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CLEAN COAL TECHNOLOGY—A TECHNICAL RESPONSE TO THE ENVIRONMENTAL CHALLENGES

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ABSTRACT

Coal occurs in 70 countries of the world. Total proved reserve of coal in the world is about 909 billion tonnes. India contributes about 105 billion tonnes of proven coal reserves and ranks fourth in the world after USA, Russia and China. India is also the third largest producer of coal in the world, producing about 400 million tonnes annually. Jharkhand has 39480 million tonnes of proved coal reserve and ranks first in the country.

Coal produces 40% of the world's electricity and around 70% of the world's steel. Coal is used in cement, paper, chemical, pharmaceutical industries and also used as liquid fuel in transportation and electricity. Coal is mined in over 50 countries and 7 million people are employed in coal mining sector. In developing countries the coal industry is export oriented and is a major source of foreign currency. Thus, coal makes a significant contribution to global economic development.

Beside above facts mining of coal and its uses in different industries have a number of adverse environmental impacts. Use of coal causes emissions of oxides of nitrogen and sulphur, ash, trace elements and carbon dioxide. Ash from coal combustion can effect people's respiratory systems and it also impacts local visibility. This ash also causes environmental pollution. Emissions of trace elements like selenium and arsenic can be harmful to human health and the environment. During the combustion process NO_2 and SO_2 gas formed and it can increase ground level ozone, acid rain, green house effect, smog and acidic aerosols. Similarly, coal mining, particularly surface mining, also raises a number of environmental challenges like soil erosion, dust, noise and water pollution etc. which has an impact on local biodiversity.

To overcome the above challenges **"Clean Coal Technologies"** have been developed. Thus, clean coal technology is a technical response to the environmental challenges. The technology is based on the following factors:

- Carbon capture and storage technology to reduce carbon dioxide emissions.
- Improving combustion technology to increase efficiency and to reduce carbon dioxide and other emissions.
- Eliminating emission of pollutants such as particulates (ash), oxides of sulphur and nitrogen.
- Liquefaction and gasification of coal can also provide low cost secure alternatives to oil and natural gas for use in electricity, transport etc.
- Coal can also be used to generate hydrogen for completely clean future energy system.

The present paper deals with the adverse environmental impacts of coal mining and its uses in different industries, suggesting solution of this world wide problem by adopting "clean coal technologies".

Keywords: *Environmental impacts of coal mining, Environmental impacts of coal use, Clean coal technologies, Technological research.*

INTRODUCTION

Coal is an extremely important and widely distributed fossil fuel of the world. The total proved reserve of coal in the world is about 909 billion tonnes. India contributes about 105 billion tonnes of proven coal reserves and ranks fourth in the world. India is also the third largest producer of coal in the world, producing about 400 million tonnes annually. Jharkhand has 39480 million tonnes of proved coal reserve and ranks first in the country.

Coal is also a widely used fossil fuel of the world. About 40% of world's electricity and 70% of world's steel production are dependent on coal. Some 23% of primary energy needs are also met by coal. The International Energy Agency expecting 43% increase in use of coal by 2020. So, coal is a very important fossil fuel of the world.

Beside above facts mining of coal and its uses in different industries have many adverse environmental impacts also. Burning of coal can cause emissions of oxides of nitrogen and sulphur, ash, trace elements and carbon dioxide. These emissions are very harmful to human health and environment. Similarly, mining of coal also has a number of environmental challenges like soil erosion, dust, noise and water pollution etc. which has an impact on local biodiversity. To overcome these challenges "Clean Coal Technologies" have been developed.

ENVIRONMENTAL IMPACTS OF COAL MINING

Mine subsidence

In underground mines ground level lowers as a result of coal being mined beneath. A thorough study of subsidence pattern of a particular region is required to minimize the problem.

Water pollution

Coal mining activities can expose rocks which contains pyrite. This pyrite reacts with air and water to form sulphuric acid and dissolved iron, called 'acid mine drainage' (AMD). This AMD dissolves heavy metals such as copper, lead and mercury into the underground and surface water. AMD can be treated by adopting following methods:

Active treatment: It involves installing a water treatment plant, where AMD is first dose with the lime to neutralise the acid and then pass through settling tank to remove the sediments and heavy metals.

Passive Treatment: It is a self operating system that can automatically treat the effluent without constant human intervention.

Dust pollution

It is mainly caused by drilling and coal crushing operations. Trucks being driven on unmetalled road and wind blowing over mined areas can also cause dust pollution.

