO_2 (one of the major green-house-gases) in suitable geological formations acting as traps for the offending gas. The lecture brought out all details of the process including various uses of the locked up gas. Unfortunately, geo-sequestration of CO_2, being an unproductive activity, although it has benefits like enhanced oil recovery and CBM as well as mineral carbonation, the investors has not yet adopted it in a big way world-wide.

The excellent technical paper on Nanotechnology by Dr MSV Ramayya gives us a fairly comprehensive idea about the intricate workings of carbon atoms in cellular state. His suggested diversification, however, seems unlikely to have an appreciable impact for coal industry, since requirement of coal in manufacture of carbon nanotubes would be negligible.

The paper on beneficiation of inferior grade coking coal opens up a new vista on the possibility of utilization of low grade coking coal having suitable petrographic characters as determined by studies. Efficacy of universal application of the method is to be tested before industrial adoption.

Effect of naphthalene on reduction characteristics of iron ore nuggets using boiler grade coals have been painstakingly studied in the Jadavpur University by Dr Rajib Dey et al. Since the reduction is partial, industrial application is still not prevalent.

Dr TK Mallik's paper on marine geology may convey some information to an expert on the subject, however not very comprehensive for a general reader.

Bibhas C Bhattacharya
Hony. Editor

PRESIDENTIAL ADDRESS (110TH AGM)

AN Sahay*

My friends of MGMI & Ladies and Gentlemen,

I extend a warm welcome to all present here at the 110th Annual General Meeting of MGMI,a premier institute having a history of more than a century and convey my thanks to you all for showing confidence in me by electing President.

Strength of MGMI isthe available technical knowledge bank, which needs to become a contributing factor for sustainability of the energy sector of the country as there is no substitute of fossil fuel in our country at least for the next couple of decades. Even this being the fact, the mineral sector in general and the coal sector in particular are not getting their due recognition, rather are always being criticised for the negative impact like :

- Land degradation;
- Environmental degradation;
- Displacement etc.

But the constraints with which the sector is growing and the effort being put by each and every individual of this sector to overcome the same, needs to be highlighted by this institute. When we talk about the sustainability, we should look into it in totality.

Without the contribution of coal sector, sustainability in the energy sector or the country is always in question. Now, if this sector does not take pains even after being criticised and does not take measures for sustainability, the energy sector will not remain sustainable for next few decades or so. All of us present here should understand this aspect and advocate for the same.

There are some constraints for the sectoral growth of mining like :

- Environmental clearance
- Land acquisition
- Resettlement and rehabilitation
- Ecological restoration
- Social Impact

which need to be addressed by expert team of MGMI.

Energy sustainability of the country is directly dependent on sustainability of this sector and so is the sustainability of society and political stability of the country. We need to advocate this in all the forum/platform. We should further advocate the best use of land by extracting mineral upto 1200 metre depth instead of 200 to 300 metre i.e. the present depth of workings.

The exploration of our coal reserve isupto 1200 metre depth and our average mining depth currently is less than 300 metre. This is an area where introspection is urgently required. If available land mass is used upto greater depths as being done in countries abroad, we can ensure availability of fossil fuel for energy security of the country without much additional requirement of land. The emphasis should be on **vertical expansion** rather than **horizontal expansion**.

Extraction of mineral should be planned beyond 300 metre and upto 1200 metre depth which will solve the land requirement constraint to a great extent. Coal blocks should be allocated keeping in mind the vertical expansion concept. But for this we require to transfer the

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* Shri AN Sahay, President, MGMI & Former CMD, MCL

* 110th Annual General Meeting at Hotel Novotel, Kolkata on 20th September 2016

available state-of-the-art global technology for the extraction of minerals at higher depth. This will address sustainability of Energy sector to a great extent. The mining sector will have less negative impact on environment and land degradation and will ultimately bring social stability.

Weare always blamed for degradation of the ecology and environment. A model is already available in coal companies where ecological restoration is being done under the technical guidance of FRI, Dehradun as well as Delhi University and has emerged as a very successful model. If it is replicated in a big way after extraction of minerals we can recreate natural forest. This will rehabilitate the displaced forest dwellers.

It is a matter of pride that the quality and contents of the MGMI News Journal is being appreciated by the readers. I congratulate the News Journal team especially Shri B.C.Bhattacharyya, Hony. Editor for this and at the same time wish that more and more efforts are made to further improve and enrich the contents of the News Journal for the benefit of the readers and the members. Further, I am of the view that the observations made by the critics, if any, should also find a place in the Journal which ultimately will be a guiding path for improvement.

MGMI should work more on ecological restoration and use of surplus mine water model in the sector and we should establish our expertise in this field. MGMI team can work on the model further and make plan which can be patented for the mining sector in the country as a whole for the growth story to continue and be sustainable in the long range.

It has been observed that except 4 to 5 branches, most of MGMI branches have become nearly dormant. It has also been observed that some of the branches have been organizing activities in the name of MGMI, without any information to MGMI Headquarters. It has been felt that such activities, without the knowledge of MGMI Headquarters were not in the interest of MGMI. It is my desire that all the branches need to be reactivated and all the programmes conducted by the branches should be brought under the knowledge of the Headquarters. This would strengthen MGMI and its activities in a unified manner.

As it is the Annual General Meeting of MGMI and many senior members are present here, so, I take the opportunity of requesting them to kindly take some initiative to revamp the dormant branches.

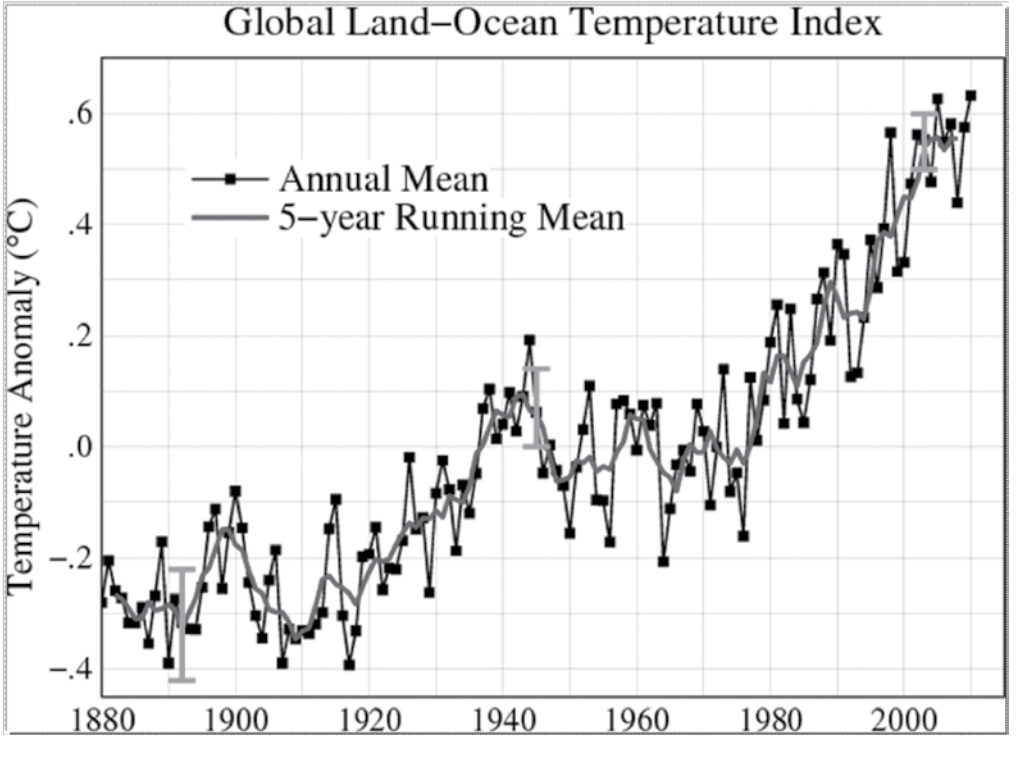
I am sure, you all present here will agree with me that with the knowledge bank and practical experience available with MGMI members and if we decide to use it, We can make a huge difference in the way Mineral sector is perceived by general mass.

REDUCING GLOBAL WARMING BY INJECTING CO_2 IN SUITABLE GEOLOGICAL FORMATIONS IN INDIA

Padmashri Prof (Dr) VP Dimri*

INTRODUCTION

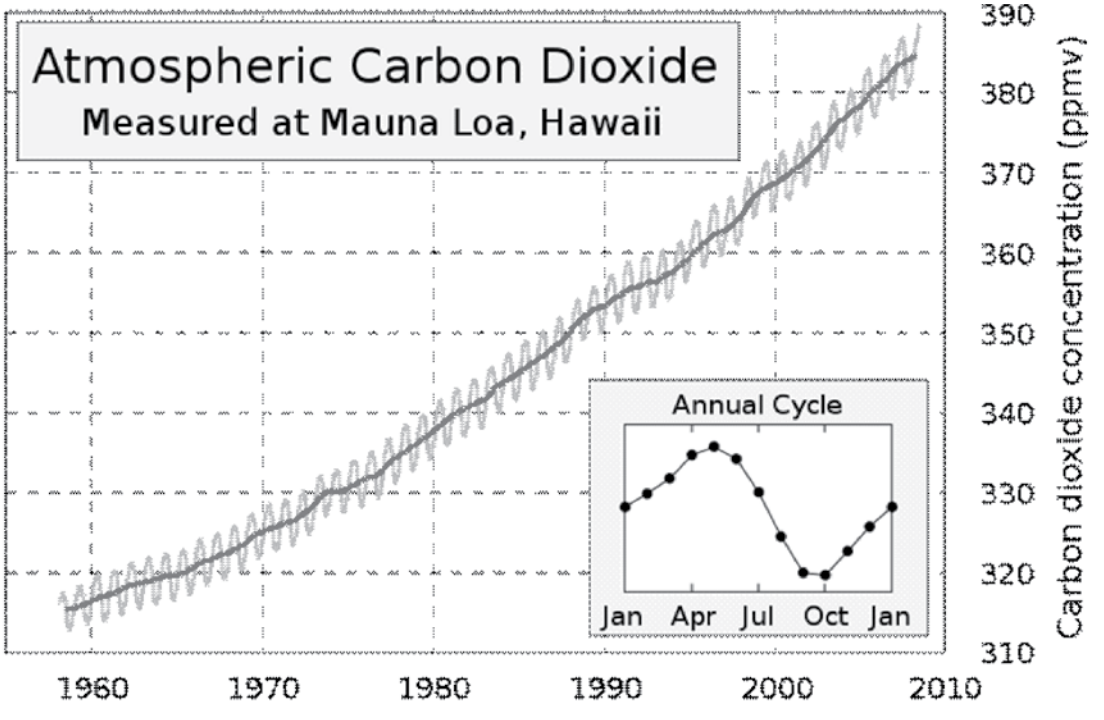
In the last 100 years, Earth's average surface temperature increased by about 0.8 °C with maximum increase occurring over just the last three decades.Most of the observed warming occurred during two periods, 1910 to 1945 and 1976 to 2000. A cooling or plateau was also observed from 1945 to 1976 which has been attributed to sulphate aerosol or a result of uncorrected instrumental biases in the sea surface temperature record.The Intergovernmental Panel on Climate Change (IPCC) stated in its Fourth Assessment Report that the temperature rise over the 100 year period from 1906–2005 was 0.74 °C with a confidence interval of 90%.For the last 50 years, the warming trend has been linear i.e. 0.13°C per decade. However, this abused CO2 principally considered as the main source of anthropogenic cause of global warming has several uses in ecosystem (e.g for the plants and oceans), however, in this address we will discuss some of its uses in energy sector, and its long term storage.



* Padmashri Prof Dr VP Dimri, Dr Homi Bhabha Chair Professor
* 15th Foundation Day Lecture at hotel, Hyatt Regency, Kolkata

CAUSES OF GLOBAL WARMING

There are many causes for global temperature rise like increase in greenhouse gas concentrations, changes in solar luminosity, volcanic eruptionsand variations in Earth's orbit around the Sun etc. However sudden rise in global temperature is mainly attributed to natural or anthropogenic factors causing increase in greenhouse gases concentration in the atmosphere. Out of the six green house gases accepted under Kyoto protocol, concentration of CO_2 in the atmosphere is highest; hence it is blamed for the global warming and climate change.



ATMOSPHERIC CO_2

Over the last 100 years, concentration of atmospheric Carbon dioxide (CO_2) has increased from about 280 ppm to 390 ppm and the majority of these additions have occurred in the last 50 years. Though the anthropogenic cause of rise in temperature due to increased CO_2 emission is highly debated but everyone accepts the rise in CO_2 concentration in the atmosphere.

The concentration of carbon dioxide in Earth's atmosphere is approximately 392 ppm by volume as of 2011 and rose by 2.0 ppm/yr during 2000–2009. 40 years earlier, the rise was only 0.9 ppm/yr. This shows a rapid acceleration of concentrations. The increase of concentration from pre-industrial concentrations of 280 ppm has almost doubled in just the last 33 years.

Natural sources of atmospheric carbon dioxide include volcanic outgassing, the combustion of organic matter, and the respiration processes of living aerobic organisms. Man-made

sources of carbon dioxide include the burning of fossil fuels for heating, power generation and transport, as well as some industrial processes such as cement making. CO_2 is also produced by various microorganisms from fermentation and cellular respiration.

Emission of CO_2 by natural sources is nearly balanced by natural sinks, the physical and biological processes which remove carbon dioxide from the atmosphere. For example, some part of emitted CO_2 is directly removed from the atmosphere by plants for photosynthesisand it is soluble in water (ocean) forming carbonic acid.There is a large natural flux of CO_2 into and out of the biosphere and oceans. In the pre-industrial era these fluxes were largely in balance. Even now about 57% of human-emitted CO_2 is removed by the biosphere and oceans.

In industrial era, burning fossil fuels such as coal and petroleum is the leading cause of increased anthropogenic CO_2 and deforestation is the second major cause. In 2008, 8.67 gigatonnes of carbon (31.8 gigatonnes of CO_2) were released from fossil fuels worldwide, compared to 6.14 gigatonnes in 1990. In the period 1751 to 1900 about 12 gigatonnes of carbon were released as carbon dioxide to the atmosphere from burning of fossil fuels, whereas from 1901 to 2008 the figure was about 334 gigatonnes. This addition is sufficient to exceed the balancing effect of sinks. As a result, carbon dioxide has gradually accumulated in the atmosphere, and as of 2009, its concentration is 39% above pre-industrial levels.

MAJOR EFFECTS OF GLOBAL WARMING AND CLIMATE CHANGE

- Changes in agricultural yields
- Sea level rise
- Increase of intensity of extreme weather events
- Changes in precipitation pattern & amount
- Mass species extinction
- Effects on Glaciers
- Changes in the timing of seasonal patterns in ecosystems
- Other effects of economic importance

Out of the various techniques proposed for removing excess carbon dioxide from the atmosphere, geo-sequestration is the most important and feasible one. This process describes long-term storage of carbon dioxide or other forms of carbon in suitable geological formations.

POSSIBLE GEOLOGICAL FORMATIONS

There could be several possible traps for efficient CO_2 storage, however a few known traps are :

- Abandoned hydrocarbon reservoirs
- Old oil fields, for enhanced oil recovery
- Saline Reservoirs
- Non-economic coal seams or deep coal seams (CBM)
- Shale formations
- Basalt formations

OPTIONS FOR UTILITY OF CO_2

Potential use of CO_2 can be in the following areas to meet the growing demand of energy and the excess amount can be sequestered permanently to form mineral carbonates :

- Enhanced Oil Recovery (EOR)
- Coal Bed Methane (CBM)
- Mineral Carbonation

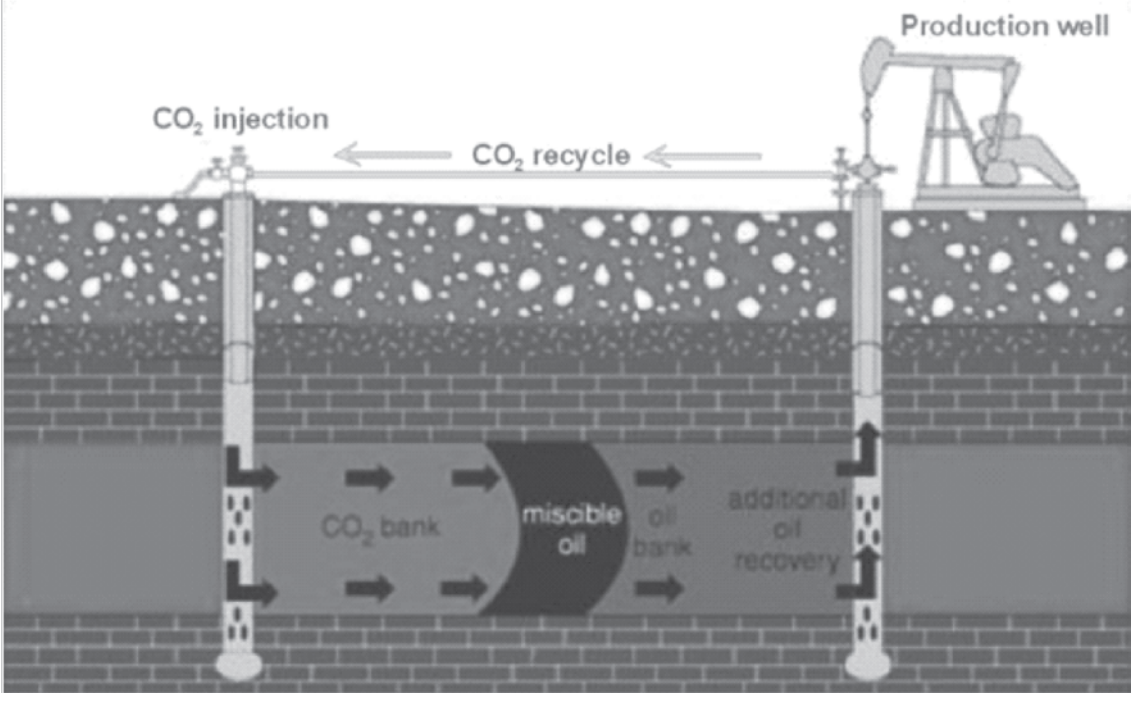
In the following section a brief use of CO_2 for enhanced oil recovery is given. NGRI has an ambitious project on CO_2 – EOR in collaboration with SINTEF, Petroleum Research, Norway

to study the possibility of CO_2 – EOR from a mature land oil field operated by Oil and Natural Gas Corporation (ONGC).

ENHANCED OIL RECOVERY

Carbon dioxide injection in depleting reservoir serves two purposes, one to reduce CO2 from atmosphere and other to enhance oil recovery from declining oil fields.

It is observed that chemical properties of the CO_2 are very good to push the oil forward. This is because CO_2 is miscible with the lighter hydrocarbons in some cases, depending on minimum miscibility pressure. Immiscible CO_2 also has very good sweep efficiency. This works on the same principle what we know that to clean oil from our hands, water will get a little of the oil off, soap and water will do a better job, but a solventwill clean the oil entirely. This is because a solvent can mix with the oil, form a homogeneous mixture, and carry the oil away.

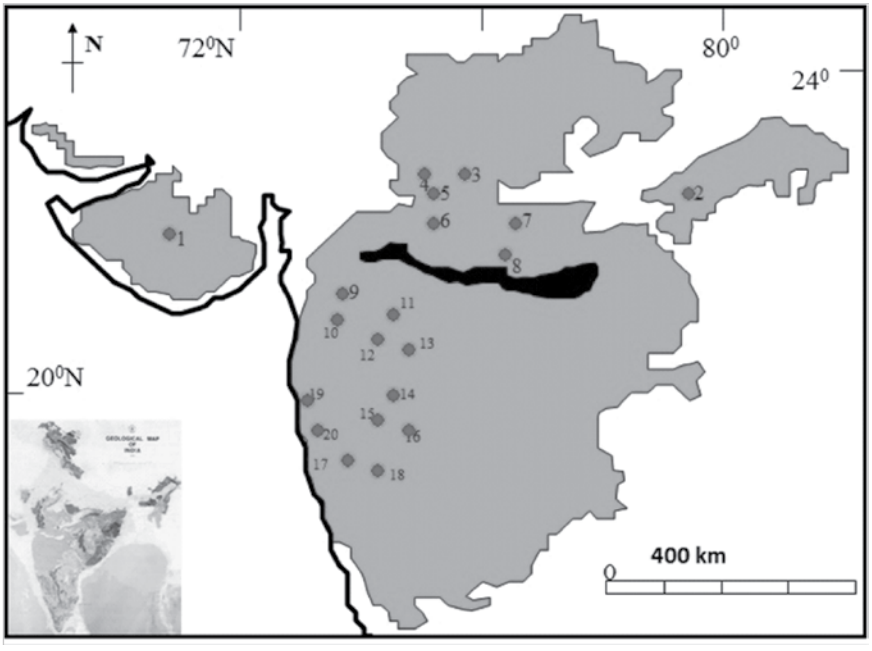


BASALT FORMATION

The Deccan Volcanic Province (DVP) of western India is one of the great igneous provinces on Earth. Vast amounts of basalts erupted some 65 Ma years ago at the Upper Cretaceous-Tertiary (K-T) boundary, commonly believed to be due to the northward passage of the Indian plate over the Reunion hotspot. The basaltic layers (traps) cover an area of approx. 500 000 km2 of the Indian peninsular shield, reaching average thicknesses of several hundred metres up to 2 km. CO_2 can be injected into intra-trapians of DVP. Another attractive alternate zone is in the Mesozoic sediments below DVP.

ADAPTATION AND MITIGATION FOR CLIMATE CHANGE

Climate change mitigation involves reductions in the concentrations of greenhouse gases,



either by reducing their sources or by increasing their sinks. Thus, geo-sequestration of CO_2 comes under climate change mitigation which may combat climate change but it will take several years of time to come into effect. Another strategy to combat climate change is adaptation of the practices which reduce carbon emissions; viz. efficient light lamps, green buildings, less use of individual motor vehicles and more of mass transport, tapping of the CO_2 emissions from the factories right at the source for processing and further sequestration etc. to reduce the vulnerability of natural and human systems to climate change effects.

Even if emissions are stabilized relatively soon because of mitigation processes, climate change and its effects will last many years, and in any case adaptation will be necessary specially in developing world. According to IPCC, adaptive capacity of a country is closely linked to social and economic development and adaptation to the climate change will be more difficult for larger magnitudes of climate change.

CONCLUSIONS

Carbon dioxide sequestration serves two purposes, one to reduce CO_2 from atmosphere and other to enhance oil recovery from brown oil fields.

We can reduce the CO_2 emissions to save the environment by

- Tree plantation
- Using energy saving devices e.g use of CFL
- Using mass transport
- Harnessing solar, wind and geothermalenergy
- Harnessing hydroelectric power
- Nuclear energy

All these measures of mitigation of Global warming must be implemented from individual to national and international level. For this common man should be made aware of effects of global warming.

