ABSTRACT

World energy demand is growing. The US Department of Energy (DOE) predicts that world energy demand will increase by nearly 44% from 472 quadrillion Btu in 2006 to 678 quadrillion Btu in 2030. The reason for this is the continuing growth in world population, especially in the newly industrialized and developing countries, although figures have slowed down somewhat in recent years. This factor, combined with the economic catch-up process, has resulted in an enormous accumulated demand for energy. If world energy supplies are to be safeguarded, then a contribution will be needed from each and every type of fuel. Renewable energies, backed up by political support and substantial development aid, will increase their share of the market in the years ahead. There are major political reservations about nuclear energy in many countries. The traditional fuels, namely oil, gas and coal, will therefore still be called upon to bear the brunt of the energy-supply load and by 2030 these three sources will be responsible for meeting almost 70% of world energy demand.

The world still has an abundant availability of coal deposits, an advantage not shared by other fuels such as oil and gas. When measured against current production levels, existing reserves are expected to last for another 200 years and are therefore capable of meeting phenomenal growth in energy demand.

Overall Installed capacity of power generation in India (2009-10) is to the tune of 1,56,092 MW against the demand of 2,00,000 MW and against very low per capita power consumption and a projected demand of 3,50,000 MW in 2020. There are four major categories of source of Power in India namely Coal Based Power Plants or Thermal Power Plants (64.6 %), Hydroelectricity (24.7...
Nuclear Power (2.9%) & Other Energy Sources (7.7%) like Solar Energy, Wind Energy, Bio-gas Energy etc. In Indian scenario we can not increase the hydroelectricity share rather it will reduce once the demand of power grows. This is because of the various socio-political hindrances and resistances. Nuclear power will also not pick up due to apprehended nuclear proliferation. Thus only two options are left as far as supply of power in India is concerned. Again due to lack of political will and poor policy implementation records wind and solar energy potential is not going to be harnessed on mass scale. Thus only one option of thermal energy seems to be the major source of power supply in India in near future.

Mahanadi Coalfields Limited (MCL) is a subsidiary of Coal India Limited (CIL) dealing with coal mines of Orissa State. It was established on 03.04.1992 and has now become the second largest coal company in CIL. There are two coalfields in MCL, Ib-Valley in Jharsuguda & Sundergarh districts and Talcher in Angul district with Hq. at Jagriti Vihar, Burla, Sambalpur.

Out of India’s total coal reserves of 267.21 B T Orissa has 65 B T (24.6%) and ranks 2nd in India. Out of India’s recoverable coal reserves of 73 B T Orissa has 23 B T (32%) and ranks 1st in India (http://www.gsi.gov.in/). Ib-Valley Coalfield contains 35% of the total coal reserves of Orissa while Talcher Coalfield contains 65% of the coal reserve.

Coal production in MCL in the year of inception was 23.14 Mte which is going to touch 137 Mte in the year 2011-12, registering a whopping growth of 492% compared with the year of inception. Average yearly growth rate is 9.4% since inception, comparable with growth rate of China and much better than average.
growth rate of World standing at 5%. Such ambitious coal production programme is only feasible through high capacity opencast mines. Such big mines can not give sustained production without control of environmental pollution in the mining areas. Air Pollution, Water Pollution and Land degradation are the three major environmental pollution due to opencast mining activities. Out of the these, Air pollution due to dust is the most important. All major mining activities in opencast mining contribute to the problem of suspended particulate matter (SPM) or dust directly or indirectly. Therefore, assessment and prediction are required to prevent and minimize the deterioration of dust due to various opencast mining operations.

It has been established that the main air pollutant generated by opencast quarrying is dust, and that the impact of other air pollutants is not significant. Therefore, for the purpose of the current study, only particulate matter has been considered.