Dust pollution can be controlled by spraying water on roads, stockpiles and conveyors. Fitting of dust collection systems on drilling equipments can also minimize the problem.

Noise pollution

Noise pollution can be controlled through the careful selection of equipment, insulation, lubricant and sound enclosures around the machinery.

Rehabilitation and reclamation

Mine reclamation activities includes shaping and contouring of spoil piles, replacement of top soil, seeding with grasses and plantation of trees in the mine-out areas. Care should also be taken to relocate stream, wild life and other valuable resources. The reclaimed land now can be used for agriculture, forestry, wildlife habitation and recreation.

Methane gas

Methane (CH_4) is a potent greenhouse gas released from the coal seam during mining operations. This gas can be utilized rather than released to the atmosphere.

ENVIRONMENTAL IMPACTS OF COAL USE

- *Particulate emissions:* Particulate emissions such as ash from coal combustion affect people's respiratory system, impacts local visibility and also causes dust problems.
- *Trace elements:* Trace elements emissions from coal-fired plant includes mercury, selenium and arsenic. These trace elements are very harmful to human wealth.
- *NOx:* Oxides of Nitrogen (NOx) formed during combustion process may lead to acid rain, smog and global warming.
- *SOx:* Mainly sulphur dioxide (SO_2) is formed during combustion of elemental sulphur present in many coal seams.
- *CO_2:* Carbon dioxide is formed when coal is burnt to get heat and electricity. Burning of coal produces about 9 billion tonnes of carbon dioxide every year which is being released to the atmosphere. This carbon dioxide is also a significant greenhouse gas and main cause of global warming. Burning coal without adding to global carbon dioxide level is a major technological challenge of the world.
- *Waste from coal:* It consists mainly of un-combustible mineral matter.

CLEAN COAL TECHNOLOGIES

The technologies employed and being developed to meet with environmental challenges of coal mining and its use in different industries are termed as "Clean Coal Technologies". These technologies are detailed below:

Carbon capture and storage (CCS) technology

Carbon capture and storage technology allow emissions of carbon dioxide (CO_2) to be 'captured' and 'stored,—preventing them from entering in the atmosphere. Power plants with CCS technology could reduce carbon dioxide emissions by 80 to 90%.

Process of carbon capture

(a) *Post combustion capture:* In this process an amine solvent is used to remove the carbon dioxide from the other flue gases – primarily air. The CO_2 is then stripped off from the solvent and the re-generated solvent is re-used. All conventional power plants can adopt this technology to remove the CO_2 from the flue gas stream.
(b) *Pre combustion capture:* It involves IGCC technology, in which hydrogen is produced along with CO_2. The hydrogen is then combusted in a gas turbine and the CO_2 is captured for storage or use.
(c) *Oxy fuel combustion:* In this process coal is burnt in a oxygen rich atmosphere to produce a pure stream of CO_2. The same technology can be used in "steel production" also.
(d) *Chemical looping:* In this process coal is combusts indirectly in an air fired boiler that uses a continuously looping solid oxygen-carrier. It oxidises the fuel into water and CO_2. Condensation of water then yields a fairly pure stream of CO_2 for compression and liquefaction.

Process of carbon storage

The process is also called as "Geological Storage" or "Sequestration Process". In this process CO_2 is pumped deep underground and is compressed by the higher pressures to become a liquid which then easily be trapped in the pore spaces of rocks. In other words 'Sequestration' refers to disposal of liquid carbon dioxide, into deep geological strata.

Geological features being considered for CO_2 storage falls into three categories:

(a) *Deep saline formations:* These are deep permeable reservoir rocks such as sandstones that are saturated with very salty water and are covered by a layer of impermeable cap rock such a shale or clay. CO_2 can inject into these permeable strata which dissolve in the saline water of the reservoir rock.
(b) *Depleted oil and gas fields:* CO_2 have a positive commercial value in the oil industry for enhanced oil recovery (EOR). When CO_2 is injected into an oil field, it mixes with the crude oil causing it to swell and thereby reducing its viscosity. It causes movement of the crude oil towards the production well. In other situation injected CO_2 if not mixes with oil, it raises the pressure in the reservoir, helping to switch the oil towards production well.
(c) *Unmineable coal seam storage:* When CO_2 is injected into the in situ coal seams it accumulates on its surface and displaced other harmful gases such as methane. In this process CO_2 had been stored in the unmineable coal seams and CO_2 is not found in the produced methane gas.