59TH HOLLAND MEMORIAL LECTURE

Padmashri Prof Harsh Gupta*

INTRODUCTION

Artificial water reservoirs are created worldwidefor flood control, irrigation and power generation. Reservoir triggered seismicity (RTS) is an anthropogenic effect of filling large artificial water reservoirs. The first scientifically accepted case of RTS is from Lake Mead in USA in 1945. Over the years many more cases of RTS have been reported. At present there are over 120 sites globally where RTS has occurred. Damaging earthquakes exceeding magnitude 6 have occurred at Hsingfenkiang, China (1962); Kariba, Zambia-Zimbabwe border (1963); Kremasta, Greece (1966) and Koyna, India (1967). The Koyna RTS event of M 6.3 that occurred on December 10, 1967 is so far the largest RTS event globally. There were ~ 200 human lives lost, thousands got injured and the Koyna Township was in shambles. In the recent years there has been a controversy whether the Mw 7.9 Wenchuan earthquake of May 12, 2008 in China that claimed an estimated 80,000 human lives was triggered by the nearby Zipingpu reservoir.

The occurrence and the level of RTS have been associated with a number of factors. First of all, the site of the potential RTS should be stressed close to critical, where a normal earthquake would have occurred at some time in the future. The loading of the reservoir influences the mechanical properties of the media and increases heterogeneity. This helps in releasing the accumulated strains in piecemeal, resulting in a number of smaller earthquakes. The factors that control the level of RTS include the rate of loading, the highest water levels reached, and the duration of retention of high water levels. In many cases of RTS bigger earthquakes are triggered when the previous water maxima in the reservoir is exceeded (Kaiser effect). The role of reservoir loading and the influence of pore fluid in causing RTS have been deliberated in detail. There has been a considerable advance in comprehending the role of individual factors in triggering earthquakes due to an artificial water reservoir. However, an integrated model of RTS is still to be realized.

Koyna is located near the west coast of India in the ~ 65 Ma old flood basalt terrains, also known as Deccan Traps and is the most significant site of RTS in the world. ShivajiSagar Lake created by the Koyna Dam was impounded in 1962 and the triggered earthquakes started soon after. The first triggered earthquake exceeding magnitude 5 occurred on September 13, 1967. And then on December 10, 1967 the M 6.3 earthquake occurred. There was a further impetus to RTS in the region when the nearbyWarna Reservoir was impounded in 1985. Over the years 22 earthquakes of M> = 5, some 200 earthquakes of M > = 4 and several thousand smaller earthquakes have occurred in the region. The focal depth estimates were not accurate till 2005 as only a few seismic stations operated in the region. Earthquakes are by and large deeper near the Koyna reservoir and shallower as we move south. There is a very strong correlation between the water levels in the Koyna and Warna reservoirs and the level of RTS. Every year, the reservoirs get filled and the water level peaks during the period end of July and beginning of August soon after the monsoons. The seismic activity is most pronounced in the months of November and December, a few weeks after the peak levels are reached. The other spurts of RTS occur in the month of August following the rapid rise in water level,

* Padmashri Prof Harsa Gupta, NGRI, Hyderabad, Member AERB and President, Geological Society of India

and again in months of April and May related with the emptying of the reservoir.

The Council of Scientific and Industrial Research (CSIR) - National Geophysical Research Institute (NGRI) has been operating 10 digital seismograph stations in the Koyna region since August 2005, a near real time monitoring of seismicity in Koyna region started with the data being transmitted to CSIR-NGRI through V-Sat. It was observed that earthquakes of M ~ 4 in the Koyna region are usually preceded by a well- defined nucleation. Identification of this nucleation in real time has led to short term earthquake forecast and 8 M ~ 4 earthquakes have been accurately forecast. It must be mentioned that no wrong forecast was made. With the passage of time, a general shift of seismicity toward south is noticed. Focal mechanism of the earthquakes in the region has been inferred from moment-tensor studies. It has been found that the earthquakes in the vicinity of Koyna have a dominating strike slip component, whereas those in the vicinity of Warna reservoir are purely normal type. Focal depths are mostly in 2 to 10 km in the Koyna region, which shoals to 1 to 5 km in the Warna region.

Koyna is a very unique region as earthquakes occur in a small area of 30 km x 20 km, are shallow (mostly 2 to 7 km deep) and there is no other source of earthquakes within 50 km of the Koyna Dam. The region is very accessible for carrying out all kinds of field studies and instrumentation. In a detailed study, it was inferred that the region was stressed close to critical before the impoundment of the Koyna Dam, and it was capable of hosting an M 6.8 earthquake. Filling of the reservoir(s) increased the heterogeneity of the media and energy began to be released in smaller events. The total energy released so far is ~ 60% of an M 6.8 earthquake. It was further postulated that the activity shall continue for another two decades or so. The occurrence of M ~ 5 earthquakes would be controlled by the factors like rate of loading, maximum water levels reached, duration of retention of high water levels and the fact whether the previous reservoir level maxima has been exceeded or not. It was noticed that no M ~ 5 earthquake epicenter has repeated. It appears that there is no fault of ~ 10 km length left intact in the region to host another M 6.3 earthquake like that of December 10, 1967. All these facts make Koyna an ideal site to carry out detailed studies, including near field source studies to comprehend the genesis of RTS. This led to submitting a proposal to the International Continental Drilling Program (ICDP;http://www.icdp-online.org/home/) to hold a workshop to examine the suitability of the Koyna site for scientific deep drilling and setting up of a deep borehole observatory to study critical parameters in the near field of the earthquakes.

A very successful ICDP workshop was held from 21- 25 March 2011 at CSIR-NGRI, where participants came with experience of San Andreas Fault Observatory at Depth (SAFOD), California; Chelungpu Fault Drilling Project in Taiwan; Nojima Fault Drilling in Japan Gulf of Cornith in Greece; and the Latur fault drilling in India.There were 26 participants from outside India (Canada, France, Germany, Italy, Japan, New Zealand, Poland, Taiwan, and the USA) and 50 from India. There was a unanimous agreement that Koyna is an outstanding geological site to set up a deep borehole observatory to study earthquakes in near field and comprehend the genesis of RTS. A number of suggestions, such as compiling of all the available data, improving the locations of the earthquakes, detailed airborne gravity and magnetic studies, magnetotelluric (MT) surveys, LiDAR and study of hydraulic connectivity through 4 boreholes penetrating the basalt cover and going a couple of hundred meters into the basement were made. Detailed

investigations covering these suggestions were carried out during the period 2011 to 2014 and the second ICDP workshop was held from 18 to 20 May 2014 at Koyna. There were 49 participants in the second workshop, 37 from India and 12 from Canada, Germany, Japan, New Zealand, Norway, Spain and the USA. The results of the work carried out since the first work-shop were discussed, and the following questions were addressed (several of these questions are taken from the SAFOD program) :

1. What is the 3-D/4-D nature of the fault zones?
2. How do stress orientation and magnitude vary across fault zones?
3. How do earthquakes nucleate?
4. How do earthquake ruptures propagate?
5. How do earthquake source parameters scale with magnitude and depth?
6. What is the role of water reservoirs in triggering earthquakes?
7. What is the fluid pressure and permeability within and adjacent to the fault zones and influence on stress changes?
8. What are the composition and origin of fault-zone fluids and gases?

CONFIGURATION OF THE DONACHIWADA FAULT BOREHOLE SEISMOLOGY

Several fault zones have been equipped with borehole seismometers for precise location of earthquakes. Such deployments provide high quality recording of seismic events in near field. After the occurrence of the disastrous Kobe earthquake of 1985, the Nojima fault in Japan was one of the earliest to have such instrumentation. The strike – slip San Andreas fault in California; the Chelungpu thrust fault in Taiwan are some other successful examples of such deployments. The accuracies in the locations of earthquakes have been limited in view of the inaccessibility of the main seismic zone of the Koyna region, being under reserve forest zone. A unique program of scientific drilling in this region is undertaken to set up seismometers within the granitic basement, surrounding the seismic zone. 9 cored boreholes have been drilled with a good azimuthal coverage of the seismic zone and as of now, 6 borehole seismometers have been successfully installed at the bottom of the six borehole locations and data are getting recorded continuously. The borehole seismic stations are equipped with velocity-type (4.5 Hz) three component seismometers placed at the bottom of each borehole with the Reftek recording system on the surface connected through cables. The depths of these boreholes are varying from 981 m – 1522 m. Two more borehole seismometers are to be installed in near future.

The main idea was to eliminate the noise due to overlying basalt cover of the study region. As envisioned, the borehole seismometers are providing quality data that permits to detect even smaller earthquakes of magnitude – 0.1M. The absolute locations of earthquakes using the dense broad-band seismic network comprising of 20 surface seismic stations provide accuracies up to ±600 m. With the addition of the 6 borehole seismic stations, these accuracies have been improved to ±300 m.The errors in the estimation of arrival times have been reduced to about 60% in the borehole records. It is foreseen that the proposed deployment of an array of seismometers in the upcoming pilot borehole will provide the accuracies of a few tens of meters in the locations of earthquakes to be able to demarcate the fault geometry better. Since it is not possible to place the borehole seismometers at the bottom of the borehole

with desired orientation of the horizontal components, amplitudes of P waves were used to decipher the true orientations after installation. Theoretically, if the two orthogonal horizontal components of a seismograph are deployed in true geographical N-S and E-W directions, and an event occurs due south of the seismograph location, the 'P' wave amplitude would be maximum on the N-S component and minimum on the E-W component. This fact is used to determine the true orientation of the seismographs after their installation. Accordingly, the deviation of the north-south horizontal component of the seismometers with respect to true/geographic north has been estimated of all the borehole seismic stations.

PLAN FOR DEEP DRILLING

To comprehend the genesis of reservoir triggered seismicity in the region, the lack of information on the physical properties of rocks and fluids in the fault zones and how they affect the build-up of stress over extended periods of time in the near-field presents a critical information gap. To address this issue, it is proposed to undertake scientific deep drilling and set up an observatory at a depth of about 5 km to study pre-seismic, co-seismic and post-seismic changes in physical, chemical and mechanical properties in the near field of earthquakes. Deep drilling is being undertaken in two phases. In the pilot phase, drilling is planned to a depth of 3000 m at two sites in the Koyna seismic zone, one of which is to be located within a few km of the KBH-7 site and the Donachiwada fault zone. A suite of in-situ and laboratory measurements will be carried out to understand the physical and mechanical behaviour of rock in the vicinity of the earthquake source zone. Repeat geophysical and hydrological measurements are planned in one of the boreholes to study temporal changes associated with earthquake occurrences. The thickness of Deccan flood basalt pile, constrained by data from the nearby KBH-7 borehole, is estimated to be in the range 1200-1300 m. The borehole configuration incorporates an industry-standard drilling and casing policy with the option to have an open well section below 1500 m depth.

The second borehole (location being finalized) will house a dedicated, multi-level seismometer array to monitor the micro-seismic activity in the vicinity of the fault(s) under low-noise conditions. The enhanced signal-to-noise ratio is likely to significantly improve the detection threshold of micro-seismic events and their focal parameters. Data from this installation, together with those from exploratory borehole seismometers, would be analysed to delineate the subsurface fault(s) and constrain their geometry as precisely as possible.

The pilot boreholes will be followed by a 5000 m deep borehole to set up a fault zone observatory at depth. The maximum depth of the borehole is constrained from analysis of broadband seismic data, which indicates the possibility of reaching the hypocentral region of the $M \geq 2$ earthquakes within a depth of about 5 km. Accurate information of the subsurface fault geometries including their orientation and dips are critically required to steer the deep borehole to reach the vicinity of active fault(s). The trajectory of this borehole would, therefore, be guided by the seismic data from the pilot phase. The design for drilling and instrumentation are based on a maximum temperature of 150oC, as estimated from precise heat flow determination and rock thermal properties measurements and laboratory measurements of physical properties. The borehole will be cased and cemented for carrying out measurements and monitoring for several years.

The deep borehole observatory will comprise a suite of instruments and sensors installed

inside the borehole. Potential installations include (i) arrays of 3-component geophones and deformation sensors at different levels, (ii) pore pressure transducers, (iii) temperature sensors and (iv) gas/fluid testing equipment. Monitoring of several parameters will be continued for a number of years after completion of drilling and instrumentation. Analysis of the near-field data sets and constrained modeling studies may lead to a better understanding of the genesis of reservoir triggered earthquakes.

The scientific deep drilling project will generate new information and knowledge about artificial water reservoir triggered seismicity within an intraplate setting, and complement the other active fault zone drilling projects elsewhere, e.g., SAFOD (USA), Nojima fault (Japan), NanTroSEIZE (Japan), Chelungpu fault (Taiwan), Gulf of Corinth (Greece) and the GONAF (Turkey). Additionally, the multi-disciplinary geological, geophysical and seismological datasets may shed new light on the Deccan volcanism, the tectonics of the Western Ghats and the geodynamic evolution of the western continental margin of India.

CONCLUDING REMARKS

i. RTS at Koyna, near the west coast of India, started soon after the impoundment of the reservoir in 1962 and it is continuing. There is a correspondence between the water levels in the reservoir and RTS events. The role of reservoir in inducing RTS is not well understood.

ii. Koyna, where RTS is confined to a small area of 30 km x 20 km, the focal depths are mostly between 2 and 7 km, there is no other source of seismic activity within 50 km of the Koyna Dam and the region is accessible for observations; is an ideal site for setting up of a deep bore hole laboratory for near field investigations of earthquakes.

iii. Although the surface topography is highly undulating, the basement is about 300 m below the present sea level and more or less flat on the plateau side. There are no sediments below the basalt cover, and it lies directly on the basement granitoids, which are highly fractured and crushed at multiple depths with evidence of shear movement.

iv. The Magneto-telluric (MT) surveys have provided the basalt-basement contact at each location. There is a direct correspondence between the resistivity as inferred from MT observations and weak zones. One of the boreholes (Udgiri), located on a weak zone as inferred from MT observations, encountered very fractured strata.

v. The magnetic anomaly map brings out NW-SE and E-W positive anomalies in the region between the Koyna and Warna reservoirs. The sharp gradients in density contrasts in the 3D model correspond to resistivity changes derived from MT data. The density values from direct logging independently corroborate the densities used in the 3D model and resistivity values used in MT model.

vi. Measurements of borehole temperature profiles and conductivity of rocks show that the temperatures at a depth of 6 km shall not exceed 150 C.

vii. The qualitative evaluation of the well logs from the Koyna-Warna boreholes underscores the differences in physical parameters of the basalts and granite-

gneiss basement in each borehole, indicative of the heterogeneity of the Koyna-Warna seismic zone. The well log data from the boreholes to the west of the WGE consistently show higher degrees of deviations, which may be explained as signatures of tectonic disturbances associated with the formation of the WGE.

viii. Geological/geophysical logging in the 8 bore holes penetrating the basalt cover and going a few hundred meters in to the basement has provided very useful information. Structural logging has revealed the presence of the prominent faults aligned NE-SW and E-W with high and low angle dips respectively, dip direction being west and south. Foliation planes are aligned primarily in the NW-SE direction, with high angle westerly dips; the strike direction is same as regional features such as the Kurduwadi lineament. The fractures are dominantly N-S with lower dip angles commonly to the east. It may be inferred that the genesis of the three types of features are attributable to different processes.

ix. With the operation of the 6 borehole seismometers at depths of ~ 1500 m, earthquakes of M 0.5 are located without failure in the region. The focal parameter errors have been reduced from ~ 600 m to 300 m. A much more pronounced effect of rate of emptying of the Koyna and Warna reservoirs during 2015 on RTS is noticed. The high precision earthquake clusters of M 0.5 – 3.0 are invariably located in the high altitude region bordering the WGE.

x. The Bare Earth Model developed using LiDAR has made it possible to identify surface features, which were not clearly seen earlier. Surface manifestations of the Donachiwada fault, which hosted the M 6.3 Koyna earthquake of December 10, 1967 is depicted.

xi. From among the 5 locations originally considered for putting the pilot bore hole, the one lying south of the Koyna Dam, in the vicinity of the Donachiwada fault and site of exploratory borehole KBH-7 and outside the reserve forest cover has been identified for the first of the two pilot boreholes.

xii. A first order plan of scientific drilling and instrumentation of the pilot borehole has been prepared. The drilling for the pilot bore has been contracted and spudding is scheduled in the late 2016.

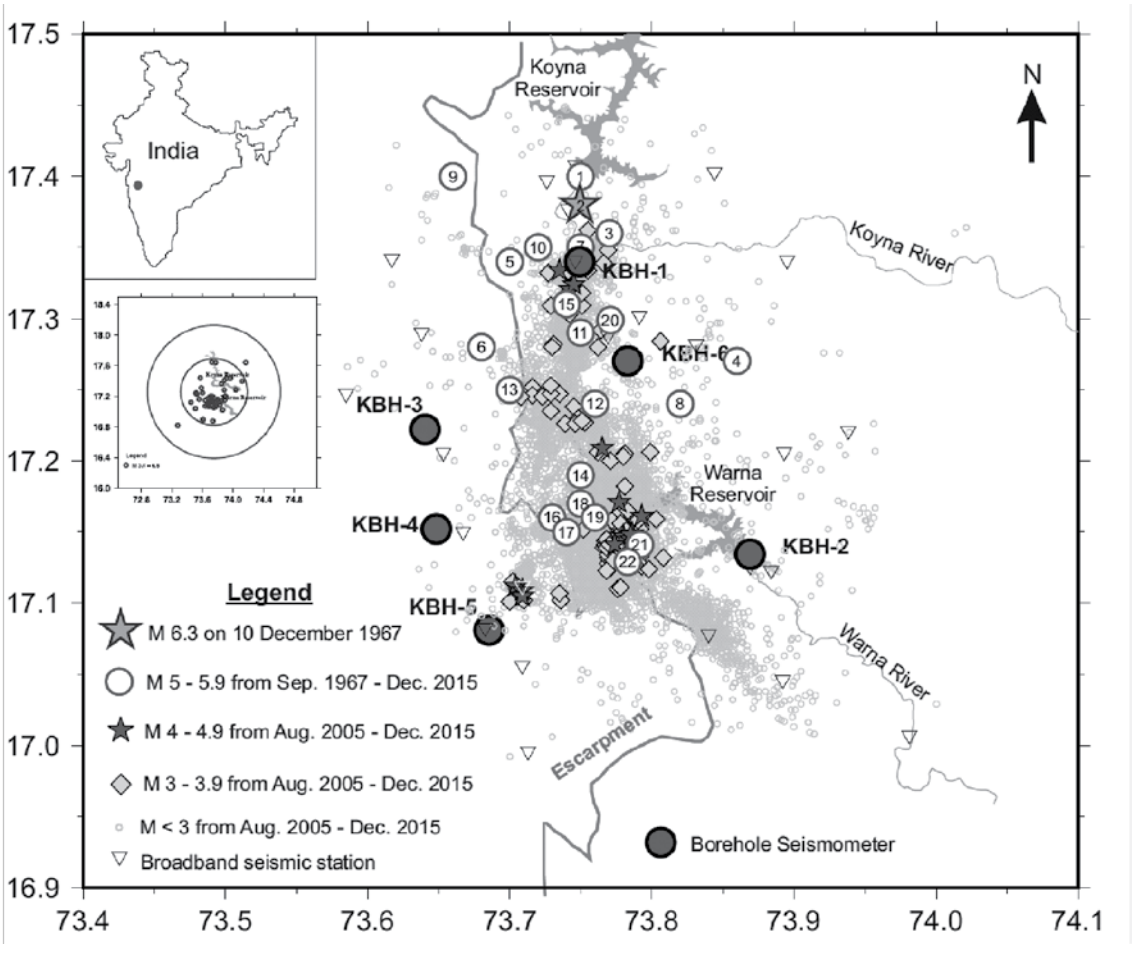


Figure 1 : Map of the Koyna-Warna region showing the locations of the 1967 main shock, M≥5 earthquakes since September 1967 and M<5 earthquakes during Aug 2005 - Dec 2015. Numbers, 1 to 22, inside circles show the chronological order of occurrence of the M≥5 events. The network of borehole and surface seismic stations is shown. The thick curve indicates the Western Ghat Escarpment (WGE) feature. Inset (I) location of Koyna on the outline map of India. Inset (II) shows the distribution of earthquakes of M≥ 3.7 during 1967- 2015 (USGS) in the vicinity of Koyna-Warna region and outer circle of 100km radius which shows there is almost no seismic activity outside the Koyna-Warna region.

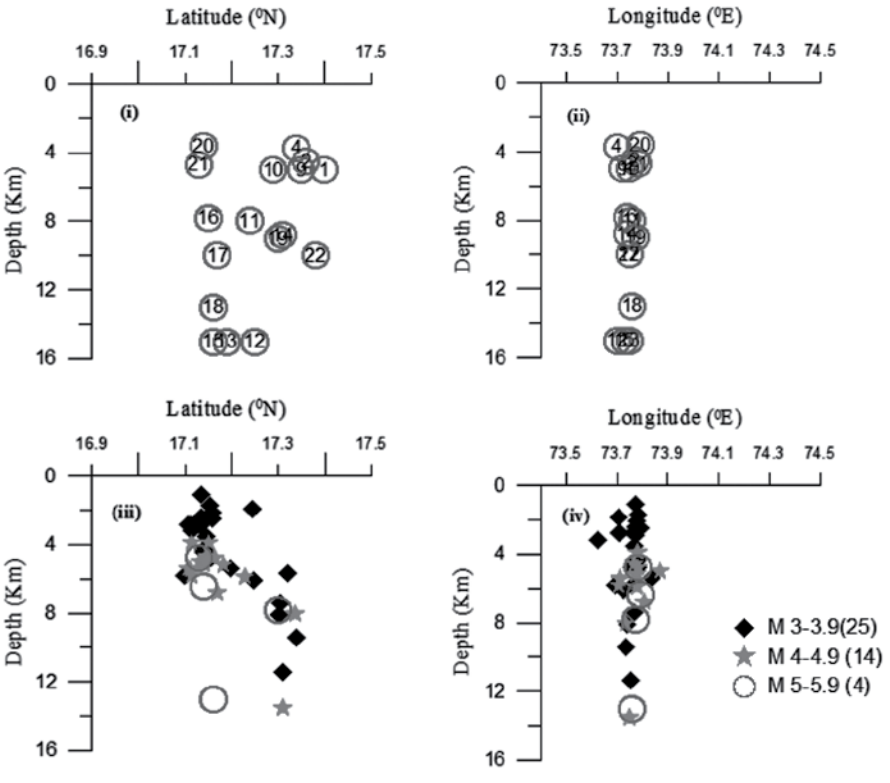


Figure 2 : Depth sections of earthquakes of M ≥ 5.0 as shown in Figure 1 along (i) Latitude; (ii) Longitude. Also depth sections of earthquakes of M ≥ 3.5 are plotted along (iii) Latitude and (iv) Longitude. The symbols are as in Figure 1.