For animals coal dust is a tumorigenic agent (Capable of causing tumors) associated with lymphomas (any of various usually malignant tumors that arise in the lymph nodes or in other lymphoid tissue) and adrenal cortex tumors. Coal dust causes pneumoconiosis, bronchitis and emphysema in exposed community. Plants exposed to toxic dust exhibit lesser growth, become more prone to disease attack and rodent attack, their stomata and other holes get choked and they also gasp for oxygen. Fruits, vegetable and cereals from these plants contain toxins. On-set of bio-chemical reaction when constituents present in the coal dust starts reacting with the constituents of the host surface materials resulting in increase in the rate of weathering/weakening.
Air pollution, especially dust, is a major environmental issue in the coal mining areas. Dust generation may be loosely defined as the process by which particulate matter becomes airborne, to be carried downwind from the point of origin or source. Such generation is termed a fugitive (or open) dust source. The main sources of dust generation at Talcher Coalfield include mining operations in the active quarry zone like Drilling, Blasting, Loading of overburden, Loading of coal, transportation of overburden, dozing of overburden, transportation of coal from the active mining areas to the crushing units and to dispatch points like sidings, Coal Handling Plants where coal is crushed to -100 mm size and finally Railway sidings where coal is loaded by mechanical means into the wagons. In addition to these, non mining sources also contributes heavily towards the pollution which include Rampant burning of coal for domestic purposes, Dhabas (road-side small hotels) etc and other industrial uses like brick clins etc. There has been tremendous increase in the number of Dhabas in Talcher Coalfield in the recent past. This is because there are variety of job in the mining areas like contractor laboures working in CHP, Siding, Private Workshops, persons working in explosive companies, tipper and truck drivers and their helpers, payloader operators etc. The volume of coal to be handled is so huge that it generates many jobs. Availability of theft coal is very easy and therefore these dhabas are a big success for the investors. They contribute a lot towards SPM. Similarly, Brick Clins and other industrial activities based on burning of coal are also mushrooming in the coalfields area. Transportation of Coal loaded tippers to the washeries, transportation of the empty tippers to the mine for taking another load and transportation of washed coal to the Railway
Dispersion Model is a powerful tool for prediction of impact on air quality due to any activity which causes air pollution. Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Complex mathematical operations are performed through a computer programming to give the desired output. This basically requires various input information regarding the source of pollution, rate of emission, characteristics of pollutants, meteorological data, topographical features etc and in turn output information is obtained in terms of pollution level at various receptor location and in addition dust deposition rate is also obtained. Mostly Fugitive Dust Model (FDM) and in some cases Industrial Source Complex (ISC) models have been used for opencast coal mines (CMRI, 1998). These models have been tried extensively by Central Mining Research Institute (CMRI), Dhanbad and other research organizations in India like Indian School of Mines (ISM), Dhanbad, Regional Research Laboratory (RRL), Bhubaneswar, IT-BHU etc. CMRI (Chaulia et.al,2002) and other Scientists have concluded that Fugitive Dust Model is preferred over the Industrial Source Complex Model although the FDM model used for air quality modelling cannot include terrain features, and the model can be used only for local scale predictions. However, this model offers improved performance over both the Industrial Source Complex Model and also the Point, Area and Line source model. In view of this fact FDM model has been used for this research project.
Although models have been used earlier by the research organizations but its validation part has not been so effective. This research therefore aims at validation of the FDM model i.e determining dust concentration at predetermined important receptor locations for different meteorological inputs during the entire one year period (three seasons) + one repeat season using the FDM model and also generating extensive data at these stations by measuring the dust concentration through very sensitive Digital Dust Monitor and then comparing the predicted concentration with the actual measurement value for validation of the model. In addition, the % share of major dust generating sources has been estimated along with calculation of dissemination of dust with respect to distance from the transportation road.

Talcher coalfield, located in the Angul district of Orissa State, is one of the major coalfields containing huge reserves of power grade non-coking coal. The total area of the Talcher coalfield is approximately 1860 km², whereas potential area is 1580 km². The total geological reserve of coal at Talcher Coalfield is 42.8 Billion tonnes, which constitutes 16 % of the country’s total reserve of 267.21 Billion tones as on 1/4/2009.

Out of total production at Talcher Coalfield approximately 99.2 % is produced from Opencast mines and only 0.8 % is produced from Underground mines. Shovels of normally 5 m³ bucket capacity & Dumpers of 50 te capacity are deployed for removal of overburden for exposing the coal seam and coal is extracted by Surface Miner or through conventional drilling and blasting and then loading the coal by pay loader into the tippers of 16-17 te capacity.
In order to know the normal/ background dust level in the study area monitoring was carried out for RPM & SPM concentration at 4 locations almost free from industrial activities in all the four directions from the study area for determination of the base-line SPM concentration during all the three seasons of a year (except monsoon) and the first repeat season of second year. Average background concentration of SPM was found to be 122 μg/m³. Average background concentration of SPM was found to be 49 μg/m³.

For feeding in the FDM model, co-ordinates of the sources of pollution (Point, Line & Area Sources) and the co-ordinates of the receptor locations are required which were generated through a very advanced software by feeding Latitude and Longitude of the desired locations.

The amount of dust being formed or emitted due to a mining activity depends on a number of site-specific variable factors including the mining practice being followed, the type and size of equipment in use, topography, climate, slope, vegetation cover, brittleness and hardness of the material being handled, clay, silt and moisture content of the rock or soil material, wind speed in the region, the size of the machinery or transport equipment, speed of the vehicle, frequency of vehicle movement etc. Activity-wise emission rates have to be estimated using the empirical formulae in order to insert them as input data in the FDM Model to predict the concentration of dust at the receptor locations without actually measuring the dust level at these locations. Formulae have been used to evaluate the emission rate for the different mining activities like dust generation from transportation on haul roads, dust generation from coal transportation road, loading operations of coal at face, at CHP and at Railway
siding, unloading operations of coal at CHP Feeder Breaker end and at Railway Siding, loading operations of OB at face, unloading operations of OB at dump yard, dozing operations at OB dumping yards, coal dumping yards, CHP and Railway Siding etc.

After running the Model, RPM (PM$_{10}$) concentration at 20 receptor locations were predicted. The predicted values at receptor locations were added to the regional background level to get the total predicted 24-hr average RPM concentration for the seasons covered under the study period.