Combustion technologies

A number of advanced coal combustion technologies have been developed to improve the efficiency of coal fired power generation plants, which reduces the emissions of CO_2, NOx, SOx and particulates. These technologies are:

(a) *Fluidised bed combustion (FBC) technology:* The technology reduces SOx and NOx emissions by 90%. In this technology, coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. By elevating pressure within the bed, a high pressure gas stream is produced which can be used to drive a gas turbine to generate electricity.
(b) *Supercritical and ultra supercritical boilers:* Supercritical and ultra supercritical power plants operate at temperature and pressure above the critical point. At this condition working

fluid (water) no longer turns into steam but decreases in density. This results in higher efficiencies and lower emissions than traditional coal fired plants. More than 240 such high efficient units are in operation world wide. China has 22 such units.

(c) *Integrated gasification combined cycle (IGCC):* In this technology coal is gasified through a controlled shortage of air or oxygen in a pressurised reactor called "gasifier" to create a 'syn gas' – a mixture of hydrogen (H_2) and carbon monoxide (CO). This 'syn gas' is first cooled and cleaned of impurities like sulphur, then combusted with air or oxygen to drive a gas turbine. The exhaust gases are then converted into superheated steam, which can also drives a steam turbine. The technology reduces emissions of NOx by 33%, SOx by 75% and almost no emissions of particulates.

Pollution control technologies

(a) *Coal cleaning:* It is a process of 'coal washing' or 'beneficiation', by which mineral matters such as clay, sand and carbonates are removed from mined coal to produce a cleaner product. The process reduces ash content of coal by over 50% and also reduces CO_2 and SO_2 emissions. It also increases heating value and quality of coal by reducing sulphur and other mineral constituents.

(b) *Particulate emissions:* Technologies that can be applied to reduce particulate emissions are:

- *Electromagnetic precipitators (ESPs):* In this technology particulate/dust laden flue gases are passed horizontally between collecting plates having an electric field. The electric field creates a charge on dust particle which attracted towards the collecting plate and then accumulates on the plate. By this process fly ash emissions can be reduced up to 99.8%. Example – The Lethabo power station of South Africa uses ESPs.
- *Fabric filters:* Fabric filters collects particulates from the flue gas on a tightly woven fabric by sieving and other mechanism.
- *Hot gas filtration systems:* The system operates at higher temperature (500–1000°C) and pressures (1–2 MPa) eliminating the particulates before cooling of the gas.
- *Wet particle scrubbers:* In these scrubbers water is injected into the flue gas stream to form droplets. The fly ash particles meet with the droplets to form a wet by-product and disposed easily. The technology has limited use in USA with particulate removal efficiency of about 90 to 99%.

(c) *SOx and NOx:* Technologies are available to minimize SOx / NOx by over 90%. These are:

- *Flue gas desulphurisation (FGD) technologies:* The FGD technologies are in use in USA to remove post combustion emissions of sulphur dioxides up to 97%. There are six main FGD technologies – wet scrubbers, spray dry scrubbers, sorbent injection process, dry scrubbers, regenerable process and combined SOx / NOx removal process. Wet scrubbers commonly uses lime or limestone based alkaline slurry which reacts with sulphur dioxide of the flue gas to form gypsum.
- *Low NOx burners:* Low NOx burners can reduce NOx emissions up to 55%. Currently there are over 370 coal fired units worldwide that uses low NOx burners.
- *Selective catalytic and non-catalytic reduction (SCR and SNCR):* These techniques can lower NOx emissions up to 90%. In SCR ammonia vapour is used as the reducing agent and is injected into the flue gas stream passing over a catalyst. The reducing agent reacts with NOx of the flue gas to form water and nitrogen. In SNCR technique catalyst is not needed but it requires higher temperature between 870°C to 1200°C.

Gasification and liquefaction techniques

(a) *Gasified coal:* Coal gasification converts solid coal into a gas which can be used for power generation, chemical production and also converted into liquid fuels. China, America and European countries already producing 'syn gas' for lighting and other purposes.

(b) *Underground coal gasification (UCG):* UCG is a method of converting unmined coal into combustible 'syn gas' – a combination of Hydrogen and Carbon monoxide. Two wells are drilled in the unmined coal, one for the injection of the 'oxidants' (water/air or water/oxygen mixtures) and other some distance away to bring the product gas to the surface. The coal at the base of the first well heated to temperature that normally may cause the coal to burn. But through careful regulation of the oxidant flow, the coal does not burn, rather separates into 'syn gas' and is drawn out from the second well.