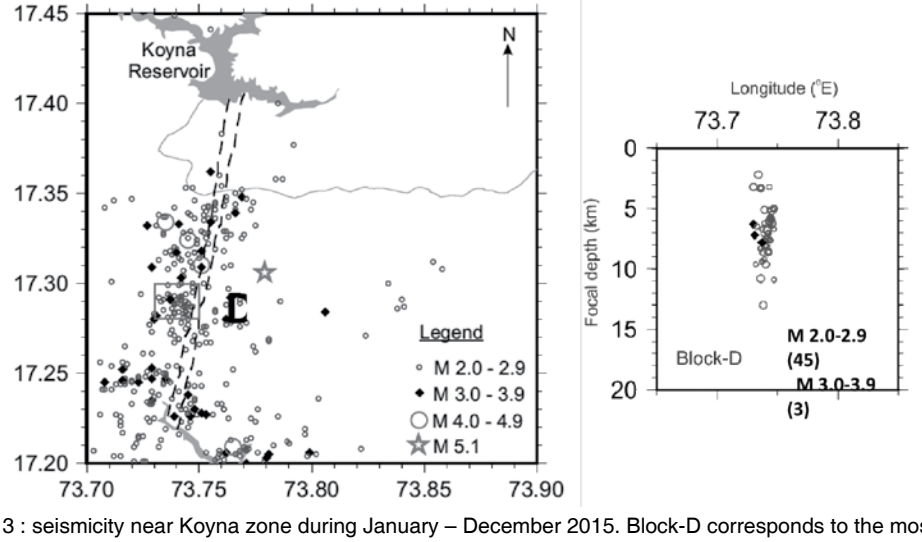


Figure 3 : seismicity near Koyna zone during January – December 2015. Block-D corresponds to the most active site in terms of repeated earthquakes and identified for the next phase of scientific drilling or pilot borehole studies. Lines (black) indicate the Donachiwada fault zone. (b) The focal depth section of earthquakes of Block-D is shown.

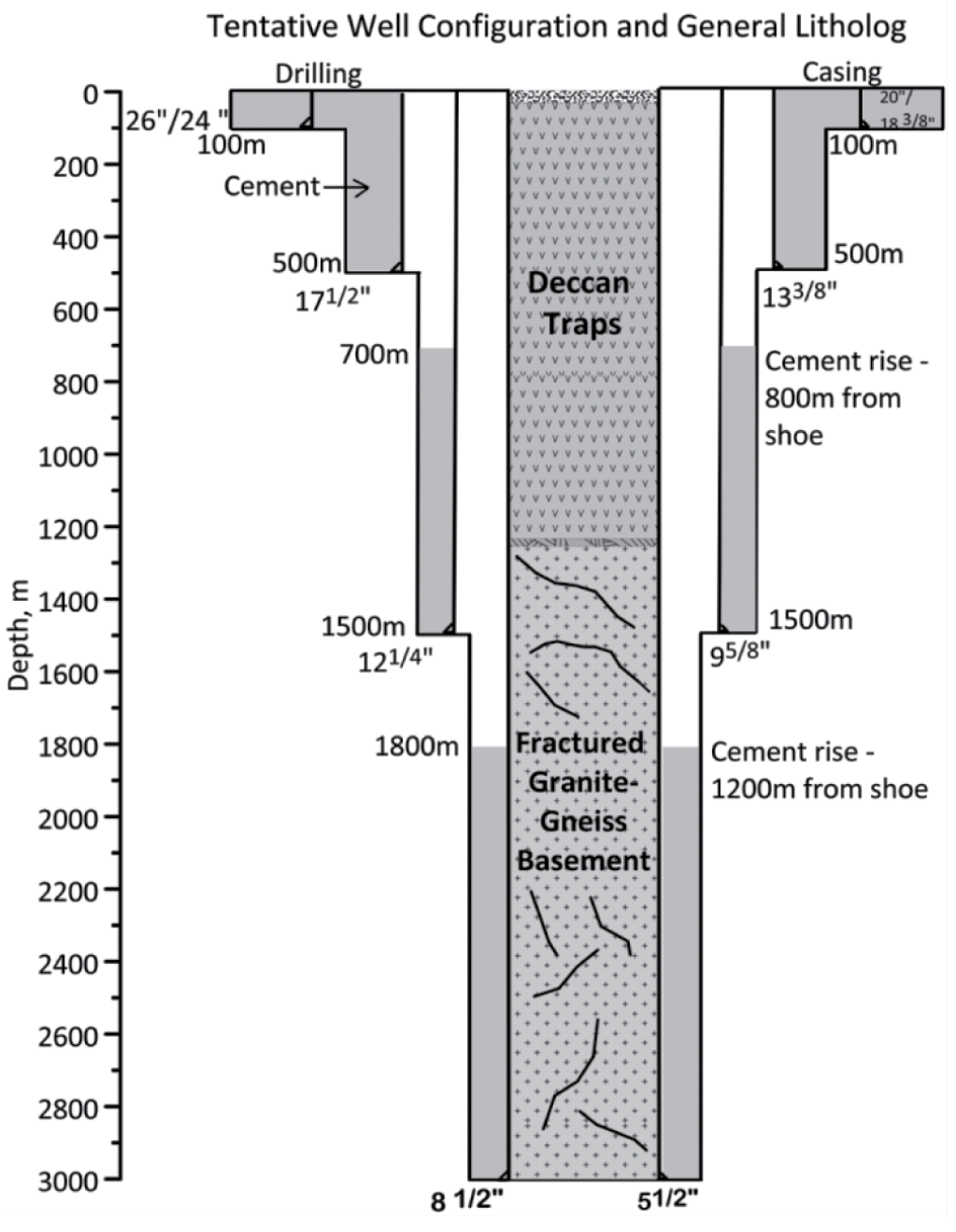


Figure 4 : Generalised configuration of the 3000m – deep pilot borehole showing the tentative drilling and casing policy. The borehole is likely to pass through 1200-1300 m of Deccan flood basalt underlain directly by Precambrian granite-gneiss.

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BRIEF BACKGROUND ON MARINE GEOLOGICAL WORK DURING LAST 50 YEARS

Dr TK Mallik*

INTRODUCTION

WHY STUDY THE SEA AND THE COASTAL ZONE

Earth's history is linked with the coastal zone and the sea. Through the coastal tracts the Sea is receiving sediments which records the history of geological events Episodic physical events like sea level rise, coastal erosion, changing weather pattern, storm surges, cyclones, Tsunamis affect the coast quite often.

Initially marine geology and biology became increasingly applied to the study of the potential of the seabed. This is evidenced by large scale surveys that has been conducted for manganese nodules and the plans to exploit the metalliferous Red sea deposits and the interest in the deep sea bed as disposal areas for radioactive wastes. Gradually there was a refinement in the approaches with ultimate goal for large scale exploitation of the seafloor and correct understanding of the various processes.

Extensive deposits of metalliferous muds have been found and evaluated in the Red Sea, However it is only recently after the spectacular discoveries of active hydrothermal fields on the East Pacific Rise that other areas of the seafloor have been looked at for these deposits.

Coastal zone is that part of the land affected by proximity of the sea and that part of the sea affected by the proximity of the land. Till today the zone has not been defined properly for adaptation by all countries. Scientific and legal definition varies from place to place. Society depends on the coastal zone for its biological diversity, mineral resources, for fulfilling recreational opportunities, for sustaining important Industries, for waste disposal, transportation and also reflects the modification of climate. There is a massive increase in population living in this zone. Lot of problems arise due to storm damage, sea level rise, coastal erosion and silting.

In the next few decades a great increase in the seafloor use is likely. This will include not only the mining activities and petroleum extraction. but also environmental usage such as waste disposal. In order to demonstrate the feasibility of the method of waste disposal studies have to be carried out, The studies will also provide fundamental information on the deep sea processes. The geological and geophysical investigations of possible dump sites should be made to ensure that the site is geologically stable and the sediments are thick enough to ensure burial. Such studies are really still in its infancy but will need to be developed and used to a much greater extent in future if a true understanding of the sea floor processes is to be achieved.

PAST ACTIVITIES IN THE COASTAL ZONE

1726 – Hutton's study on Sea level changes and observations on lands initiated the study of Marine Science

1851 – GSI was set up for Geological Mapping, Mineral Exploration and studies related to coasts

1872 – THEOBOLD – indicated amount of elevations based on study of raised oyster Banks

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1878 – (ORMSTON) – Studied the Submerged forests of Bombay Island

I96O – INCOR was formed for study of Oceans as a part of IIOE

1965 – Marine unit in G.S.I and in

1966 – NIO started and emphasis had to be given on coastal zone studies because of lack of proper infrastructure which was built up later by DOD, NIOT, Dept. of Earth Science Etc.

Recently Institute of Environmental Studies and Wetland Management is carrying out an ICZM Project – WB

IMPORTANT STUDIES IN THE COASTAL ZONE

Greenhouse effect and sea level rise – climate changes are bound to occur due to human induced accumulation of carbon dioxide, nitrous oxide and methane which are increasing and causing higher global temperature.

This leads to melting of ice causing sea level rise and more erosion of the coast. These need a close monitoring of the beaches. Effect of sea level rise on the coast is important for planning and management The effect on inter tidal wetlands, coastal dunes should be monitored by satellite imageries and field traverse.

INPUTS REQUIRED FOR MARINE SURVEY WORK

Exploration on the seafloor involves a series of steps similar to that on land. A large area is selected first to delineate suitable areas for detailed exploration. In the final stage attention is paid only to the economically exploitable deposit. We have to remember about the inherent difficulties in reaching the seabed lying below thousands of meters of water. The distance between the shipboard scientist and the seafloor is a great barrier. Weather and sea condition will allow the scientist to work for limited number of days for safe execution of exploration work. The hydrostatic pressure beyond certain depth is great to prevent mapping by divers, Also the light attenuation is an adverse factor. However with the advanced technique it is possible to reveal the secrets of the sea. A suitable vessel is most important, Now all the countries have their own ship for ocean survey. Accurate positioning system is essential. A vessel should be capable of maintaining her position and reoccupy it at a later stage. Sextant and radars are useful for near coastal surveys. During the past years a number of electronic position fixing system has been evolved, Most important is the satellite navigation system by which the ship maintains her position very accurately. wtthin a few meters. Onboard computers guide the ship to maintain the required position automatically.

WORK HIGHLIGHTS MARINE AND COASTAL SURVEY DIVISION OF GSI

1. For Near shore Marine and Coastal Area and survey in the lagoons Country boats and Fishing Trawlers were used.
2. For Working in TW and EEZ of India, coastal vessels RV Samudra Kaustava and RV Samudra Shaudhikama was widely used.
3. For Survey in EEZ and beyond EEZ of India, Recently procured Vessel RV Samudra Ratnakar is being deployed.

KEY ACHIEVMENTS IN THE LAST 50 YEARS BY GSI

1. **Reconnaissance survey in the Exclusive Economic Zone of India is the Prime Objective :**

   98% completed with the help of 700 cruises from 1983 to 2013.

   Twin Research Vessels Samudra Kaustubh & Samudra Shaudhikama were procured.

The vessels have Length of 35.00 m, Draft 1.22 m Scientific Complement 12

Endurance 7 days, Equipments include Shallow seismic Multibeam Echosounder Magnetometer, Side scan sonar, Current meter, Seabed sampler (Grab, gravity, piston, vibro-corer), water sampler. On-board laboratories were used for study of samples. DGPS used for location purpose.

The vessels were used for survey of the Territorial Water of India

2. **Survey in the Bay of Bengal, Arabian sea & Indian Ocean**

For this work RV Samudra Manthan was used. Details are given below :

RV SAMUDRA MANTHAN Length 88.83 m, Draft 5.058 m, Scientific Complement 16 Endurance 25 day Onboard Equipment/Instruments include DGPS, Echo-sounder, Magnetometer, Multibeam Echosounder, Water and Seabed Sampler. Also there are on board Laboratories for various works.

(Till March, 2013, 229 cruises were completed)

3. **Publication and Compilation of Status maps** was also carried out

Total No of 2" X 2" Maps Compiled 63, Published 31

4. **Offshore Mineral Exploration :**

Commendable investigations were carried out for Placer mineral resources, construction sand, lime-mud, Phosphate bearing sediments both on the east coast and west coast of India. Placer mineral resources up to a depth of 1-1.5m thickness from the sea floor on the middle shelf has been identified in 764 sq, km. with a proven reserve of 108 million tons. Out of this potential area, 46 blocks have been notified in the Gazette of India for further exploration by IBM and exploitation by interested entrepreneurs,

PHASE OF EXPLORATION BY R.V.S. MANTHAN & COASTAL VESSELS

Targets & Achievements

i) Discovery of promising zones of offshore minerals like heavy mineral placer resources off Orissa, AP, Kerala and Maharashtra coasts. About 92 million tones was estimated with a Value Rs. 40,000 crores.

ii) **Sand Resources :** About 2,200 million tonnes. Value Rs. 3,30,000 crores.

iii) Lime mud occurrences in Gujarat and AP offshore.

iv) Carbonate sands in lagoons and banks in Lakshadweep sea and off Gujarat.

v) R&D activities at Andaman, OTEC site selection, commercial cruises for ONGC.

SURVEY IN BAY OF BENGAL, ARABIAN SEA & INDIAN OCEAN

Inner Shelf off Gopalpur-Chatrapur-Chilka Lake, Odisha

In order of abundance : Ilmenite, sillimanite**,** garnet, monazite. zircon, rutile etc. were located from an area of about 200 sq km, Water depth, 10 m to 30 m in the Offshore Upto 10-12 km Concentration : ~ 20 wt Reserve 50 million tonnes (Upto 2 m depth) with an Estimated Value : Rs. 16500 crores

OTHER SIGNIFICANT ACHIEVEMENTS

Geotechnical investigations carried out so far : 55 (RVSD) + 48 (RVSK) (ECO-I : 23 + ECO-II : 25)

Suitable locales for development of fishing harbours / minor ports and expansion of existing ports. were identified

Basic data on suitability w.r.t. geological / geophysical / basic engineering parameters were acquired.

22 sponsored projects were undertaken onboard on coastal vessels mostly for Geotechnical / Engineering surveys for ports, ONGC, BARC, MMTC, KMPDIE, Indian Navy and private bodies.

Ridge samples from Eastern offshore contains Gray to dark gray in color, calcareous, hard and compact with lot of shell fragments. Fresh coral and weed root is visible. Carbonate rocks showing the Corals were also identified.

Effect of sea level rise in the Ganga – Mahanadi Delta region was also studied

UPPER CONTINENTAL SLOPE

The upper continental slope is characterized broadly by large circular depressions with innumerable radial V-shaped incisions with intermittent relatively steep spurs of varying lengths. The slope in the head area varies from 5.96° to 18.26°. It gradually decreases to 1.47° - 7.59° towards the south-east direction. The average diameter of the circular depression at the slope head is measured to be approximately 2500m.

Detail studies of Tectonic setting around Andaman and Nicobar Group of Islands and Study around LIVE BARREN VOLCANO IN JUNE 2005 was also carried out.

STUDIES ON COASTAL AND TIDAL WATERS : Details are given below : Harnessing non-conventional source of energy at Durgaduani Creek, South 24-Parganas, West Bengal. Exploring the navigational channel and bank erosion along the Eastern Channel to Sagar Island, South 24-Parganas, West Bengal. Coastal zone management at Digha-Shankarpur, Frasergunj-Bakkhali beach, Sagar Island, West Bengal, & Ganjam-Palur, Orissa.

RELICT FOREST : Detail studies were carried out of Bakkhali, W,B, SEM studies of the samples collected indicate details of Fibrous structure. Enlarged portions show entrapment of some heavy minerals and also there is conversion of woody part to rock like material. These plants have been identified as mangrove plants - Sonneratia apetala (Sonneratiaceae), Heritiera fomes (Sterculiaceae**).**

MANGROVES : Mangroves are trees or shrubs restricted to intertidal zone and provide the habitat and food for a diverse animal community and adaptable to flooding and salinity conditions. They play important role in soil formation, shore protection and their stabilization. They absorb the force of the strong wind and waves. Mangrove mud flat being inundated due to sea level rise and often migration will result. Excessive sedimentation will also damage the mangroves by burial of roots which will interrupt the gas exchange killing the roots. Heavy metal pollution , sewage disposal also can damage the mangroves.

COASTAL HAZARD

Some of the coastal hazards are very well displayed in several sectors as given below :

Coastal erosion indicated by Dune Erosion at Digha, Displacement on embankment due to erosion, sand dune erosion at Digha and collapse of embankment at Digha due to storm surge has been well documented.

Tropical cyclonic storm effect is clearly seen in places like Digha in W,B.

Trail of devastation of the embankment after cyclone in Digha is well noted Destroyed sea wall is exposed in low tide near Lakshmipur, Bakkhali. Underlying clay with tree stumps is exposed by erosion in Bakkhali beach. Both bamboo fencing and brick linings are caving in Bakkhali beach.

Bank erosion in different channels in Sunderbans is very well marked

Attempts to protect the embankment by means of bamboo fencing and bamboo groins are the temporary preventive measures. Embankment erosion of northern bank of Ghoramara Island (December, 2005)can be noted from satellite images,. Eastern part of Ghoramara Island undergoing severe erosion (December, 2005). Collectorgunj police station on the brink of ruin (December, 2005)

Non-conventional Source of Energy :

West Bengal has an installed capacity of 150MW. West Bengal secured approval for a tidal power project in 2006. The pilot project would be set up at Durgaduani creek with an installed capacity of 3.6 MW. Detailed site specific study of the project carried out in 1994.

EFFECT OF TSUNAMI IN 2004 IN NAGAPATTINAM was observed : Motor boats have moved away more than 100 mt.

NATURAL HAZARDS also caused concentration of BLACK SANDS in East coast in several places.

Damage by cyclone in Machilipatnam was very serious, Damage of the Roads By Sea waves in Digha can be well seen and also the destruction of Brick Protection Walls at Bakkhali.

MODERNIZATION

1. Procurement of State of the Art Deep Sea Research Vessel - R. V. Samudra Ratnakar unique in the world and training to all the officers of MCS to all officers for capacity building to meet the challenges of the future.
2. Procurement process of geotechnical ship with drilling facility by 2016 is under process to meet the demands of future mineral exploration and geotechnical investigations.

FUTURE PROGRAMMES RVS RATNAKAR

With the acquisition of R.V.S. Ratnakar M & CSD is entering into II phase of offshore geological exploration. The vessel was dedicated to the Nation by Honourable Minister of Mines Shri Dinsha Patel on 12 th Oct 2013 at Kandla Port.

Capability : The vessel has a compliment of 25 scientists.. Maximum endurance period of 45 days. Running and maintenance of the scientific equipments outsourced to Norinco Pvt. Ltd. (8 engineers on board).

DEPLOYMENT OF SCIENTIFIC EQUPMENTS : RV SAMUDRA RATNAKAR

MULTICHANNEL SEISMIC SYSTEM : Operted by Seismic Airgun Array onboard. : Deployment of Seismic Streamer is done from the A frame and Deep Seismic Section as recorded onboard and Deep seismic section are noted after preliminary onboard processing

MARINE MAGNETOMETER Opertaed by Mgnetometer Winch and Signal Amplifier Side Scan Sonar can show different textures that make up the sea floor. Sidescan Sonar can also detect object on the seabed

Onboard Multibeam Echosounder has been very useful. and interesting images were brought out.

Multichannel bathymetric mapping of part of Central Andaman Trough and study of evolutionary history and possible locales of submarine hydrothermal mineralization in the basin and surround area. was carried out. NNE-SSW trending linear features demarcated on valley floor and on both flanks / banks of the valley. Submarine channels have been identified near Laxmi Ridge.

Part of Sub bottom profile section from Central Andaman Trough area show diaper structure.. Some Sub-bottom profile sections show Continuous reflectors observed in large part of the valley and Arching / doming of strata can be observed at some places in the valley part

Other equipments include G-882 Marine Magnetometer (cesium-vapour)

M/s. Geometrics – manufacturers and WATER SAMPLER WITH 24 COROSOLE and CTD PROBE-SBE 19PLUS V2 are also used at suitable locations.

REMOTETELY OPERATED VEHICLES are also used and deployed carefully by using rectangular frames.

SYNTHETIC APERTURE SONARS **:** was deployed up to 6000m water depth with 40cm resolution

HEAT FLOW MEASURING SYSTEM (M/S FIELAX - MANUFACTURERS Operation depth – 6000m. Total length – 8.4 m Total weight – 950 kg + additional weights can be added. (Measuring Temperature from 2-60 Degree C, Data displayed on computer collected from the probe

In the AFT deck there is A-frame with cranes from where the Instruments are lowered, Sea Trials were done in May - June 2013 from the New Ship RV Ratnakar. Ten Ton Crane on the AFT main deck Vibrocorer is deployed from the main deck which can collect sediment upto 10m below sea floor (Operation Depth 600m, Core Length 6 m)

PISTON CORER : Operation Depth is 6000m, Core Recovery is upto 30 m.

SPADE CORER **:** Penetration Depth – 600 mm. Weight of corer – 0.5 tons

Spade corer being lowered to the sea and the Spade corer retrieved back after sample collection.

VAN VEEN GRAB sampler is lowered quite often for sample collection

Okean grab sampler and Smith- Macintyre grab was also used sometimes.

DREDGE sampler generally used is of chain bag type

ONBOARD LABORATORIES : They include the following laboratories.

CORE SAMPLING LABORATORY with CORE SPLITTER and CORE CUTTER

CORE SCANNER WITH ITRAX core scanner. There is provision for XRF ANALYSIS, Radiographic X-Ray, Chemical and Density Image and

Non Destructive Analysis etc. Core scanned result are shown ON MONITOR. Fume Chamber & Centrifuge Water Purification System is also used

SEISMIC DATA ACQUISITION LABORATORY. DATA PROCESSING and GEOLOGICAL LABORATORY are also used.

MINERAL RESOURCES

ADVANTAGES & DISADVANTAGES OF THE LAND VS. NEARCOASTAL AND SEA DEPOSITS

LAND DEPOSITS; 1. Easy to locate 2. Less capital required 3. Work continued throughout the year 4. No sophistication required 5. Work can be started with limited funds 6. Cost goes on increasing 7. Nonrenewable and so mines have to face closure.

NEAR COASTAL AND SEA DEPOSITS 1. Difficult to locate 2. High investment required 3. Work continued on limited period of the year 4. Floating platform required 5. Fund requirement is high 6. Initial cost is high but once started it will fall to economic level 7. Renewable resources.

EXTRACTION OF SALT from coastal areas is known from ancient times till today

BIOGENIC RESOURCES

These deposits are formed due to Biological activities. They include mainly the Calcareous Sands derived from SHELLS, CORALS

CALCAREOUS SANDS, SHELLS

Important Shell deposits mined for cement - off Iceland, shallow offshore off SanFransisco Florida, Gulf of Mexico. Some Indian Deposits - Vembanad Lake in Kerala, Milliolite Limestone of Saurashtra, Rameswaram in T.N. and Gulf of Mannar. The Vembanad depositis formed due to accumulation of shell deposits of Villoritta a living species of lamellibranches. The water in the lake is about 3m. There is a silt and clay cover of 2m at places. The shells are dredged and pumped. The deposit has a reserve of 17-25 m.tonnes. Travancore Cements Pvt. Ltd. are dredging the shells for manufacture of white cements.

LAKSHADWEEP ATOLLS

Lakshadweep – Group of coral atolls in Arabian sea situated 200-300km from west coast of India Number of major Islands and Lagoons – 11 (Kavaratti, Kalpeni, Agatti, Chetlat, Bitra, Kiltan, Kadmat, Amini, Bangaram, Suheli, Minicoy) Submerged reefs – 4 (Beliapani, Chriapani, Perumalpar, Androth)

Banks – 5 (Basses De Pedro, Sessostris, Coradivh, Aminipitti, Elikalpeni)

ATOLLS AND SEA LEVEL CHANGES

Popular concepts of origin of coral reefs and atolls in 3 stages due to sea level changes was put forward by Darwin 1). Formation of Fringing reef around volcanic island 2). Barrier reef formation with rising of sea level or sinking of the island 3). Formation of atolls with more and more sea level rise or with complete sinking of the Island

PREVIOUS WORK

1903 – Agassiz visited the Islands on a Yale University cruise

Gardinar described atolls of Minicoy, Maldives

1935 – Sewell – Topography and bottom deposits

1965-1970 – Varadhan Mukherjee, Dhruba Rao of IBM-Guano and Limestone deposits of Lakshadwee**.**

1967-1973 – Detailed investigations in GSI by Late H.N. Siddiquie and T.K. Mallik. Subsequently a number of papers on various issues have been published by them**.**

Geological Survey of India carried out detailed sampling in the lagoons and offshore areas to assess the potentiality of calcareous sands for industrial use. (Siddiquie and Mallik,1973). Surveys indicated 288 m. tones of calcareous sands in the lagoons up to a depth of 1m.

BIODIVERSITY

The reef areas are the living places of various communities of corals belonging to different families of *Acroporidae*, *Poritidae*, *Pocilloporidae, Favidae, Fungiidae, Mussidae* etc.

Besides a large number of speices of *Gastropods, Bivalves, Echinoids, Foraminifers, Ostracods and Bryozoans* are also present.

Halimeda is the most important constituent of the lagoon sands and played most important role in building up the reef. Important coral groups and other forms have also been noted

DEPOSITS DERIVED FROM LAND AREAS

SAND,GRAVEL AND PLACERS are included in this group

Most significant is the heavy mineral placers commonly known as Black Sands which can be divided into Drowned river or Alluvial Placers, Beach or Dune Placers, Offshore Placers

Sand, Gravel and Aggregates are reworked deposits in high energy environments in shelf or near coastal areas. Mainly used as construction material in UK, USA. Denmark and Holland. Recovery started about 100 years back in North Sea and English Channel. Mining is done with the help of barges which settles during low tide. Working is successful up to limited distance which becomes double for a journey of 50km.

Sands / gravels First mineral recovered from the North Sea and English Channel.

This is an important industry in UK, Denmark and Holland. The first concession in 1860 granted to the German firm of Stantein and Becker to mine amber in Baltic Sea. Floating barges necessary for mining though depth of water may be less than 30m. Transport cost is very high. High transport cost restricted the mine owners to concentrate to the metropolitan centers.

HEAVY MINERAL PLACERS

Why go for PLACERS ?

Quick return as compared to any deep sea venture Relatively easy exploration and exploitation. Continuous growth of industrial sector causing depletion of land based mineral. Enormous possibility of placers along 7500km. Coastline in beaches, river channels, marshy land, alluvial plains, dunes, off-shore areas, submerged valleys and palaeo beaches. These are being worked from ancient times

IMPORTANT HEAVY MINERALS, THEIR USE AND OCCURRENCE

Gold – Ornamental (Alaska, California) Diamond – Jewell cutting (S. Africa) Cassiterite | Metal coating (Indonesia.Malayasia, U.K coast),

Rutile – Pigment, metal (Australia, Africa) : Ilmenite - Pigment (S. Africa, SriLanka, India) : Magnetite - Steel (Newzeland) Zircon - Refractory, Foundry sand (Australia, SriLanka) : Garnet - Abrasive (Australia, India) _ Monazite - Catalyst for Oil Refining (Australia, Chavra, Manavalakuruchi) : Sillimanite - Refractory (India) Apatite- Fertiliser (Peru. Chile)

GARNET MINING - is done in Tuticorin : Garnet is mined by INDIAN OCEAN GARNET, mine site NE of Kanyakumari. 100 M. tonnes mined in1982. Present production nearly 24000 M tonnes ALMANDITE 3FeO, Al2O3, 3SiO2 is the best abrasive garnet. blasting Grade garnet used for cleaning of ships, water tanks, boilers, pipes, Jet Cutting grades cutting steel, Alloys etc.

Black sands in beaches is well seen, H.M. layers below the surface can also be seen. Double crested ripples on intertidal flat has prominent heavy mineral layers.

OSCOM - IS EXTRACTING THE PLACER MINERALS FROM ORISSA AND KERALA., TAMILNADU areas.

When studied under SEM the following features were noted :

Enlarged View of Monazite show rounded edges, irregular pits, removal of blocks and some depositional features showing white flakes, Highly rounded monazite grain showing removal of blocks and formation of pits in

different directions Grain of ilmenite also show etch V s, breakage blocks, pits. Garnets are. partly rounded, Also show Removal of Blocks and number of pits and grooves. Some Garnet Grains are highly angular with conchoidal fracture and embayment due to solution effect Kyanite grain displays striations, impact features. Zircon grains are euhedral. Sometimes rounded at the edges due to transport. Some portion indicate formation of pits. Biotite grain. s are often serrated

PROCESS RESPONSE DEPOSITIONAL MODEL

IMPORTANT PROCESSES are Collision during Wave Action, Aquous collision resulting grain Fracturing, Mechanical Impact, Wearing. removal of Blocks, Grinding, Chemica Action, Dissolution Etc.

RESPONSES are conchoidal Fractires, grooves, pitting, Pits, upturned Plates, Etch-Vs, furrows, Comb structures, Precipitation structures etc.

DEPOSITIONAL ENVIRONMENTS : Medium to High Energy Environment in littoral or nea rshore zone by fluvial Transport, some deposion in dune environments, Tropical or High energy environments or a combination of all processes.

Sedimentary Structures :

Various types of structures are found in the beach like ripples, cross bedding, mud balls and a number of pelletal designs. Presence of relict forest is conspicuous in some areas containing Mangrove Plants Sonneratia apetala or Heritiera fomes. They are nearly 3000 years old (C 14) Wide Accretionary Beach show Ripple Marks and Mud balls., Internal structures of older coastal dune sand with HM layers is common. Modern mobile beach dunes in beach is also seen. Internal structures of the older stabilized and oxidised coastal dune sand with cross bedded structures are also present.

BIOLOGICAL TOOL FOR EXPLORATION

Beaches show extensive biological activities. Pellets are common in W.B coast Mineralogy of pellet sands is useful in selecting or discarding areas for placer exploration This clue has been useful to a limited extent till date important placer concentration has been noted in several beach sectors of India and this biological clue is being attempted modestly for the first time

NATURE OF STUDY SITES

Only red spots are visible at first sight represented by Ocypod group of crabs which are very common. Other associated crabs are metaplax and Ilyplax. Each hole has an array of pellets of various designs and colours. signs can be concentric, radiating, asteroid, mossy etc. llets developed during food search by the animals. e shape of the pellets are rounded, elliptical or globular or mossy and they indicate different types of environments.

The beach show only Red Spots with burrowing activity. Extensive Biological Reworking by the Crabs is a major cause of Erosion of the Digha Beach in West Bengal

ENVIRONMENT IMPACT ASSESSMENT

1. Area and place of dumping determined. 2. Effect on human population, agriculture to be assessed. 3. Industrial Wastes generated will increase the pollution. 4. Sustainability of the deposit, industrial use should be determined. 5. Use of Waste Sand in reclamation, glass industry etc. 6. In case of Placer Mining the radiation resulted from radioactive minerals like Monazite should not exceed the tolerance limit for the workers. 7. Major activities should

not damage the important cultural, historical and sites of scenic importance. 8. Social and Economic Factors controlling the life style should be kept in mind. 9. Possibility of Fresh water supply should be kept in mind. 10. All activity should be related to CZM

OIL AND GAS

Extensive work has been carried out by ONGC in the near coastal areas. Discovery of Oil in Bombay High Region, Gulf of Kutch and Krishna-Godavari Basin is known to every body. Gas Hydrates were known since 1960. It is a frozen form of gas. In 1990 evidence accumulated that huge quantities of carbon are stored in ocean sediments in the form of free and dissolved gas as well as gas hydrates, a solid phase made of cages of water molecules that hold gas molecules primarily as methane. Possibility of gas hydrates has already been suggested from some of our coastal areas.

ICHNOLOGY - VERY USEFUL FOR COASTAL SECTORS

Study of Trace fossils in recent sediments and in delta areas gives significant biological and environmental clues. They have been used in interpretations of paleoenvironment, paleoshorelines, in solving geotechnical problems, some polychate burrows has been used for estimating annual rates of erosion and accretion successfully**.**

TRACE FOSSIL MARKS is seen all over the beach in the delta areas.Various designs of pellets have been formed by Ocypod crabs. Burrowing Ocypode often noticed in beaches. Older dunes vs. intertidal beach with thickly populated crab *Ocypode* spp. is a common site in Digha beach

EROSION/ACCRETION RATE

Marine polychate *Diopatra* cuprea produces tubes that protrude above sed-water interface. In the top part foreign particles are attached. With erosion part of the tube without attached particle are exposed which indicates the amount of erosion. With accretion sharp boundary found below the interface and indicates amount of deposion. Considering the average life span as 2 years the rate of erosion and accretion has been calculated. Other bewildering pelletal designs produced by beach crabs on the foreshore beaches of the study areas

ASPECTS OF MANAGEMENTS.

Resource of the coastal zone is enormous and various problems also exists.

There are lot of conflicts regarding fishing, tourism or environmental protection. So there is a need for management to minimize the mitigation and protect the coast from natural hazards. Ill planned and poorly conceived development plan should be avoided. Geological knowledge can be utilised for minimizing mitigation and other natural hazards. Full exploitation of the coastal zone will then be possible and a conservative approach is necessary for sustainable development.

Other Thoughts : Different development activities without considering delicate ecosystem has caused lot of environmental problems.

Coastal erosion, storm surges, currents, sea level rise and manmade causes interrupting sediment transport are important issues.

In addition mining of minerals and sands and construction of dams, reclamation of wetlands and back waters aggravating coastal flooding and construction activities in the beach and urbanization with high density population prevented sustainable development of the coast.

Ministry of Environment and Forest in 1991, implemented the Coastal Regulation Act to regulate activities in Coastal zone.

Mapping of the Costal zone is essential. Importance of the land use pattern and demarcation of the HWL, LWL, 200m and 500m zone is to be sorted out first. Coastal regulation Act prohibited Setting up of new Industries, Fish Processing Units, Waste and effluent disposals, dumping of city wastes, Land Reclamation, bunding, Construction in sensitive areas and in beaches. Permissible activities include Construction for Defence, Ports, Harbours, Light Houses, Thermal power Plants etc.

The mining activities should be managed in a manner consistent with the principles of sustainable development such that economic, environmental and social consider ations are integrated into decision making and management.

CLASSIFICATION OF COASTAL REGULATION ACT

CRZ I - Ecologically sensitive areas. No new construction within 500m of HWL

CRZ II - Developed Urban Areas. No new building on the seaward side of coastal road or existing authorised structures**.**

CRZ III - Relatively Developed or undeveloped areas. Area upto 200m from HWL is no development zone, Controlled development from 200-500m.

CRZ IV - Islands. No new structures within 200m zone in A & N. In Islands buildings shall not have more than 2 floors. Corals are not to be used for construction.

COASTAL REGULATIONS ZONE NOTIFICATION - 2011

Objective :

Ensure livelihood Security of Fishing Community

To conserve and Protect Coastal stretches

Promote development in a sustainable manner based on scientific principles taking into account the dangers of natural hazard, sealevel rise and global warming**.**

NOTIFICATION 2011

CRZ Notification of 2011 includes not only the area covered in 1991 i.e. 500m from HTL in landward side including intertidal area on the seafront and 100m width of the creek whichever is less from HW line on landward side along the tidal influenced water bodies. It also includes the land areas which falls in the hazard zone beyond 500m and also the aquatic area up to 12 nautical miles in the territorial waters and tidal influenced water bodies are also included.

PROHIBITED ACTIVITIES

Setting of New Industries. Expansion of Industries except those directly, related to waterfront or needing foreshore facilities, projects of DAE

Facilities for generating power by nonconventional energy sources and setting of desalinization plants

Setting of expansion of fish processing units, Land reclamation, bunding, discharge of untreated wastes. effluents

ISLAND COASTAL REGULATION ZONE set of for Andamans and Lakshadweep will be classified as

CRZ 1 Ecologically sensitive maintaining the integrity of the coast between LTL and HTL

CRZII – Areas developed closed to important structures.

III - Relatively undisturbed areas rural areas and partly designated urban areas.

IV - The water from LTL to 12 nautical mile in the seaward side. Shall include the water area of the tidal influenced water body from

the mouth of the water body at the sea upto influence of tide which is 5parts per thousand during the driest season of the year

MODEL STUDIES - COASTAL ZONE

1. Mineral Investigation Programme 2. Shoreline studies 3. Estuarine Studies 4. Harbour Studies 5. Wave Studies 6. Offshore Studies 7. Sediment Transport Studies. 8. Studies on Special aspects like Ichnology, Mud banks etc. 9. Preparation of Data Base and Maps

DEPLOYMENT & FUTURE PROGRAMME OF R.V. SAMUDRA RATNAKAR

SHIPS EXPECTED LIFE : 35 YEARS

1. One voyage for 35 to 45 days In a year 8 to 6 voyage per year

   These surveys will be undertaken in exclusice economic zone and international waters. The important prommes will be as follows :

   Search for phosphate rich sediments, lime mud, ferromanganese encrustations, etc.

   High resolution survey for gas hydrate occurrences and selection of site for OTEC.

   Survey for cobalt rich encrustations and poly-metallic nodules in selected sectors of Indian Ocean. Surveys in the Mid oceanic Ridge area.

PROSPECTIVE AREAS FOR MARINE MINERALS IN INDIAN OCEAN

Carlsberg Ridge, Central Indian Ridge, SE Indian Ridge. SW Indian Ridge

Rodriguez Triple Junction Middle east to india deep water pipeline by

South Asia Gas Enterprise

CSIR-National Institute of Oceanography *with its H.Q at Dona Paula, GOA and Regional Centres at Kochi, Mumbai and Vishakhapatnam was established in 1966 following the IIOE, The Institute has a strength of 200 Scientists, 200 Technical Staff and 170 Administrative and Support staff.*

The main objective of the Institute is advancement of the science of the oceans with special emphasis on highlighting the processes arising from special characteristics of the Indian Ocean. They are involved in the exploration of non living resources (polymetallic nodules, placer minerals and petroleum hydrocarbons). Their work led to recognition of India as a Pioneer Investor by the International Sea bed Authority and allocation of mining site in the Central Indian Ocean. They also explored the legendary submerged city of Dwarka and other evidences of ancient Indian civilization. They were also involved in the evaluation of ongoing human induced alterations in marine environment. They also offered services to private and public sector organizations, Industries on various issues of coastal zone utilization and managements. They could also earn about 200 crores from sponsored projects. Their Research vessels RV Sindhu Sankalp and RV Sindhu sadhana has been used for various surveys. They have published around 3800 research papers on varius SCI journals.. They have played a major role in human resource development. It is very dfficult to give a detailed account of all the activities of NIO in this paper. Interested readers may visit www.nio.org, for further information.

CONCLUSIONS

1. Our first objective-solve societal problems like coastal erosion. earthquake hazard, tsunami effect, sea level changes, pollution studies and studies on climate etc.

2 We have to concentrate on easily exploitable placer deposits along the coasts. the calcareous sand deposits can also give quick return.

3 Infrastructure should be developed with reference to instrument, manpower, public awareness and education.

4. While taking up basic research problems, we have to remember about our service of humanity.

5. Event detection system for catastrophies should be thought.

6. Proper attention should be given for the essential support needs like education, research, field activity, analytical facilities, model development, training etc.

   Close interactions with scientists of different disciplines will help in achieving our target

7. There is an urgent need for evolving integrated national earth science Policy and role of National Agencies.

8. All activities should strictly be guided by the Coastal Regulation Acts. and in accordance with the International development and legal regimes.

SOME OTHER SUGGESTIONS

We have to think of improved Coastal Protection System. Stabilisation and conservation of dunes and formation of neodunes by artificial methods will be useful Sites for Fisheries, Fish Farming and human settlements have to be considered carefully.Infrastructural developments for tourism and other beach resorts should be constructed wisely. Much emphasis has to be given on Ichnology. Beach mining and transportation of beach sands should be stopped. Constant watch on artificial structures and their repair has to be monitored. We have to think of improved Coastal Protection System. Stabilisation and conservation of dunes and formation of neodunes by artificial methods will be useful. Sites for Fisheries, Fish Farming and human settlements have to be considered carefully. Infrastructural developments for tourism and other beach resorts should be constructed wisely. Much emphasis has to be given on Ichnology.. Beach mining and transportation of beach sands should be stopped. Constant watch on artificial structures and their repair has to be monitored.

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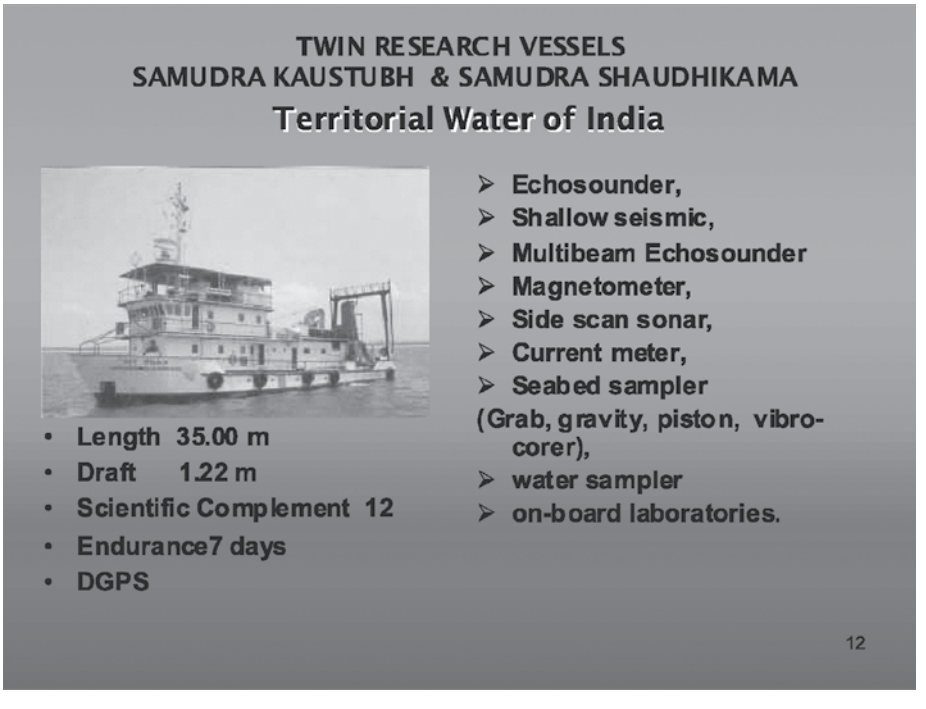
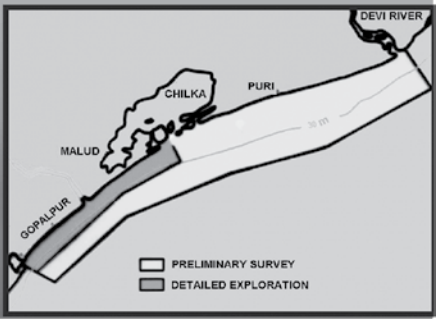


Inner Shelf off Gopalpur-Chatrapur-Chilka Lake, Odisha

- Area : about 200 sq km
- Water depth : 10 m to 30 m
- Offshore : Upto 10-12 km
- Concentration : ~ 20 wt%
- Reserve : 50 million tonnes (Upto 2 m depth)
- Estimated Value : Rs. 16500 crores

In order of abundance:

ilmenite
sillimanite
garnet
monazite
zircon
rutile



30/12/2015

R.V. Samudra Ratnakar in search of Mineral Wealth

SURVEY IN BAY OF BENGAL, ARABIAN SEA & INDIAN OCEAN

R V SAMUDRA MANTHAN

Till March, 2013

229 cruises

- Length 88.83 m
- Draft 5.058 m
- Scientific Complement 16
- Endurance 25 days

Onboard Equipment/Instruments

- DGPS
- Echo-sounder
- Magnetometer
- Multibeam Echosounder
- Water and Seabed Sampler
- On board Laboratories

EFFECT OF NAPHTHALENE ON REDUCTION CHARACTERISTICS OF IRON ORE NUGGETS USING BOILER GRADE COAL

Rajib Dey[1], Chanchal Biswas[1†], Mahua Ghosh Chaudhuri[2]

ABSTRACT

Iron ore nuggets are reduced by devolatilization products of boiler grade coal. Gas solid reactions play a major role in this process. Thus porosity of nuggets is one of the controlling factors of this reduction process. In this present study the effects of porosity on the reduction behavior of the nuggets are discussed in details. During synthesis of the nuggets naphthalene is added with other raw materials. At the high temperature of reaction naphthalene vapour goes out and generates porosity of the nuggets. Volatile matters of coal i.e. CO, H_2, etc then pass easily through the process path, more contact area with solid surface and fast and complete reaction occurs. Characterizations of the iron nuggets are carried out by using X-ray Diffractometer (XRD), Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectrometer (EDX). Extent of reduction and the degree of metallization are also calculated. It is observed that iron ore could be significantly reduced to metallic iron by using the devolatilization product of lean grade coal. Reducibility is found to improve with higher porosity.