Chinchilla project of Australia is using UCG method. USA, W. Europe, China and Japan also have undergoing demonstration project.

(c) *Coal to liquids (CTL):* Coal derived liquid fuels are sulphur free, low in particulates and NOx. These liquid fuels can be used for transport, cooking, power generation and also used in chemical industry. South Africa has the only CTL industry in operation. In Australia and China, CTL projects are under development.

Methods of liquefaction

(i) *Direct liquefaction:* It works by dissolving the coal directly in a solvent at high temperature and pressure. The process is highly efficient but requires further refining.

(ii) *Indirect liquefaction:* Coal gasification produces 'syn gas' and the 'syn gas' is then condensed over a catalyst to produce high quality ultra clean petroleum, diesel, lubricants and other liquid fuels.

(iii) *Hydrogen based energy system:* Hydrogen produced from coal can be used to produce electricity from gas turbines and fuel cells. It can also be used as conventional transport fuels. Some countries like USA and Japan already have vehicles operating on hydrogen today.

Hydrogen can be produced from coal by first gasifying the coal into 'syn gas'. The 'syn gas' is then shifted with the addition of steam to produce additional hydrogen and to convert the carbon monoxide to carbon dioxide. The CO_2 is then separated having a pure stream of hydrogen.

TECHNOLOGICAL RESEARCH

Research, development and demonstration (R, D and D) programmes have been undertaken by the many countries of the world. These programmes have huge contributions in the development of clean coal technologies and highly efficient coal fired power plants. A number of programmes are also aimed at achieving an ultra low or near zero emissions future.

Some ongoing projects are detailed below:

(a) *AD 700 power project - Europe:* Funded by EUs, the project is beginning its operation in Germany in 2005. The focus of this project is to establish ultra supercritical coal fired plant to raise the efficiency level by 55% and reduction in CO_2 emissions by 15%.

(b) *Canadian Clean Power Coalition (CCPC):* CCPC is a coalition of Canada's coal fired electricity generation companies and Electric Power Research Institute, USA. The aim of

CCPC to demonstrate commercially viable carbon capture and storage technology in a coal fired power plant by 2012.

(c) *CANMET energy technology centre - Canada:* It is a research unit under the Department of Natural Researches, Canada. The main research is on oxy-fuel combustion and fluidised bed combustion technology to reduce CO_2, SOx and NOx emissions.

(d) *Carbon Sequestration Leadership Forum (CSLF):* CSLF is an international initiative for the development of carbon capture and storage technology through collaboration. Some 21 countries and European commission are members of this forum.

(e) *COAL-21-Australia:* COAl-21 is a major initiative of the Australia Coal Association aiming towards zero emission technology to produce electricity from coal.

(f) *Co-operative research centre for coal in sustainable development (CCSD):* CCSD is an Australian initiative to optimise coal's contribution to a sustainable future.

(g) *EAGLE Project, Japan:* It is a major project to develop coal gasification technology for use in fuel cells.

(h) *Future gen USA:* The project was launched in 2003 with an aim to create the world's first zero emissions fossil fuel plant.

(i) *UK and China clean coal agreement:* In 2005 the UK signed an agreement with China on near zero emissions coal fired electricity (nZEC). The project is aimed to demonstrate carbon capture and storage technology in coal-fired power generation plants in both countries by 2020.

(j) *Central Institute of Mining and Fuel Research (CIMFR), India:* The CIMFR Dhanbad, is a constituent laboratory of Council of Scientific and Industrial Research (CSIR) of India. It is aimed to provide R&D inputs for the entire coal-energy chain from mining to consumption.

INDIA AND CLEAN COAL TEHNOLOGIES

All operating coal fired plant in India uses subcritical steam condition. Two supercritical power plants are under development at Sipat, Chhattisgarh. India has a 6.2 MWe IGCC demonstration plant at Triuchipalli in Tamilnadu. Another demonstration plant is also in operation at Aurya in U.P. Carbon capture and storage is another option being investigated by India. India is also member of the 'Carbon Sequestration Leadership Forum' and involved in the 'Future Gen Project'.

CONCLUSION

Coal is the cheapest and most abundant source of energy in the world. The present scenario is that its demand is increasing day by day. As a result CO_2 and other emissions will increase by 55% in the coming 20 years. Due to which the whole World will have to face either energy crisis or environmental disorders such as global warming and climatic change. "Clean Coal Technologies" are the only solution to get rid of these problems and will prove to be a boon for the mankind.

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