Keyword : Iron Nugget, Coal Devolatisation, Solid State Reduction, Iron Making, Extent of Reduction

1.0 INTRODUCTION

Due to mechanized mining operation of the raw ores usually leads to generation of huge amount of iron ore fines. [1] These fines are utilized properly by nuggeting process that leads to agglomeration. [2] Porosity usually improves reducibility of an ore. In this research work, porosity was controlled by predetermined addition of naphthalene. The contents used are 0% (no addition), 5% and 10% by weight. The mechanical properties of these nuggets are then tested. The nuggets are heated at 120^0C before reduction. This causes the naphthalene to escape as gases, thus creating pores. These nuggets are used for reduction in a coal gasification furnace at various temperatures at various time intervals. [3-5] Pyrolysis of coal generates hydrogen, carbon monoxide gas and carbon soot, which act as reducing agents. The above mentioned gases can easily pass through the pores, thus improving the reaction rate. Enhanced porosity leads to better surface area of contact for gas-solid reactions. After that the reduction are

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carried out in different temperature and time of the nuggets. The pre-reduced nuggets [6] can be used in the blast furnace itself either as a coolant or simply as a raw material which will reduce the coke rate of the furnace because of its pre-reduced character. [7] Iron ore fines occupy huge space and cause environmental and ecological problems. It is essential to beneficiate and recover the additional iron values from these fines & slimes. It is not only used to earn additional revenue to iron and steel industries but also from the view point of control of mineral wealth. Agglomeration processes enable the usage of concentrate fines in Iron making. [8-10]

Nasr et al. 1996 established that at all the reduction temperatures, swelling of pellets and compacts increased with the progress of reduction up to about 70–90% till a maximum value of swelling was achieved. It was followed by a decrease till completion of reduction due to sintering and densification of iron grains. [11] According to J Janowski et al, the investigations were carried out on a natural hematite grain to reduce into magnetite at 723 K. From the Stereologic analysis enabled the porosity of this material was calculated. It was measured on the basis of grain contours and volume fractions of the grain components of hematite, magnetite and pores. The porosity value was determined by the classical mercury method. [12] J. Janowski et al, evaluated the microscopic image analysis applied for determination of porosity of hematite grains reduced to magnetite at different temperature and time. The porosity was observed by the phase transformation hematite to magnetite. The porosity determined by mercury porosimeter agreed reasonably with microscopic data. [13] J. Janowski et al investigated the evolution of porosity profiles of magnetite phase during reduction of high temperature application of hematite phase. The value of total porosity obtained by mercury porosimetry agreed in a reasonable way with microscopic data. It was found that the local porosity of the already reduced layer varied also with time. [14] B. Weiss et al. performed the reduction of iron ore fines structural changes in particles and it had a significant influence on the rate of reduction. Investigations regarding on specific surface area, porosity and mean pore diameters of hematite phase was reduced with hydrogen rich reducing gases were performed by mercury porosimetry. In the phase transformation during reduction of hematite to wustite progressive conversion and important increase in the mean pore diameter were evaluated. [15] Keith B. Lodge evaluated a method for the determination of the porosity of an individual pellet. An important property was porosity. Pellets with optimum porosity were desirable for the reduction to iron in the blast furnace. It was developed for single items of fruit, to measure the envelope volume of independent taconite pellets and their concerned on reduction. [16]

2.0 MATERIALS AND METHOD

2.1 Materials Used :

Iron Ore : Iron ore are supplied from Rashtriya Ispet Nigam Limited, (RINL), Visakhapatnam, Andhra Pradesh, India. **Boiler Coal** : Boiler coal is obtained from Talcher & IB Valley sources of Mahanadi Coal Field (MCL), India. **Bentonite** : Bentonite is collected from JSW Steel, toranagallu, Bellary, Karnataka, India. **Molasses** : Molasses is procured from Tata steel plant, Jamshedpur, Jharkhand, India. **Naphthalene** : Commercial Naphthalene available in the market is collected from supplier.

2.2 Preparation of Raw Materials :

Below -10 mm size fraction hematite is crushed by jaw crusher, roll milling and ball mill. Then it is subjected to sieve analysis to arrive at

different size of particles. Three ranges of size fractions are selected for nuggets, coarse (-0.5, + 0.178 mm), semi coarse (-0.178, + 0.104 mm) and fines (-0.104, +.044 mm) by BSS standard mesh size. To prepare the samples, optimized size fraction of the iron ore is selected and mixed with 0%, 5% and 10% naphthalene by weight as given in **Table 1**. Boiler grade coal is crushed by jaw crusher. The size fraction of charged boiler grade coal is 6.3–19 mm.

Sample	Size fraction of the samples			Naphthalene (%)
	Fines	Semi Coarse	Coarse	
SE1N1	60	20	20	0
SE1N2	60	20	20	5
SE1N3	60	20	20	10

Table 1 : Details of different sample prepared for nuggets

2.3 Nugget Making :

Iron ore is mixed with 4% bentonite, 4% molasses, 2% moisture and three different percentage of naphthalene (0%, 5%, and 10%) by weight. The binder percentage is selected on the basis of optimization with respect to mechanical properties. They are mixed thoroughly to get a homogenous mixture as far as possible and cured overnight before making nuggets. 12.5 grams of that mixture is taken into the cylindrical die. The die along with sample is placed in the hydraulic press (hand operating). The pressure is applied to the die was 350 Kg. The die is kept in rest for a while (1 minute). Then the sample is removed and separated. Cylindrical shape is formed.

2.4 Characterization of Raw Materials, Reduced and Smelted Samples :

Phase analysis of the samples are carried out using X-ray diffractometer (XRD), (Rigaku Ultima-III, Cu Kα, 40 kV, 30 mV) at a scan rate is 5^0 / minute from 20 to 80^0. The surface topography, composition of raw ore and reduced samples are analysed by Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectrometer (EDX). (SEM model no - JEOL JSM-8360) and EDX oxford instrument). Wavelength Dispersive X-ray Fluorescence (WDXRF) quantifying raw ore composition by (MagiX2424, PANatytical Super Q). Proximate analysis of boiler grade coal is also carried out and the results are compared with the TGA/DTA results. Boiler grade coals are characterised by TGA/DTA (Model no - Pyris diamond TG-DTA Perkin-Elmer instrument) in the range of 35^0C to 1000^0C at the rate of 10^0C / min in N_2 atmosphere. Model no. of gas chromatograph (CHEMETO - 8610) is used for gas analyses which are generated from coal volatilization of boiler grade coal. Carbon shoot are analysed by XRD and FESEM, which are generated from coal volatilization of boiler grade coal. Shatter and abrasion index of the nuggets are obtained in the standard shatter and abrasion lab scale apparatus before and after reduction. The chemical analysis of the reduced samples is evaluated by the standard procedure of the Bureau of Indian Standards (BIS 10812:1992). The extents of reduction are calculated from the weight loss method.

Flow Diagram : The flow diagram of the total process to find out the pig iron production from iron ore nuggets is given in **Fig. 1**.

(A) Iron Ore (B) Bentonite (C) Molasses (D) Moisture (E) Homogeneous Mixture of all Ingredients (F) Nuggeting Die and Piston 0% Naphthalene (G) Nuggeting Die and Piston 5% Naphthalene (H) Nuggeting Die and Piston 10% Naphthalene (I) Nugget (J) Coal devolatilization Furnace for reduction (K) Reduced Nuggets

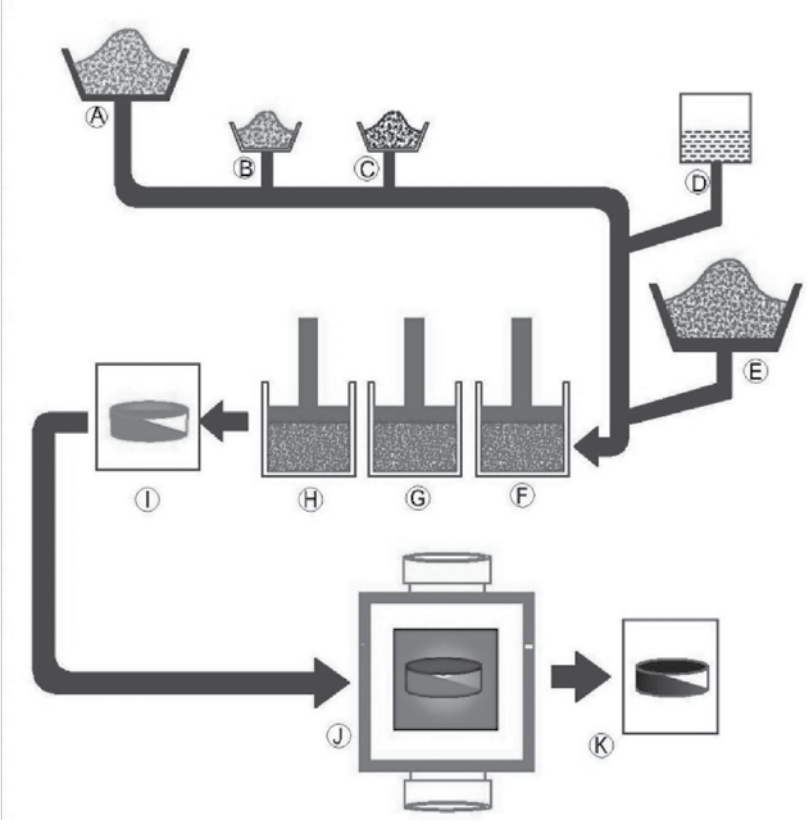

Fig. 1: Schematic Flow diagram of the total process

3.0 RESULTS AND DISCURSIONS

3.1 Analysis of Raw Materials :

The characterization of raw iron ore is performed in different standard analysis method.

3.1.1 WDXRF Analysis of Iron Ore :

Elemental analysis of hematite ore fines, total Fe content of the ore and major oxide concentrations are measured by WDXRF is given in **Table 2**. The details of the analysis are shown in weight percentage (%).

Fe (T)	SiO_2	Al_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	S	P_2O_5
64.05	4.03	2.29	0.05	0.28	0.36	0.02	<0.01	0.24	0.1	0.06

Table 2 : WDXRF result of iron ore

3.1.2 Chemical Analysis of Raw Ore :

The results of the total chemical analysis of raw iron ores are given in **Table 3**. The most important elements and components of iron ores are the content of total Fe, total hematite and gangue SiO_2 & Al_2O_3. It is observed that raw iron ore is hematite (Fe_2O_3) with low gangue content. [17]

Chemical composition of raw iron ore :

Chemical Composition	Weight Percentage (%)
Total Fe	64
Total Hematite	91.5
Alumina	1.27
Silica	3.18

Table 3 : Chemical composition of raw iron ore

3.1.3 Proximate and Ultimate Analysis of Boiler Grade Coal :

The amount of fixed carbon, moisture content, volatile matter and ash content for boiler grade coal are calculated using the result of proximate analysis and is given in **Table 4**.

Sample	Fixed carbon	Volatile matter	Moisture	Ash
Boiler grade coal	28.08 (%)	28.31 (%)	7.4 (%)	36.21 (%)

Table 4 : Proximate analysis of boiler grade coal

The data of proximate analysis is further refined by Ultimate analysis (Leco Tru Spec) of coal which is supplied by Vizag steel plant. The ultimate analysis of coal is given in **Table 5**.

Sl. No.	Parameters	Sample tagged as boiler grade coal
1	**Total moisture % (as received basis)**	2
2	**Analytical moisture**	7.3
3	**Volatile matter % (air dry)**	29.13
4	**Ash % (Air dry)**	33.05
5	**Fixed Carbon % (Air Dry)**	30.52
6	**Sulfur % (Dry Air)**	0.561
7	**Ultimate analysis**	
	Dry basis	
	% Carbon	50.9
	% Hydrogen	3.47
	% Nitrogen	0.803

Table 5 : Ultimate Analysis of coal

3.1.4 TGA/DTA Analysis of Boiler Grade Coal :

The TG/DTA study of boiler grade coal is essential for the design of the coal gasification part of the project, as it is necessary to know its gasification properties. TG/DTA analysis of the boiler grade coal is given in **Fig. 2**.

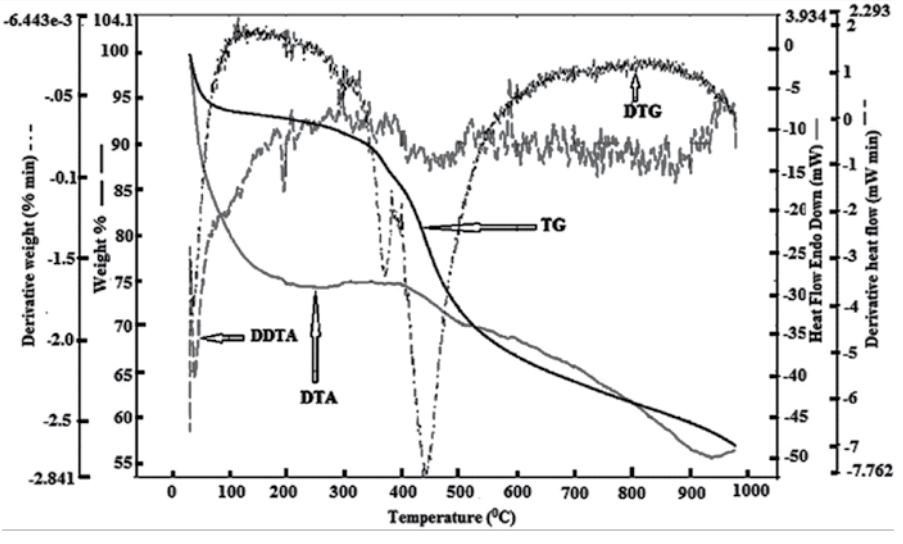

Fig. 2 : TG/DTA plot of the boiler grade coal

The nature of the weight loss confirms the data from the proximate analysis of the boiler coal. The graph shows a weight loss up to 110^{0}C, which is caused due to the expulsion of the moisture (7-8 %) in the coal. The major weight loss from 400 to 550^{0}C is due to the removal of the volatile matter (25-30 %). This is the single most important step during the devolatilization. After 550^{0}C the weight loss is very slow. This may be occurring due to soot formation or mild oxidation by the trace amount of oxygen present in nitrogen which is used as a shielding gas in the experiment. The derivative weight loss and derivative heat flow curve is shown **Fig. 2**. The loss around 375^{o}C may have arisen because of the burning of organic matter in the coal.

3.1.5 GC Analysis of Boiler Coal :

The components of the gas mixture obtained by heating the coal at 650°C are analyzed using GC. **Fig. 3** is the GC plot which shows the presence of CO, CO_2, H_2 and CH4 in the gas mixture. The percentage of each gas obtained by heating the coal at different temperatures is correlated in **Fig. 4**.

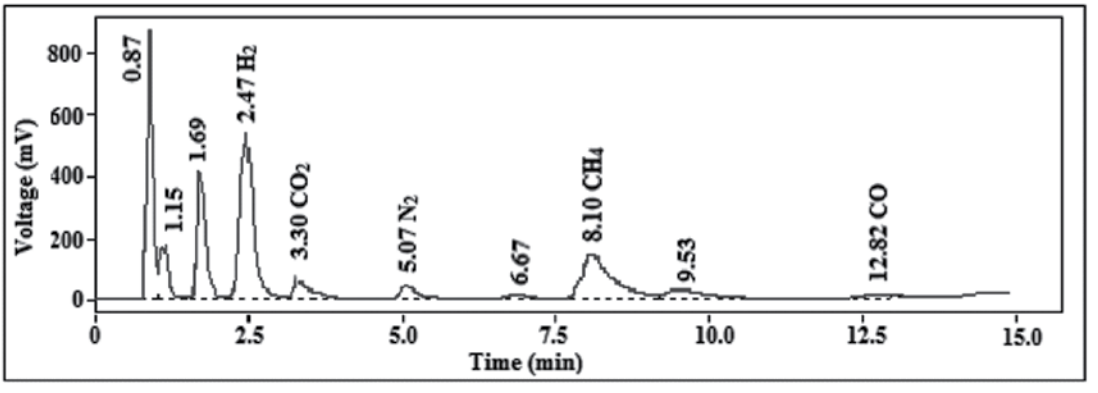

Fig. 3 : GC analysis of boiler grade coal at 650^{0}C

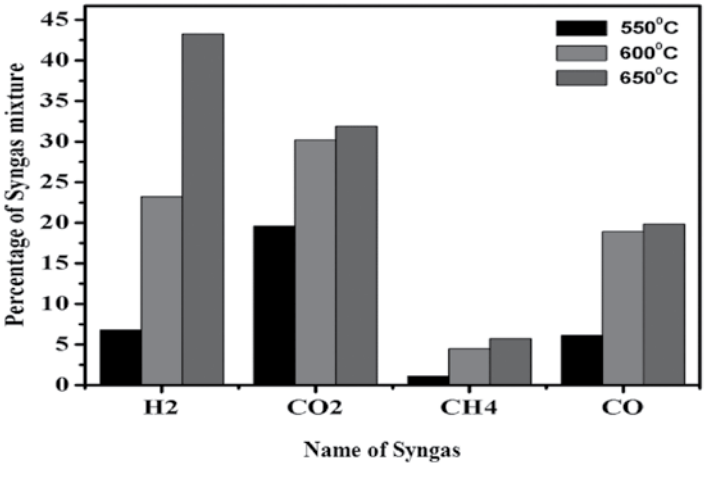

Fig. 4 : Syngas mixture of boiler grade coal at different temperatures

So it can be inferred that Hydrogen, carbon monoxide, carbon dioxide, and methane percentage of the reducing gas increases with temperature.

3.1.6 Analysis of Carbon Soot :

The carbon soot generated during pyrolysis is analyzed using XRD and FESEM techniques. Fig. 5 shows the XRD plot of carbon soot which was obtained from the pyrolysis of boiler grade coal when heated at 650°C. The plot does not show a sharp intensity peak for graphite. Instead, it shows a hump around 25°C suggesting the presence of fine amorphous carbon in the pyrolysis product. The FESEM image of the carbon soot is shown in Fig. 6. The images show agglomerated amorphous carbon particles. The size distribution of the particles is in nanometer range. This fine carbon is highly reactive for better reduction.

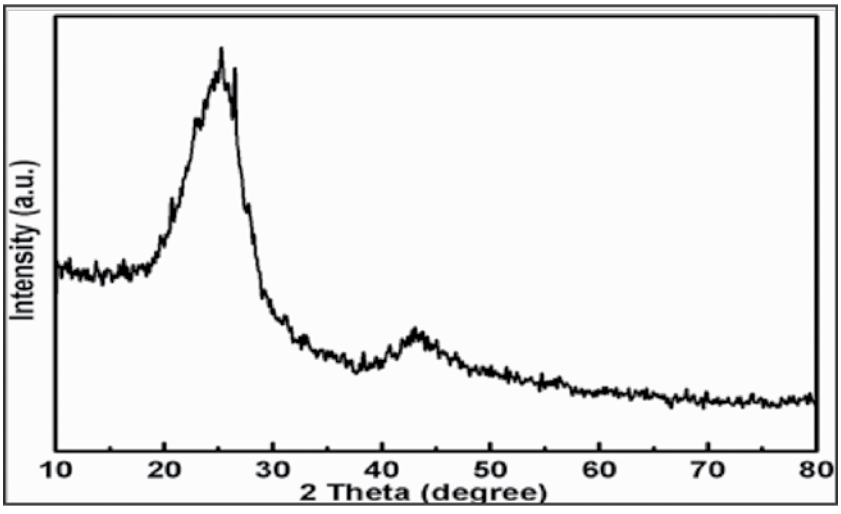

Fig. 5 : XRD pattern of the carbon soot generated from the pyrolysis of boiler grade coal at 650^{0}C

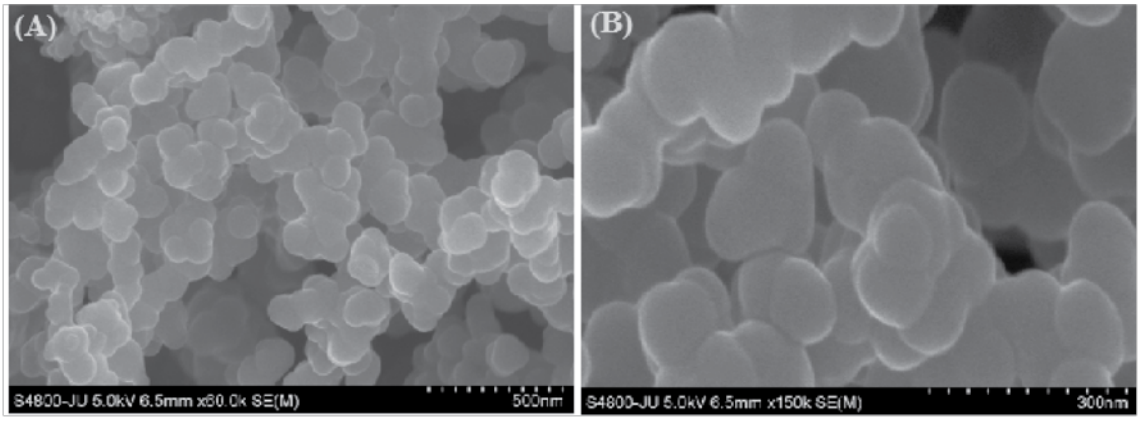

Fig. 6 : FESEM micro photograph of the carbon soot at different magnifications A-500 nm and B-300 nm

3.1.7 Analysis of Naphthalene :

Naphthalene is an organic compound, white in color. [**18**] It is highly volatiles and the simplest of the fused. Density of the naphthalene at room temperature, melting point and boiling point are calculated given in **Table 6**.

Properties	Unit
Density	1.0153 g/cm^3
Melting Point	80^{0}C
Boling Point	220^{0}C

Table 6 : Properties of naphthalene

3.2 Mechanical Properties of the Nuggets :

The shatter and abrasion indexes of the nuggets are determined for assessing their mechanical properties. Shatter index and abrasion index of each set of nuggets is given below in **Fig. 7**.

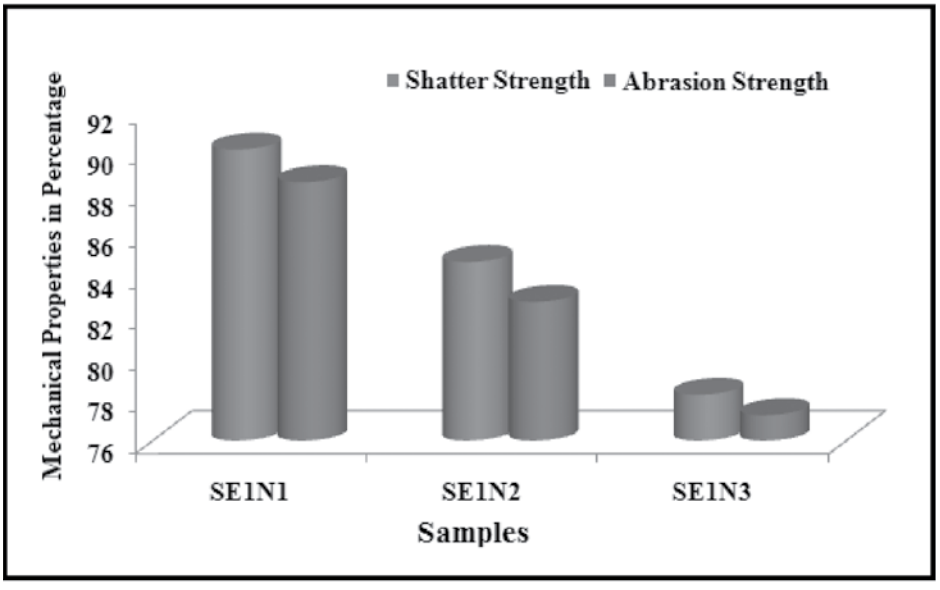

Fig. 7 : Mechanical properties of the agglomerated nuggets

It can be concluded from the **Fig. 7** that mechanical stability of agglomerated iron ore nuggets decrease on raising the naphthalene percentage and very poor shatter and abrasion index for SE1N3 sample containing 10% naphthalene.

3.3 Reduction Process of the Nuggets :

The cylindrical nuggets are fixed diameter of 25 mm, a height of approximately 5.2 mm and a mass of around 10.58 gm. Before the reduction process the nuggets are heated at 120^{0}C. This caused the naphthalene to escape as gases, thus creating pores. After that reduction is carried out by coal devolatilization

process. The reduction is performed similar to the manner as described the published in journals. [19] Reduction is carried out at 1100^{0}C, 1150^{0}C and 1200^{0}C respectively for 60 minutes.

3.4 Extent of Reduction of the Reduced Nuggets :

The extents of reduction of reduced samples are calculated from mass loss. This is calculated on the basis of reweighing the sample after reaction. A theoretical calculation of mass loss for complete reduction is calculated beforehand, also taking in account other possible cases of mass loss (e.g. loss on ignition) to reduce their effect on final calculation. It means that 100% extent of reduction signifies a complete transformation from hematite to metallic iron. The details of extent of reduction of coal devolatilization reduced samples in the form of graphical representations are given in **Fig. 8-9**. The extent of reduction is calculated from weight loss which is given details in appendix (i).

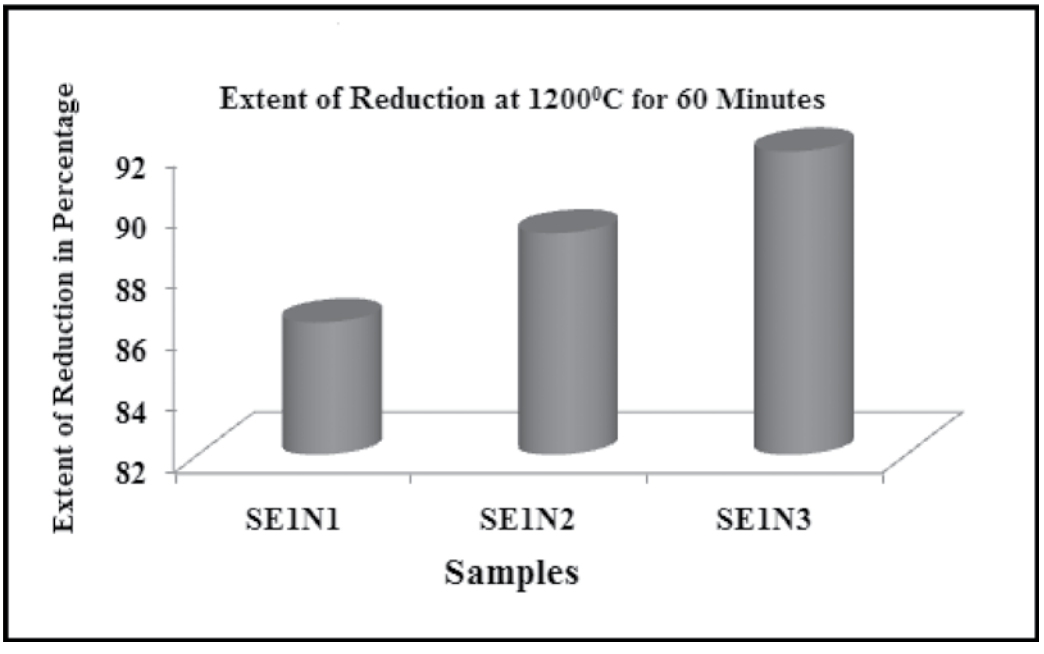

Fig. 8 : Extent of reduction at 1200^{0}C for different set of the reduced samples

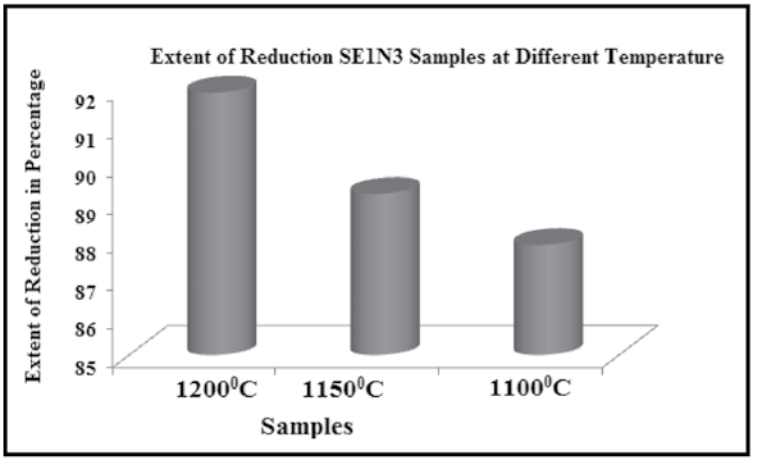

Fig. 9 : Extent of reduction of SE1N3 set of reduced samples at different temperature for 60 minutes

From the above Extent of reduction analysis, it can be concluded that the extent of reduction increases with higher naphthalene percentage. On increasing the Reduction Temperature, extent of reduction is also increased.

3.5 XRD Analysis of the Reduced Samples :

❖ **Effects on Naphthalene Percentage :**

XRD analysis of reduced iron ore nuggets are performed to identify the Phase transformation during coal devolatilization process are evaluated by XRD as shown in Fig. 10-11.

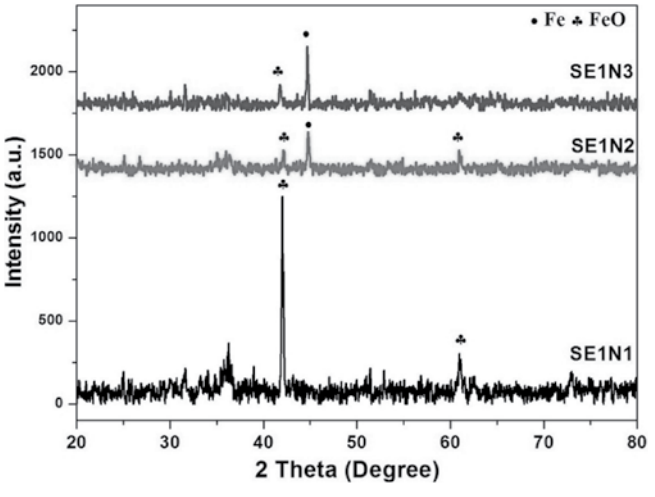

Fig. 10 : XRD analysis of the different reduced samples (SE1N1, SE1N2 and SE1N3) heat treated at 1200⁰C for 60 minutes.

Fig. 10 Show the XRD analysis of the reduced samples with different percentage of naphthalene (SE1N1, SE1N2 and SE1N3) reduced samples which are heat treated at 1200^{0}C for 60 minutes. From the XRD plots it is observed that for 0% no conversion is achieved from oxide to metal. However, with increase in naphthalene weight percentage, more conversion to metallic iron occurs as indicate by the presence of Fe peak in the XRD plot. Maximum conversion is achieved for 10% of weight percentage naphthalene samples, as indicated by decrease in the number of FeO peak.

❖ Effects on Temperature :

Fig. 11 represents the XRD plots of reduced SE1N3 samples are heat-treated at 1100^{0}C, 1150^{0}C and 1200^{0}C for 60 minute comparing the peak heights of Fe and FeO phases in the same plot, it can be inferred that at lower heat treatment temperature conversion is less and as the heat treatment temperature is raised Fe peaks becomes more prominent compare to FeO, indicating more conversion.

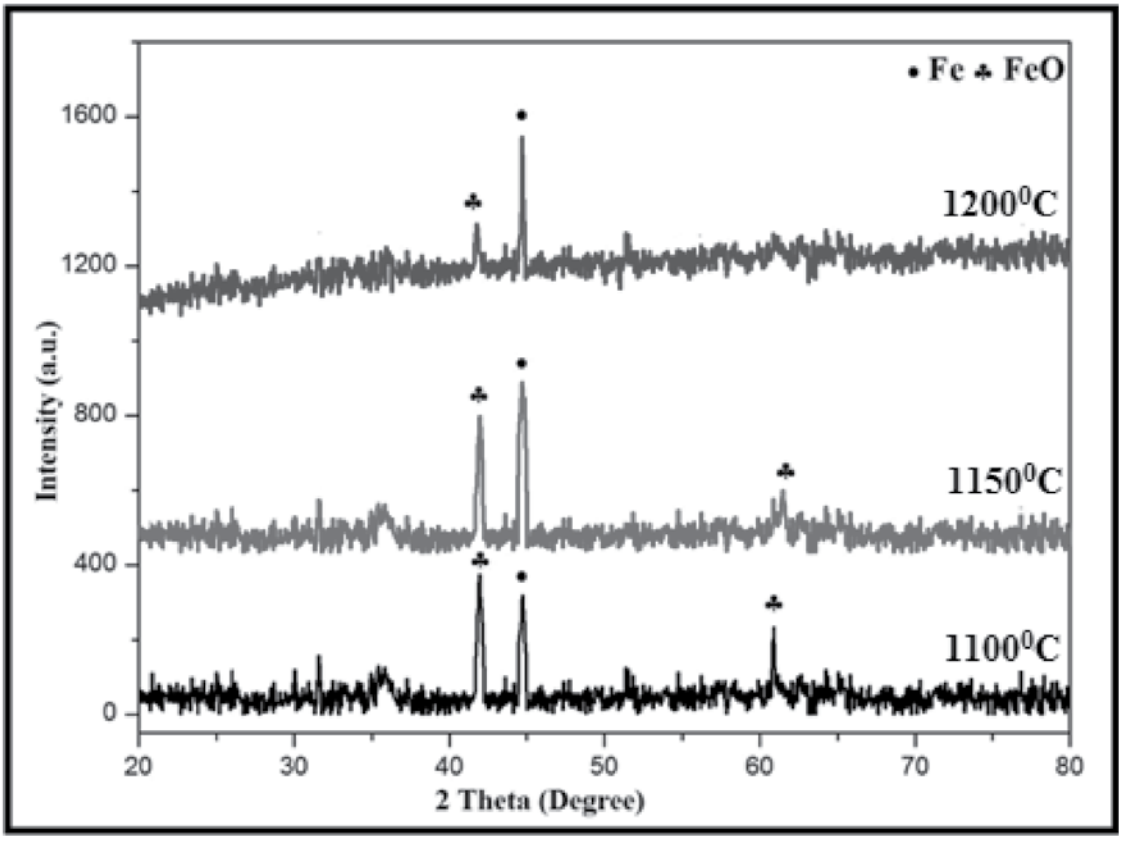

Fig. 11 : XRD plots of the SE1N3 samples, heat-treated at 1100^{0}C, 1150^{0}C and 1200^{0}C for 60 minute

From the above XRD analysis, addition of the volatile naphthalene in different percentage to achieve the porosity of the nuggets which help the gases to pass easily though the iron ore nuggets and leads to better reduction. Due to porosity, iron is found at 1100^{0}C, 1150^{0}C and 1200^{0}C for 60 minute reduction by pyrolysis process of boiler grade coal. In the previous chapter without naphthalene, transformation to Fe phase is possible only after 2 hours of heat treatment at the same temperature. Thus naphthalene addition is beneficial to the reduction of iron ore nuggets.

3.6 SEM and EDX Analysis of the Reduced Samples :

Fig. 12 (A), (B) and (C) shows the SEM micro photograph of the SE1N3, SE1N2 and SE1N1 samples which are heated at 1200^{0}C for 60 minute. The image shows agglomerated spongy honey comb structure. It is observed that with increase in naphthalene percentages the particle size increase.

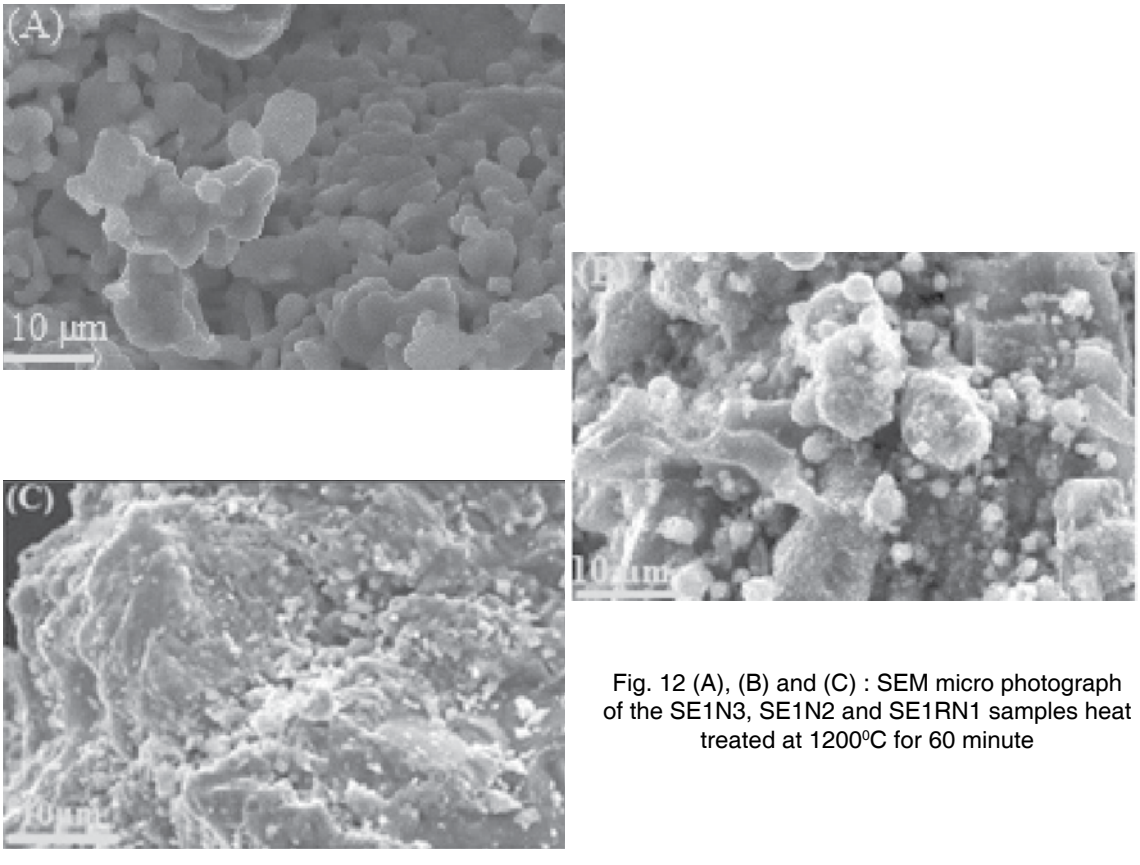

Fig. 12 (A), (B) and (C) : SEM micro photograph of the SE1N3, SE1N2 and SE1RN1 samples heat treated at 1200^{0}C for 60 minute

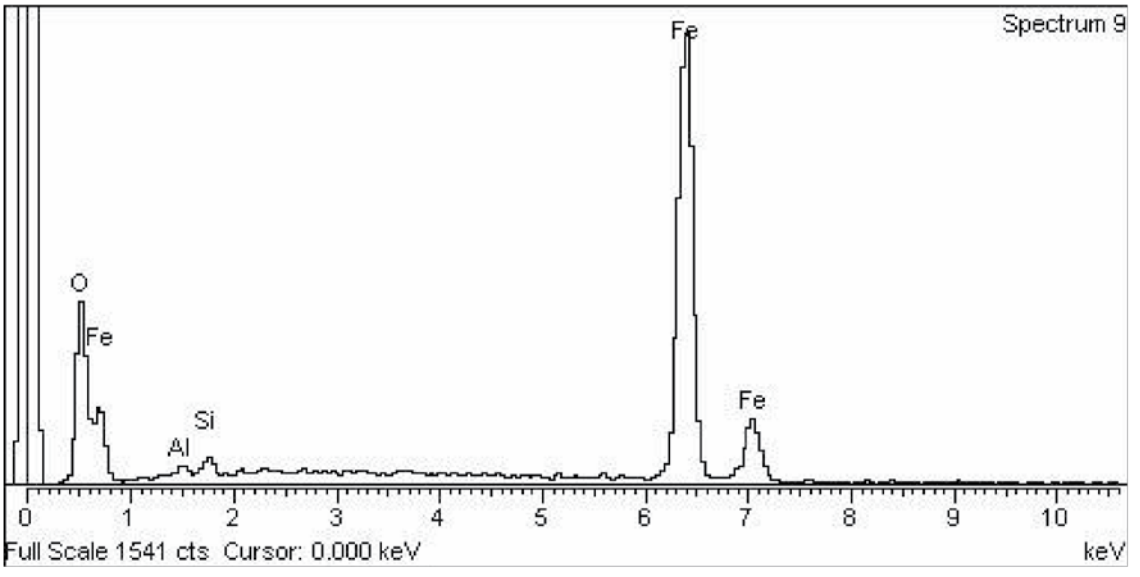

Fig. 13 : EDX plot of the SE1N3 reduced samples heat-treated at 1200^{0}C for 60 minutes

EDX plot of the SE1N3 reduced sample at 1200^{0}C for 60 minutes are given in **Fig. 13**. It shows presence of high value of Fe and small value of Al, Si, and O and the details are given in **Table 8** results represents the weight percentage and atomic percentage of the elements in the sample after heat treatment.

Element	Weight%	Atomic%
O K	11.06	31.01
Al K	0.48	0.74
Si K	0.99	1.47
Fe K	87.48	66.78
Totals	**100.00**	**100.00**

Table 8 : EDX results of the SE1N3 reduced samples heat-treated at 1200^{0}C for 60 minutes

3.7 Degree of Metallization of the Reduced Samples :

The chemical analysis of the reduced samples is performed by the standard procedure of the Bureau of Indian Standards (BIS 10812:1992). In brief, a 0.2 g sample has been taken in a dry conical flask and a 100 ml freshly prepared ferric chloride solution (10 g in 100 ml distilled water) is added to it. Then it is stirred for 30 min. A prepared acid mixture (25 ml hydrochloric acid and 25 ml orthophosphoric acid) v added to the conical flask and cooled. After cooling, the solution is titrated against 0.1 N potassium dichromate solution using BDS indicator. The burette reading is then recorded and calculated to get the total metallic iron content of the reduced sample. The results of degree of metallization are given in **Table 9**.

Samples	Degree of Metallization (%) (60 Minutes)	
	1150^{0}C	1200^{0}C
SE1N1	0	0
SE1N2	36.2	51.32
SE1N3	41.81	64.74

Table 9 : Degree of metallization of the reduced samples with different naphthalene content

From the above analysis, it can be concluded that degree of metallization increases with higher amount naphthalene percentage and temperature.

3.8 Mechanical Properties of the Reduced Samples :

The reduced porous nugget resembles a very strong and stable agglomerated metallic aggregate. On shatter and abrasion test, it is demonstrated negligible loss of material due to impact, which will make it suitable for charging in a blast furnace.

4.0 CONCLUSION

- Iron ore nuggets are made porous by adding naphthalene with the raw materials. It increases the extent of reduction (up to 91.5%) by facilitating the gas-solid reaction.
- Mechanical properties such as shatter and abrasion index are found to deteriorate with higher naphthalene percentage.
- Porosity increases with increases in naphthalene weight % and extent of reduction also become higher accordingly.
- Addition of the naphthalene in different percentage are found to give better porosity of the nuggets, which helps for better reduction by syngas as they can pass easily though the iron ore nuggets.
- Degree of metallization of the reduced hematite sample is approx 66% in the reduced samples containing 10% naphthalene.
- The pre-reduced nuggets with higher mechanical stability can be used in the blast furnace itself either as a coolant or simply as a raw material which will reduce the coke rate of the furnace because of its pre-reduced character

5.0 ACKNOWLEDGEMENTS

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Appendix 1 :

A nuggets contains 4% molasses + 4% bentonite + 2% moisture + rest iron ore

Experimental weight before reduction = 0.43 gm molasses + 0.43 gm bentonite + 0.21 gm moisture + 9.51 gm iron ore

Total weight of the Nuggets = 10.58

Loss on heating = (95%) of 4 gm molasses + (18%) of 4 gm bentonite + oxygen contained in hematite + (100%) of 2 gm moisture

100gm ore contains 91.5 gm hematite

9.51 gm ‘’ ‘’ 8.7 gm‘’

91.5gm hematite contains 64 gm iron (From WDXRF and Chemical Analysis)

8.70 gm ‘’ ‘’ 6.08 gm iron

Oxygen content = 8.70 – 7.08 = 2.62 gm

Weight loss from the nuggets in case of 100% reduction = (0.40 + 0.07 + 0.31 + 2.62) = 3.30gm

Remaining weight after reduction = (10.58-3.30) = 7.28 gm

Experimental weight after reduction = 7.51 gm

Experimental weight loss of the nuggets after reduction = (10.58 - 7.51) = 3.07 gm

Fixed weight loss of the nuggets after reduction = (0.40 + 0.07 + 0.21) = 0.68gm

Total loss of oxygen after reduction = 3.07 – 0.68 = 2.39 gm

Extent of reduction = (weight loss of oxygen after reduction / weight of oxygen before reduction)

Percentage of extent of reduction = (2.39/2.62)*100 = 91.22%

NANOTECHNOLOGY – COAL AND CARBON NANOTUBES - A PROPOSAL FOR SUSTAINABILITY OF COAL UNDER 'MAKE IN INDIA'

Dr MS Venkata Ramayya*

ABSTRACT

Nanoscience and nanotechnology is the latest science and technology for study at molecular and atomic scale, which is presently the most sought after research topics world wide. It's multidisciplinary and expected to affect the future civilization.

Coal industry from the era of its use for burning at home to steam engines is mostly used presently for generation of electricity. However, its impact on environment during mining and utilization in electricity generation and transmission is environmentally not acceptable to the modern world.

Nanotechnology benefits from the unique structure of carbon having delocalized electrons and exceptional nature of their bonding with their own and other atoms. Carbon nanotubes are used in various applications of the Nanotechnology because of their enhanced physical properties over conventional material like steel, etc. Carbon nanotubes are being manufactured from the thermal Coal and advanced research is resulting in developing carbon nanotubes at a cost of 15 to 30 $/gm.

This paper deals with the Nanoscience and Nanotechnology, its impact on Coal industry and proposes for diversification into manufacturing of Carbon nanotubes from thermal Coal for sustaining Coal mining industry.

Key words :

Nanoscience and Nano technology, Coal, Carbon nanotubes, Buckyballs, Sustainability.

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1.0 INTRODUCTION

Nano, Greek for 'dwarf'means one billionth. Measurement at this level is in nanometers (nm) – billionth of a meter. Fig. (1) shows a typical comparision of nanoscale materials.

Different authors have defined Nanotechnology from their field of study. However, as per the definition of the National Nanotechnology Institute (2015) which is popularly using Nanotechnology

- Involves research and technology development at the 1 nm – 100 nm range.
- Creates and uses structures that have novel properties because of their small size.
- Builds on the ability to control or manipulate at the atomic scale.

Further, nanotechnology deals with creation of materials, structures, devices, systems and architectures of any size by controlling matter at the nanometer length scale and more importantly, by taking advantage of novel properties that arise because of the nanoscale. Indeed, properties of materials – physical, chemical, electrical, magnetic, optical, mechanical, etc. – change when going from bulk to nanoscale. An important and fundamental idea emerging from the development of nanoscience and nanotechnology is that size is a new parameter that can be used to control the form and function of materials.

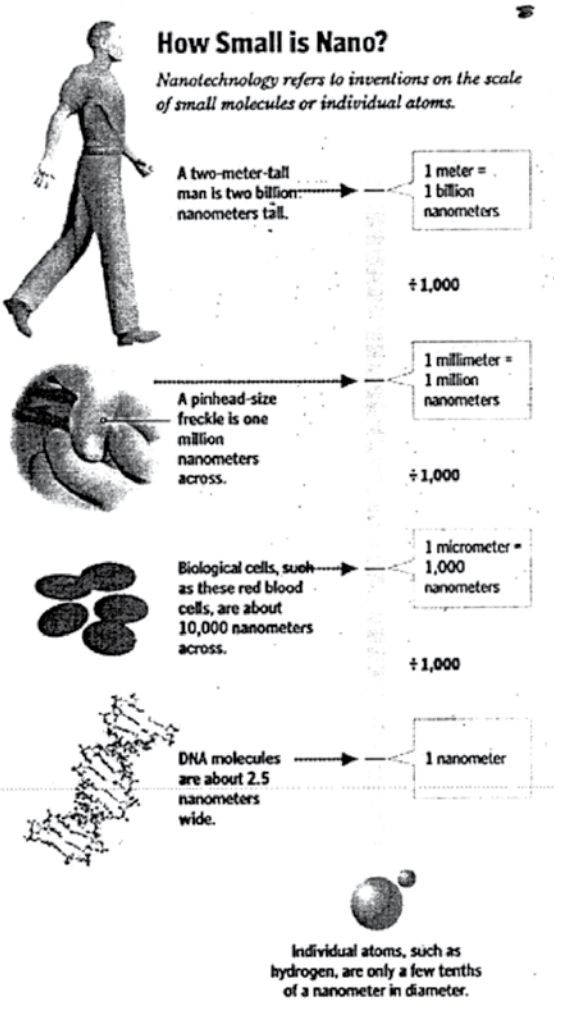


Fig. (1) How Small is Nano
Source : National Science and Technology Center
By Seethamblin and Louis Spirito –
The Washington Post

2.0 HISTORY AND FUTURE OF NANOTECHNOLOGY

Nano particles are not new to the world. They were existing in nature or generated for the use of various applications like medicines and cosmetics. However, they were not visible since the limitation of naked eye was 20

microns (a human hair which is about 50-100 microns thick).

Light microscopes invented in the 16th century could facilitate us to see 1 micron size. Scanning Electron Microscope (SEM) invented in 1930's could facilitate to see upto 10 nanometers, scanning probe microscopes developed in 1980's gave us a new way to observe at nanoscale.

Bhattacharya & Mukherjee (2008) studied the naked metal Particles. They further observed that gold particles were used in medicines during 2500BC by Chinese and also Indian Ayurveda Medicine like 'Swarna Bhasma' and 'Makaradhwaja'.

Rathore et.al (2013) have studied the physico chemical characterization of 'Swarna Bhasmas' with help of Scanning Electron Microscope (SEM). They found that nano particles of 88nm – 206nm were present in some of the Bhasmas.

Faraday made 'diffused divided gold' in 1857; which is now established to be nanoparticles of gold.

However, the vision of nanotechnology was given by Richard Feynman in 1959 in his famous talk "There's Plenty of Room at the Bottom", outlining the prospects for atomic engineering. Later, the word of nanotechnology was coined by Nario Taniguchi in 1974 to describe machining with tolerances of less than a micron.

In 1981, Gerd Binnig and Heinrich Rohrer created the scanning tunneling microscope (STM) which enabled to see and manipulate atoms for the first time.

During 1985, Robert F. Curl Jr., Harold W. Kroto and Richard E. Smalley discovered buckminsterfullerenes (buckyballs) which are soccer ball shaped molecules made of carbon and measuring roughly 0.7nm. wide. Drexler (1986) explained that what we can do depends on what we can build and studied the possible ways of stacking atoms. He further predicted that we could manufacture assembling machines smaller than living cells with atom – stacking machines.

Teri (2010) suggested that "Nanotechnology is today regarded as a revolutionary technology that can help address key needs relating to energy, environmental, health and agriculture in developing countries.

3.0 APPLICATION OF NANOTECHNOLOGY AND CARBON NANOTUBES

Nanotechnology is, at heart, interdisciplinary. It uses chemistry to get the properties of the atoms on the nano level – adding physics and quantum mechanics to the mix gives a truer picture of nano materials. Chemists, physicists and medical doctors are working along side engineers, biologists and computer scientists to determine the applications, direction and development of nanotechnology. In essence nanotechnology in many disciplines is building upon one another.

Industries such as material manufacturing, computer manufacturing and health care are all contributing directly from nanotechnological advances which indirectly benefits other industries.

Carbon nanotubes are allotropes of carbon with a tube shaped nanostructure. They are generally referred to as "CNTs" in short. Nanotubes are developed with a length-to-width proportion of upto 132,000,000:1. They have amazing properties that are significant for nanotechnology, hardware, optics and numerous different fields of materials science and innovation. Because of their phenomenal warm conductivity, mechanical and electrical properties, they discover applications as added substances to different auxiliary materials.

3.1 Forms of carbon and their significance

Carbon atoms are all over the place. They are available in millions of molecules. They have wide range of properties and are found in the form of gases such as propane to solids such as diamonds, the hardest material found in nature. Significance of carbon atoms is :

a) Carbon atoms bond covalently with many types of atoms to form molecules with properties that vary according to the atoms they have bonded.

b) Each carbon atom can form covalent bonds with four other atoms at a time. Their four bond capability allows carbon atoms to bond to other carbon atoms to make chains of atoms. They also bond with other kinds of atoms at various points along such chains. These combinations of atoms in a molecule allows for correspondingly wide range of potential properties.

c) There is no other element in the periodic table that binds as strongly to itself and in as many ways as the carbon atom.

Some of the forms of carbon, benzene, graphite and buckyballs are explained below and Fig. 2a, 2b, 2c, 3a, 3b and 3c are referred by Booker et al (2010). The details are as follows :

3.2 Benzene and delocalized electrons

Electrons in some carbon-based molecules are organized to orbitals that allow the electrons to travel between atoms in the molecule. These travelling electrons are called delocalized electrons. Carbon-based materials that have delocalized electrons can conduct electric current. The benzene is a ring of six carbon atoms, each with one hydrogen atom attached and a total of 6 delocalized electrons shown in Fig. 2(a).

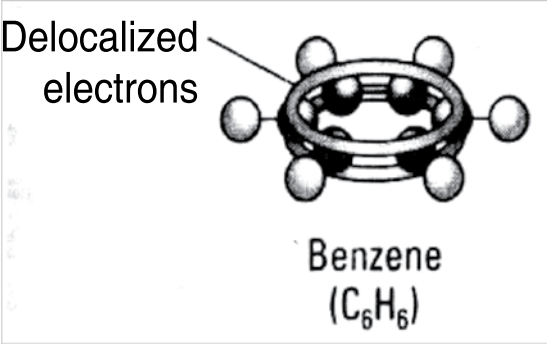


Fig. 2(a) Delocalized Electrons

3.3 Graphite and its importance

Graphite is a material that can be viewed as being built up of carbon rings (benzene without H atoms). The same electrons that benzene uses to bond each carbon atom to a hydrogen atoms in adjacent carbon rings resulting in a sheet of interlocking hexagonal carbon rings, as shown in Figure 2(b). In this structure, each carbon atom bonds covalently to three other carbon atoms. The bonds are carbon-to-carbon to the edge of the graphite sheet, where the carbon atoms bond to hydrogen atoms (one each)

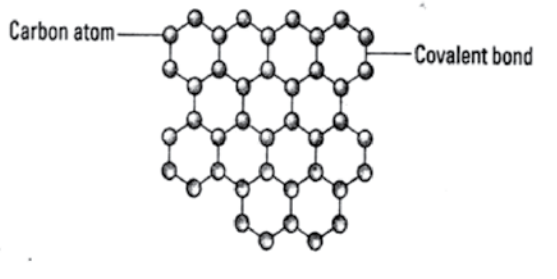


Fig. 2 (b) Structure of Carbon Atoms Connected by Covalent Bonds in a Sheet of Graphite

As with benzene, each carbon atom in graphite has an extra electron – one more than the number of atoms it's bonded to. The atomic

orbitals for these electrons overlap to form a molecular orbital that allows delocalized electrons to move freely throughout an entire graphite sheet. That's why graphite conduct electricity.

3.4 Buckyballs & Fullerness

A buckyball (short for buckministerfullerene) is a molecule containing 60 carbon atoms. After much discussion and modeling, researchers determined that 60 carbon atoms form a single stable molecule only if they are arranged in 20 hexagons and 12 pentagons that are linked to form a sphere, it's the same arrangement of hexagons and pentagons proposed by American architect and engineer Buckminister Fuller. These molecules were named as buckninisterfullernes ('fullernes' in short) in his honor. This type of spherical carbon molecule has been found in various other sizes. Each carbon atom is bonded to three adjacent carbon atoms in buckyball form a teensy-weensy sphere that's about 1 nanometer in diameter, as shown in Figure 2(c). Because one of the properties of carbon atoms is that they can bond to many other types of atoms, researchers use them to create customized molecules.

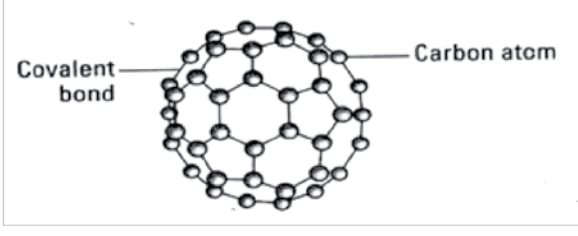


Fig. 2 (c) Sixty Carbon Atoms in the Shape of A Sphere – A Buckyball

The fullerene family of molecules is often identified by the letter C followed by the number of carbon atoms, for example C60, C70, C80, etc.

4.0 CARBON NANOTUBES

Ijima (1991) conceptualized the development of carbon nanotube.

Qiu et al (2000)has studied the preparation of fullerenes using carbon rods manufactured from Chinese hard Coals. It is found that fullerene yield increases as the carbon content in Coal increases and as ash content in Coal decreases.

The authors also experimented for the large scale synthesis of high quality double walled carbon nanotubes from Coal based carbon rods in vacuum by arc discharge method.

Harris (1996) has found that carbon nanotubes, nano particles and other graphite carbon structures are sometimes present as contaminants on transmission electron microscope (TEM) support films.

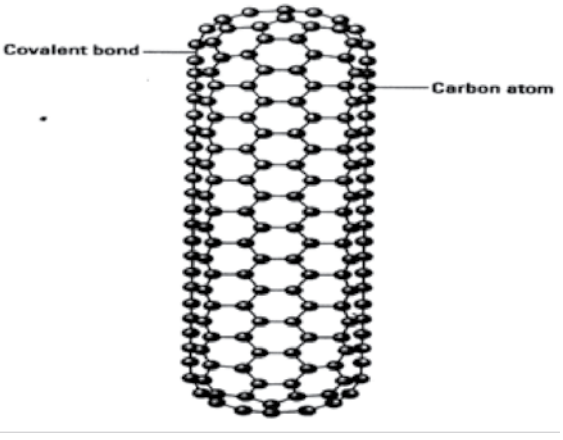


Fig. 3(a) Single Walled Carbon Nanotube (SWNT)

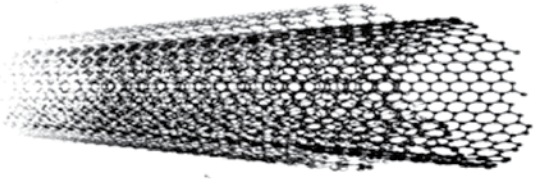


Fig. 3(b) Multiple Walled Carbon Nanotube (MWNT)

Some of the unique properties of carbon, enables them for use in development of carbon nanotubes. Nanotubes can be single walled carbon nano tubes (SWNT) or multi-walled carbon nano tubes (MWNT). (Fig. 3a & 3b.)

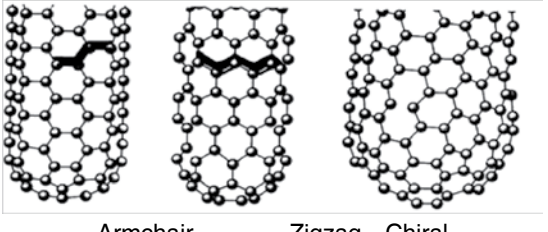
Diameter of SWNTs would be about 1 nanometer and length a few hundred nanometers.

SWNT is just a cylinder, whereas MWNT consists of multiple concentric nanotube cylinders.

4.1 Structure of Carbon Nanotubes

A carbon nanotube is a cylinder of carbon atoms covalently bonded together, resembling a sheet of graphite rolled into a cylinder. Some of these cylinders are closed at the ends and some are open. Each carbon atom is bonded to three other carbon atoms and forms a lattice in the shape of hexagons (six-sided rings of carbon atoms), except near the end. For nanotubes with closed ends, where the ends start to curve to form a cap, the lattice forms pen-tagons (five-sided rings of carbon atoms).

The lattice can be orientated differently, which makes for three different kinds of structures of nanotubes. As shown in Fig. 3 (c) in armchair nanotubes, there is a line of hexagons parallel to the axis of the nanotube. In zigzag nanotubes, there's a line of carbon bonds down the center. Chiral nanotubes exhibit a twist or spiral (called chirality) around the nanotube. This orientation of the lattice helps determine the electrical properties of the nanotube.



Armchair Zigzag Chiral

Fig. 3 (c) Armchair, zigzag and chiral nanotubes

4.2 Main methods for production of CNTs in bulk quantities

Ijima (1991)., Qui.et al (2000)., Booker. R et al (2010)., Moothi. K et al (2012) have discussed, developed and explained the methods of production of carbon nanotubes in bulk quantities. Some of the salient points of their studies and observations are as follows :

i) HIPCO – High Pressure Carbon monoxide deposition. This method involves a heated chamber through which carbon monoxide gas and small clusters of iron atoms flow.
   - When carbon monoxide molecules land on the iron clusters, the iron acts as a catalyst and helps a carbon using in carbon atoms with no hydrogen atoms attached.

ii) CVD – Chemical Vapour Deposition. In this method a hydrocarbon for example say methane gas (CH_4), flows into a heated chamber containing a substrate coated with a catalyst such as iron particles.
   - The temperature in the chamber is high enough to break the C-H bonds in the methane molecules resulting in carbon atoms with no hydrogen atoms attached.
   - Those carbon atoms attach to the catalyst particles, where they bond to other carbon atoms – forming a nanotube.
   - Similarly when carbon monoxide (CO) is flown, the carbon atom bonds with other carbon atoms to start the nanotube lattice, the oxygen atom joins with another carbon monoxide molecule to form carbondioxide (CO_2) gas, which then floats of into air.

iii). A new method uses a plasma process to produce nanotubes.

- Methane gas, used as the source of carbon, is passed through a plasma torch.
- This method with initial success is expected to be 25 times more efficient at producing nanotubes than the first two methods.

  Further, as reported by Abdul Tehman (2012), cost of carbon nanotubes can be reduced by US $ 15 to 35 per gram, much lower than world market prices. This method known as the Continuous Production Method of Carbon Nanotubes using Rotation Reactor is the first ever created in Southeast Asia.

4.3 Carbon monoxide and Methane for generation of carbon nanotubes

a. Carbon monoxide which is generated during spontaneous combustion of Coal in Underground mines is considered to be lethal even at low percentages of 100 PPm and exposure of 30 min. Though it is an unwanted gas in mines, it can be gainfully generated and utilized in manufacture of carbon nanotubes. The disadvantage of spontaneous combustion (self heating) of Coal can be converted as an advantage and channelized for production of carbon nanotubes.

b. The study of the methods of production of carbon nanotubes reveals that carbon monoxide (CO) and methane (CH4) can be used as input gas. Most safety methods of working specialized flame proof equipment, accurate monitoring are based on the experiences of deaths due to CO poisoning and CH4 explosions.

c. Similarly methane gas is absorbed in the formation of Coal and released during development and extraction of Coal. It is flammable and also forms an explosive mixture between 5-15% in the atmosphere. Methane is also generated in Mines during distillation of Coal in advanced stages of spontaneous combustion.

d. Methane is being extracted with modern methods like Coal Bed Methane (CBM), Underground Gasification of Coal (UGC) and Abandoned Mine Methane (AMM) drainage. The CH4 gas generated by these methods is very low and not able to compete with Coal in generation of electricity, though they are beneficial for improving safety in mines and improving environment by reducing their ratio into atmosphere. Since CH4 is useful for production of carbon nanotubes, the above methods may be safely and productively used in manufacture of carbon nanotubes at a cheaper rate.

4.4 Some of the typical properties of carbon nanotubes in comparison with conventional materials developed by various researchers are as follows :

a. The tensile strength of carbon nanotubes is approximately 100 times greater than that of steel of the same diameter. There are two things that account for this strength. The first is the strength provided by the interlocking carbon to carbon covalent bonds.

   The second is the fact that each carbon nanotube is one large molecule. This means it does not have the weak spots found in other materials, such as the boundaries between the crystalline grains that form steel.

b. Young's modules for carbon nanotubes, a measurement of how much force it takes to stretch a material, is about 5 times higher than for steel.

c. In addition to being strong and elastic, carbon nanotubes are also light weight, with a density about one quarter that of steel.

d. *Thermal conductivity* : Carbon nanotubes also conduct heat, they have high thermal conductivity, some researchers predict a thermal conductivity more than 10 times that of silver. While metals primarily depend upon the movement of electrons to conduct heat, carbon nanotubes conduct heat by the vibration of the covalent bonds holding the carbon atoms together, the atoms themselves are wiggling around and transmitting the heat through the material. The stiffness of the carbon bond helps transmit this vibration throughout the nanotube, providing very good thermal conductivity. A diamond, which is also a lattice of carbon atoms covalently bonded, use the same method to conduct heat, so it is also an excellent thermal conductor as well as a stunning piece of jewellery.

e. *Van der Waals force* : Carbon nanotubes are a little bit sticky, as well. The electron clouds on the surface of each nanotube provide a mild attractive force between the nanotubes, which is called the van der waal's force. This involves forces between non polar molecules (a molecule without a positive end and a negative end). A carbon nanotube just happens to be a non polar molecule.

f. Carbon nanotubes conduct electricity better than metals. When electrons travel through metal there is some resistance to their movement. This resistance happens where electrons bump into metal atoms.

   When an electron travels through a Carbon nanotube, its travelling under the rules of quantum mechanics and so it behaves like a wave travelling down a smooth channel with no atoms to bump into. This quantum movement of an electron within nano tubes is called ballistic transport. It is mainly because of nature of bonding and electron scattering that are different in metals and Carbon nanotubes.

4.5 Uses of carbon nanotubes

Carbon nanotubes are presently used in the production of end products such as memory chips, rechargeable batteries, tennis rackets, badminton rackets, bicycles, composite to manufacture cars, airplanes and so forth.

Some of the modes of carbon nanotubes and their uses are as follows :

a. In wire mode of Carbon nanotubes, for conducting of electric current without generation of heat. It would weigh less than conventional wire, while being able to conduct huge currents the impact of which would be large saving in energy technologies..

b. Carbon nanotubes are also used for detecting chemical vapours. A molecule that of chemical vapour would land on the nanotube and attach themselves to it by forming covalent bonds with the carbon atoms in it. This changes the electrical conductivity of the nanotube by decreasing or increasing the number of localized electrons available for conduction, which could be used to trigger an alarm or alert.

   Meyyappan et al (2006) has explained the method and use of carbon nanotubes in chemical and biosensors in areas of

higher sensitivity i.e., from PPm (Parts Per million) to PPb (Parts Per billion) levels and their benefits.

c. Many molecules can interact with carbon nanotubes and to ensure that sensors are detecting the right chemical, a coating is applied on nanotubes with a polymer that allows only certain molecules to reach the nanotube and block others.

d. *Storage of hydrogen* : There is also the possibility of storing hydrogen in nanotubes. Imagine a material that can absorb hydrogen like a sponge absorbs water. This material could be used as a fuel tank for hydrogen fuel cell – powered cars.

e. *Sensing strain* : Carbon nanotubes change their electronic properties and resonant frequency when subjected to strains. Bending, twisting or flattening changes the electrical properties of carbon nanotubes which can be measured at very low levels.

4.6 Cost of production of carbon nanotubes

Qiu et al found that the general fullerent yield obtained using carbon rods produced from Chinese Coals is poorer than those of pure graphite rods and other carbon rods from excellent graded foreign Coals. However, he found that with the present cost of Chinese Coal of about $35-50 per ton, its use for fullerene production is still economically more attractive. Further, Swan. H (2004) forecast that the manufacturing of carbon nanotubes would be commercially scaled for mass markets in future. Thus, if a large-scale commercial process for fullerene production can be justified in the future, Coal will be a favourable option.

Although there are several production methods and carbon sources to synthesize various kinds of carbon nanotubes carbon nanomaterials, large quantities of high purity and high quality carbon nanotubes are still too expensive for the realization of industrial application. The market for carbon nanotubes, carbon nanofibres fullerenes and graphene has been growing rapidly in recent years. The current market prices for various types of carbon nanotubes is reducing.

Abdul Tehman proposed a new method of carbon nanotubes where cost can be reduced to US $ 15 from 35 per gram

5.0 FUTURE OF COAL AS ENERGY SOURCE

5.1 Sustainable development of Coal industry

Sustainable development is defined as “Development that meets the needs of the present without compromising the ability of future generation, to meet their own needs” (WECD 1987).

Use of Coal in steam engine is a history. A day is not far off when use of Coal for thermal energy will be reduced drastically – with alternatives becoming cheaper, eco-friendly and acceptable. We cannot stay as spectators, when the whole world is against use of Coal in energy sector and Coal’s life as an energy source is coming to end shortly because of alternative source and high pollution levels. However, Coal is a great source of carbon which we may need more for development of carbon nanotubes and buckyballs which may replace the present conventional materials like steel, aluminum, plastics, etc.

5.2 Diversification for sustainable Coal industry

To sustain Coal industry, diversification into the use of Coal – particularly other than thermal generation need to be explored.

As per Milos statement (2003) the natural resources sector has the potential to contribute to wealth creation, quality of life and sustainable development. But for this to happen new technologies for natural resources and environmental management must be continuously developed and innovative

educational programmes and process must be instituted.

As a part of sustaining the Coal reserves by proper utilization and also producing carbon nanotubes from various types of Coal along with contaminates require further research. Research in application of nanotechnology is presently by Physicists, Chemists and Engineers who are mostly not related to mining experiences. In view of this, it is necessary to encourage practicing mining engineers, geologists, geophysicists, etc. to take up advance multidisciplinary research which can be more innovative, objective and useful for sustainable development of Coal industry.

The above data shows that Coal can be synthesized as Carbon nanotubes, the use of which is estimated to dominate the future expansion of nanotechnology / nanoscience in the entire world – by generation of cheaper and bulk Carbon nanotubes.

5.3 Scope for future research

Suitability of Indian Coal for synthesis of Carbon nanotubes is an important topic for future research by Physicists, Chemists and Coal producing companies so as to commercially produce Carbon nanotubes.

Drexler (2013) in his recent work Radical abundance has explained a revolution in nanotechnology will change civilization. He forecast that the new technology would be able to produce radically more of people want and at a radically lower cost – in every sense of word – both economical and environmental. According to him – mining, refining and manufacturing will have to be viewed with application of Atomically Precise Manufacturing (APM).

Coal mining industry has to take a cue from the above challenge since nanotechnology is already making alternative energy system based on the solar, quantum dots, photo electric etc. and reducing the consumption of Coal world wide since its environmentally costlier. The impact of Paris Summit (2015) and the declaration for reducing Coal consumption in future, bring in a challenge for Coal industry's survival. However, if early measures are taken by the Coal industry in a short span of five years, they may diversify into producing carbon nanotubes and other products for nanotechnology and sustain the Coal industry. At present rate of burning Coal, the world Coal reserves of 868 Billion are estimated to cater for next 115 years. However, with reduced consumption, improved methods of recovery and innovative practices for better, profitable utilization in manufacturing of carbon nanotubes, the Coal reserves may last for atleast three more centuries.

CONCLUSIONS & RECOMMENDATIONS

1. Nanoscience and technology will have severe impact on Coal industry in the next one or two decades.
2. Production of Carbon nanotubes appear to be a promising area – wherein the quantity consumed may be less but the commercial benefits are larger. Research is advancing for further understanding of properties of Carbon nanotubes in various applications.
3. Coal's future as a source of energy is reducing. To sustain Coal industry, it has to adopt methods of diversification for manufacturing of products particularly carbon nanotubes even from lethal gas like carbon monoxide and flammable gas CH4.
4. Ministry of Coal in collaboration of National Nanotechnology Initiative has to direct Coal companies and scientific institution for research and manufacture of Carbon nanotubes at large scale so that India can lead the next change of civilization and also be useful for sustaining Coal industry.
5. Necessary changes in Mining curriculum to be made by including basics of nanoscience / technology and their application at Undergraduate & PG levels

so as to motivate young engineers towards innovative and inter disciplinary research for application of nanotechnology to Mining industry in general and Coal industry in particular.

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BENEFICIATION OF INFERIOR GRADE COKING COAL FOR COKE MAKING WITH SPECIAL REFERENCE TO THEIR PETROGRAPHIC CHARACTERISTICS

Rupak Ranjan*, Ashwani Jaiswal, Pravin Naik***
Moreshwar G Borkar* & B Lakshminarasimham*

The availability of coking coal for metallurgical coke production is inadequate worldwide and at the same time its demand is high with rising steel production. Use of this good quality coking coal in coal blend is also very expensive. Hence, to minimize the coal blend cost, it is required to use low cost inferior quality coals in coal blend, keeping in mind to produce good quality coke for the smooth Blast Furnace Operation. In today's adverse and challenging market condition feasible coal sourcing is very difficult. Although, JSPL has its own coking coal mines in overseas, but the quality produced is very poor. It is having very high Ash (up to 45%) and very low Fixed Carbon (up to 39%) percentage. One of the methods to utilize these coals is beneficiation, which is being carried out at Coal Washery unit at Raigarh. JSPL has strategically invested to modernize this coal washery unit to beneficiate the inferior grade coking coal imported from its mines. The objective of this process is to ensure an uninterrupted supply of coal to the coke oven and to maximum utilization of this inferior quality coal.

In this aspect petrographic study of coal also plays an important role in coke making. The maceral composition and reflectance values along with the V-step distribution help in the initial assessment of carbonization parameters and likely coke quality with fair amount of accuracy. Maximum benefits are achieved by stamp charging method, and petrographic study helps in selecting the proper blend for the same.

This paper deals about the washing of inferior coking coal at the modernized coal washery unit at Raigarh and further maximum utilization of washed coal in optimizing coal blend with the help of coal petrographic studies, to produce consistent quality of metallurgical coke.

***Key Words** : beneficiation; coke; coal petrographic study; maceral; reflectance; CRI; CSR.*

INTRODUCTION

Minimizing raw material costs in integrated steel works has a high priority, as it represents the largest expense in steel production. Coking coal contributes up to 60% of the cost of hot metal. Therefore, it is logical that coke quality and price are the key concern for the iron and steel industry in its efforts to be competitive. Quality of coke essentially depends on the coal types, rank, preparation and carbonization conditions.

To meet the demand of coking coal for metallurgical purposes, JSPLRaigarh has to depend mostly on imported coals from different sources. Further, the raw coal with an ash% varying from 26% - 45%, is also being

***(Department** : *TSD-R&D, **Coke oven Operation)*

supplied by the JSPL group's Mining venture in Australia. Two types of coal from two mines being supplied[1]:

1. Wongawilli coal with ash% ranging from 26% - 32%
2. Russelvalle coal with ash ranging from 33% - 45%

The ash % of the above coals is very high. The quality of coke is highly depends on the ash content in the input coal which ultimately deteriorates the quality of coke. Hence, it is very important to wash these coals prior to mix in the coal blends for coke making [2], [3]. For this purpose, JSPL undertook a modernization project of their old jig washery at the Raigarh plant. The main objectives of this modernized washery is to beneficiate the inferior grade coking coal purchased from market or imported from the company owned mines abroad, and consistently supply low ash coking coal to coke oven for coke making. This project was conceived in 2012 and the modernized plant came into operations in April 2014.

Washery beneficiates the above raw coal types to produce 13-14.5% ash clean coal for the coke oven. Rejects with an ash of about 55% are being utilized in the in house power plants.

Petrographic analysis of coal as well as trials of optimized coal blend in Pilot coke ovens is very essential to use this coal in commercial coke ovens. Withstamp charging, the blend coal with low MMR can yield a good coke with high CSR value.CSR/CRI as well as Blend proportions may be predicted from the petrographic analyses with fair amount of accuracy before charging/testing any coal/ blend in the oven.

COKING COAL WASHERY, RAIGARH

The coking coal washery at Raigarh (Fig. 1),is a 200TPH plant which comprises of a crushing and screening section, followed by the two stages dense medium cyclones, which is also equipped with the reactor cell system (RCS) froth floatation machine for fines recovery. The washery receives high ash coking coal, undergoes screening, crushing and then beneficiated in the coal washing section [1].

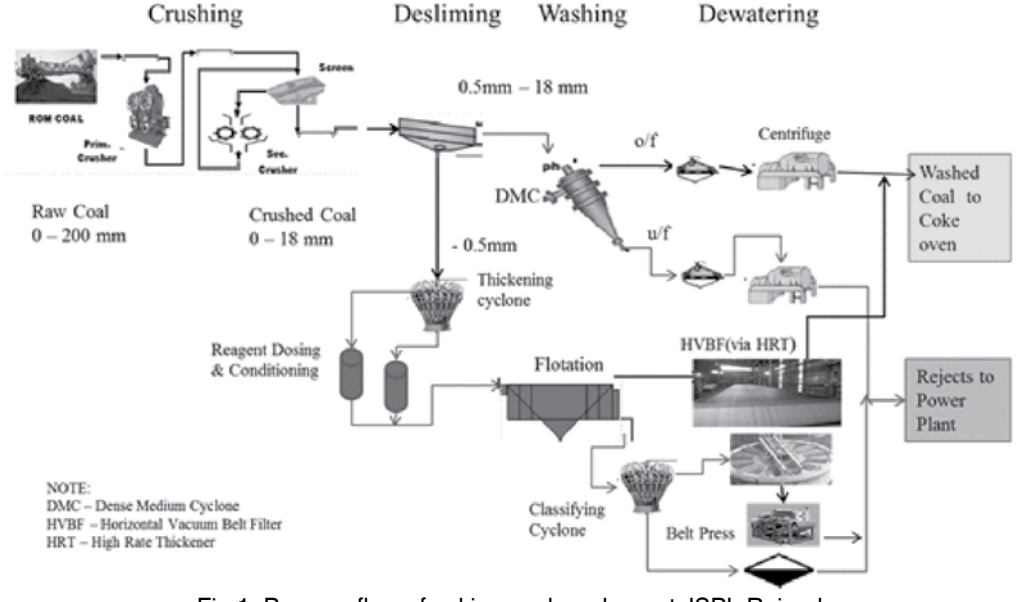

Fig.1: Process flow of coking coal washery at JSPL Raigarh

Table 1 : Input coal & product coal quality specifications

Quality	Input Coal	Wash Coal	Reject Coal
Size	0-200 mm	0-18 mm	0-18mm
Total Moisture%	8-13	14-16.50	16-19
Inherent Moisture%	1.5	1.5	1.5
Volatile Matter%	18-20	20-22	16-18
Ash%	26-45	13-14.50	52-56
Fixed Carbon%	39-50	64-65.50	28-30
CSN	2-4	6-7	<1

To ensure product quality control, an independent lab has been setup, which collects feed coal and product coal samples every hour and the analysis is done in every 4 hrs. The product dispatched is also randomly and regularly checked by the end users. Table 1 shows the input and product coal quality specifications.

USE OF WASHED COAL IN COKE OVEN

Coking coal washery plays an important role in supplying consistent quality of washed coal at 13-14.5% ash range to the coke oven but the use of this high ash washed coal in coke ovens is a challenging task. However, a deficiency of a particular property in any coal can often be supplemented by blending it with other compatible coals, since many of the properties are additive in nature. Coal petrography is very helpful for this kind of study. The potentialities of petrographic techniques have helped a lot to decide the optimum blend proportion from coal type, rank and V-step distribution pattern.

PETROGRAPHIC ASSESSMENT OF COAL

Petrographic assessment depicts the heterogeneity of the coals. Maceral composition and vitrinite reflectance percent as a rank parameter are the basic outcomes of coal petrographic studies that are in frequent use for categorizing coals [4], [5].

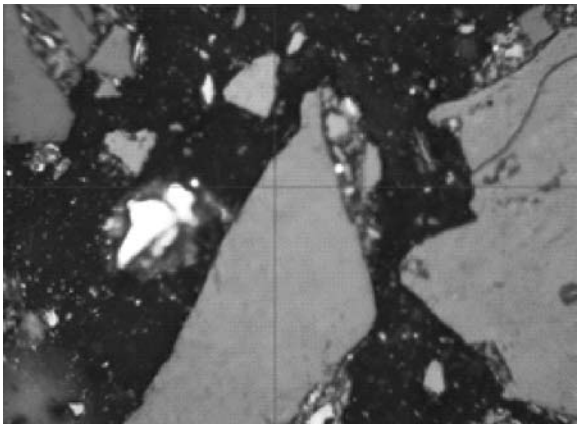

Fig. 2(a): Vitrinite under microscope

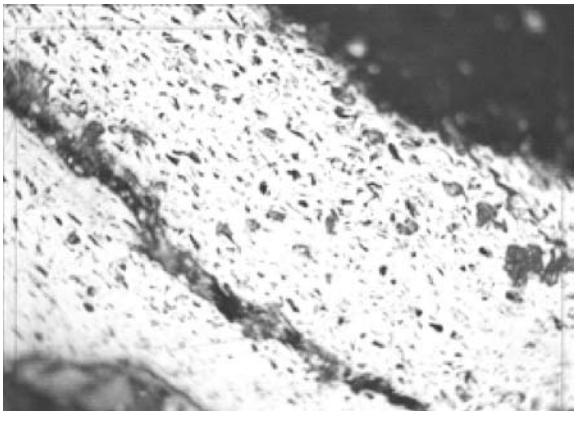

Fig. 2(b): Inertinite under microscope

Coal consists of different microscopic constituent known as macerals and associated mineral matters. The main macerals groups are Vitrinite, Semi-Vitrinite and Exinite produce plastic mass on heating in absence of air and are known as reactive. Inertinite displays negligible or no plasticity and is known as inert. Exinite contributes most to tar and gas formation. Vitrinite phase (Fig. 2a) is the principle binder. Inertinite (organic) (Fig. 2b) and mineral matters (inorganic) are the filler phases.

(Magnification : 500X)

IMPORTANCE OF VITRINITE IN COAL

Vitriniteis generally the most frequent and most important macerals group occurring in bituminous coal. The reflectivity or reflectance of the light source of Vitrinite depicts the maturity or rank of the coal.

The less matured coal will have the varying reflectance of Vitrinite in a close range, whereas the matured coal like Anthracite will have a less varying reflectance of Vitrinite.The reflectance of Vitrinite in the group of 0.8-1.4 is ideal for coke making. The reflectance of Anthracite coal will have higher reflectance>1.8.

ROLE OF MACERAL OF COAL IN COKE FORMATION

Heating coking coal at a high temperature in a coke oven for a particular period of time produces coke for metallurgical purposes.

In the course of progressive transformation, the liquid crystal phase is converted to semi coke and finally to coke. The reactive macerals (Vitrinite, Semi-Vitrinite & Liptinite) soften upon heating, becomes plastic, serves as a binder and yield varying amount of coke residue and binder depending upon the rank and particular reactive macerals composition. Liptinite depending in rank contributes to the by-products recover during coking process. Inertinite (both organic and inorganic) acts as the filler phase and binds with the reactive binder phase as such, to make a good coke there must be a definite proportion of binder phase and filler phase carbon, this is known as Composition Balance Index(CBI). V-step distribution (Table 3) is very important for judging a blend for good metallurgical coke.

The proportion of reactive to inert depending upon its rank governs the coke characteristic like coke strength after reaction (CSR) and coke reactivity index (CRI). Mineral substances convert to ash; these also act as the inorganic inerts.

EXPERIMENTAL

The preparation of coal pellets and subsequent petrographic studies of coal had been done as per BIS/ISO standards. Polarized light microscope[Leica DM4500P] (Fig. 3a) had been used for measuring the reflectance percentage and macerals analysis were done using both white light and fluorescent light irradiation at 500x magnification.

Five types of coal were tried in different combination in 250 kg Non-recovery type of pilot coke oven with stamp charging (Fig. 3b). The bulk density of cake was maintained in the range of 1.08 to 1.10. The coals were all of imported coking coals and the washed coal from JSPL Raigarh plant. The proximate and petrographic analyses aregiven in Table 2 and Table 3.

Fig. 3a : Coal Petrography Microscope

Fig. 3b : Cake charging at Pilot Coke Oven

Table 2 : Proximate Analysis and Carbonization Parameters of individual Coal

Type	Proximate Analysis					Petrographic Analysis					
								Maceral (Volume), %			
	% VM	% ASH	% M	% FC	CSN	Mean Ro	MMR	Vt	It	Lt	MM
Coal 1	21.94	9.24	11.38	68.70	7.5	1.17	1.24	68.4	21.4	5.4	4.8
Coal 2	22.88	10.05	11.83	67.08	7.5	1.12	1.19	63.2	23	8.2	5.6
Coal 3	23.91	8.82	12.87	67.28	6	1.05	1.13	62.2	23	10.8	4
Coal 4	20.79	14.05	15.55	65.53	6.5	.98	1.04	72.2	19.8	5.6	2.4
Coal 5	21.25	13.86	15.80	65.34	7	1.05	1.13	49.3	43.3	6.3	1

CSN : Crucible Swelling Number, MMR : Mean Maximum Reflectance, VT : Total vitrinite, It : Total Inertinite, Lt : Total Liptinite, MM : Mineral matter

Table 3 : Reflectance Distribution of Individual Coal

V- Step	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16
Coal 1	0	0	0	0.8	8.9	55.7	29.8	2.4	1.6	0.8	0
Coal 2	0	0	1.2	11.1	26.2	44.2	12.8	2.3	1.7	0.6	0
Coal 3	0	0.4	1.6	16.1	51	24.9	3.2	1.2	1.6	0	0
Coal 4	1.5	3.5	19	26.5	36	23	0.5	0	0	0	0
Coal 5	0	0	0	0	31.6	52	12.1	1.7	2.6	0	0

Coal 1 & Coal 2 : Hard coking coal with different MMR
Coal 3 : Semi hard coking coal
Coal 4 : Washery washed coal 1
Coal 5 : Washery washed coal 2

The complete petrographic analysis (Mean-max reflectance as well as macerals composition) is given in Table 4 with five coals.

Thirteen blends have been tried in pilot coke oven, CSR, CRI of coke with these blends have been tabulated in Table 4.

Table 4 : Petrographic Analysis of Blend and CSR CRI of resulting coke

Blend No.	Hard Coking Coal		Semi Hard	Washery washed coal 1	Washery washed coal 2	MMR	%Vt	% It	% Lt	% MM	CSR	CRI
	Coal1	Coal2	Coal3	Coal4	Coal5							
1	100					1.24	68.4	21.4	5.4	4.8	70	22
2	80		20			1.21	67.2	21.7	6.5	4.64	65	26
3		80	20			1.15	63	23	8.7	5.28	61	30
4	80		10		10	1.17	67.5	24	8.6	5.73	64	26
5	70		30			1.2	66.5	21.9	7	4.56	62	26
6	40		15	45		1.09	65.7	23	7.2	4.3	56	34
7	50		30	20		1.16	66.3	21.9	7.6	4.24	63	27
8	40	30	15	15		1.14	63.7	22.7	8.4	4.36	64	27
9	45		55			1.16	65	22.3	6.8	3.84	62	27
10	15	30	35		20	1.11	70.5	20.5	5.5	3.48	61	27
11		40	20		40	1.08	68.2	21.2	6.8	3.84	54	33
12		50	25	10	15	1.1	67.7	21.4	6.9	4	64	26
13	45	40		15		1.13	67.4	21.6	6.8	4.24	63	27

CSR in industrial ovens are 4 points higher than pilot coke oven.CRI in industrial ovens are 2 points lower than pilotcoke oven.The trials were in varying amount of hard coking coal from 100% to 0%. The required CSR value forblast furnace is 65-68 and CRI 24-26.

The best way of predicting Coke Reactivity Index (CRI) and Coke Strength after Reaction (CSR) with

Carbon dioxide can be made from micro textural analyses of coke and/or ash analyses of coal charged in the oven, along with MMR in both the cases [6]. As here these above analyses were not carried out, so in this paper prediction of CSR has been made from maceral and reflectance analysis [4]. The predicted values have been depicted in Table 4a.

Table 4a : Predicted value of CSR

BLEND NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12	13
CSR (predicted)	68	65	60	60	61	58	60	60	61	59	55	59	60

It has been observed from the predicted values that it match the experimental values with fair amount of accuracy (Fig. 4a,b)

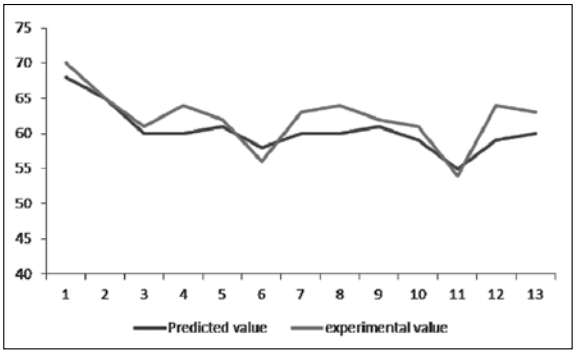

Fig. 4(a) : Chart between predicted value and experimental value of CSR

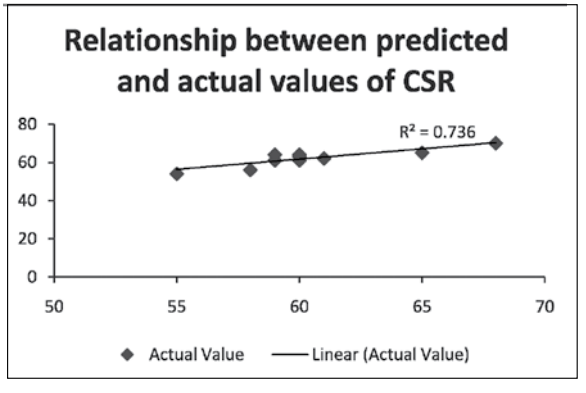

Fig. 4(b) : Relationship between predicted and actual value of CSR

RESULTS

1. Maximum use of washed coal and the semi soft coking coal has been ensured in coal blends to optimize the same with an aim to reduce the coking coal percentage.
2. We can see from the above table that when we use higher amount of hard coking coal the CSR/ CRI values is always coming good, (Blend 1).
3. Gradually by increasing of washed coal percentage and by minimizing the hard coking coal percentage in the coal blend CSR/ CRI value drops significantly, (Blend 6, 11).
4. The reflectance of vitrinite plays an important role in getting CSR value.
5. CSR of coke is very much dependent on MMR of blends. Good MMR value with close range of vitrinite distribution (V10-V12 :> 90%), gives the good CSR/ CRI Value.
6. Keeping the point no 4 and 5 in to consideration, the coal blends have been optimized. The coke result was satisfactory.
7. Till date, by optimizing the coal blends we are able to use 20% washed coal with 50% hard coking coal. The coke CSR and CRI is 63 and 27 respectively, (Blend 7).

8. Predicted values of CSR from petrographic analyses are very close to experimental values.

CONCLUSION

- Coking coal washery is playing an important role in supplying consistent quality washed coal at 13-14.5% ash range to the coke oven. Petrographic analysis of coal as well as trials of optimized coal blend in Pilot coke ovens is very essential to use this coal in commercial coke ovens. Withstamp charging, the blend coal with low MMR can yield a good coke with high CSR value. In trials, we have used maximum 20% of washed coal in coal blends which gives a good CSR/ CRI Value as per blast furnace requirement; however there is a scope to use washed coal in much higher percentage in coal blend in the coke ovens.
- It may be concluded that CSR/CRI as well as Blend proportions may be predicted from the petrographic analyses with fair amount of accuracy before charging/ testing any coal/blend in the oven.

ACKNOWLEDGEMENT

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LIST OF MGMI SPECIAL PUBLICATIONS

Name of the Publications	Year	US$	Rs
Progress of the Mineral Industry* (Golden Jubilee Vol.1906-1956)	1956	12	60
Dr. D.N. Wadia Commemorative Volume*	1965	15	100
Small Scale Mining in India and abroad*	1991	45	450
New Finds of Coal In India – Resource potential and Mining Possibilities	1993	30	300
Computer Applications in Mineral Industry*	1993	40	400
Indian Mining Directory (4th Edition)*	1993	40	400
Asian Mining 1993	1993	85	850
Mine Productivity & Technology	1994	75	500
Maintenance Management for Mining Machinery*	1995	60	600
High Production Technology for underground Mines*	1996	50	500
Mineral Industry Development in India – Issues, Perspective & Policy	1996	20	200
Disaster Prevention Management for Coal Mines, Vol I	1996	50	500
Disaster Prevention Management for Coal Mines, Vol II	1996	50	500
Business and Investment opportunities in Mining Industries (BIMI '96)*	1996	40	400
Indian Mining Directory (5th Edition)	1996	50	500
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6th Asian Mining Congress (Pen Drive)	2016	100	1000
6th Asian Mining Congress (Printed Proceeding Vol)	2016	500	5000

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