Average of model predicted RPM values (μg/m$^3$) ranged from a minimum of 50.0 to a maximum of 85.3 in pre-monsoon, 46.0 - 81.6 in post-monsoon, 47.0 - 87.8 in winter in 2008 and 48-94.6 in pre-monsoon in 2009 respectively.

**Validation of Model**

For all the 20 Receptor locations, comparison of season-wise field measured and model derived values were carried out and the results are summarized as follows.

Percentage variation between predicted values and measured values varied from 1.28 % to 19.84 % during the pre-monsoon, 0.5 % to 22.14 % during the post-monsoon, 3.53 % to 22.66 % during the winter in 2008 and 1.52 % to 23.69 % during the pre-monsoon in 2009 respectively.

Thus it can be observed that predicted values are very close to the measured value and the overall variation is approximately 11 %, thus the model can be treated as 90 % efficient.
Study of Distance Vs dust concentration from a coal transportation road

Dust particles are dispersed by their suspension and entrainment in an airflow. Dispersal is affected by particle size, shape and density, as well as wind speed and other climatic effects. Smaller dust particles remain airborne for longer dispersing widely and depositing more slowly over a wider area. Large dust particles (greater than 30 µm), that makeup the greatest proportion of dust emitted from mineral workings will largely deposit within 10 m of the sources. Intermediate sized particles (10-30 µm) are likely to travel up to 100. Smaller particles (less than 10 µm) which makeup a smaller proportion of the dust emitted from most coal workings, are only deposited slowly. Concentrations decreases rapidly on moving away from the source, due to dispersion and dilution.

From the study it was observed that dust particles will largely deposit within 100 m of the source. Concentrations decrease rapidly on moving away from the source and approached background concentrations at 300 to 500 m from the road.

Study for determining % share of the Dust Generation Activities

Dust, created through the mechanical disintegration of particulate matter, is a problem common to most surface mining operations. The broader environmental effects of dust was reviewed during this study by actuating only one source key in the model and switching off the other sources, which is possible only in computerized model, and thus an emission inventory was conducted for opencast coal mining operations. The emission inventory was
based on a characterization of open dust sources over a specific interval of time, to produce a dispersion model to enable predictions to be made concerning ambient pollution levels and the identification of major control areas. The analysis, conducted according to USEPA guidelines, found that 75% of the total emissions from the mine were attributable to dust generated from the mine haul road and coal transportation roads and the next highest source, at 15%, being attributable to CHP operations. Although a high tonnage operation, the road network on the mine was similar to other such operations and it was concluded that emissions from the road network would be typical of most opencast coal mines, when calculated on a percentage of total emissions basis.

**Conclusion and Recommendations**

World energy demand is growing and coal is the only ingredient which will fulfill this demand to the extent of 70% for at least 50 years from now because it is available in abundance. The scenario in India is almost similar and the majority of coal comes from opencast mines. In Orissa and specially in Talcher Coalfield, where this study was undertaken, the share of coal production from opencast mines constitute more than 99.2%. At present average coal production and dispatch from Talcher Coalfield of MCL ranges from 1.5 lakh te-2 lakh te/day and considering the huge demand of coal for energy starved nation this production will increase rapidly and may touch the figure of 2.5 lakh te/day very soon. Handling of such huge production results in formation of dust which is the major source of deteriorating the ambient air quality in Talcher Coalfield of MCL.
Major source of dust generation, during the opencast mining operation, crushing of coal to the required size (-100 mm) and transportation of crushed coal to the railway siding for dispatch to the Power Plants, are identified as coal transportation roads, CHPs and Railway Sidings.

Fugitive Dust Model or FDM, a conclusively more preferred model over its next competitor ISCT Model, is a powerful tool to determine the impact of various dust generation activities on the ambient air environment. This model was used to assess the impact of coal mining, crushing, transportation etc. undertaken by Mahanadi Coalfields Limited on the ambient air quality of different receptor locations and the impact was also measured by direct method of air quality sampling. The results obtained through the model were compared with the measured results to validate the model and it was found that accuracy of the model is approximately 90%.

It was also concluded that bigger size dust (more than 30 micro meter to 100 micro meter) settles within 10 m from the dust generation source like coal transportation roads, intermediate size dust (10 to 30 micro meter) are likely to settle within 100 m and smaller size dust (less than 10 micro meter size), which constitute a lesser fraction in the total generated dust, remain suspended in the ambient atmosphere for a longer period and the background concentration reaches only after 300 to 500 m from the source of dust generation.

Coal Transportation Road along with Haul Road was identified as major polluter contributing 75% dust followed by CHP which contributes 15% of dust and Railway Siding and other sources contributes 10%.
It was also observed that dust dilution potential of the prevailing atmosphere is very less during night time and thus the dust level remains high during the night time. Speed of vehicles was also found to be contributing highly towards dust generation.

**Recommendation**

**Haul Road Dust Control (Unpaved)**

Haul Road and coal transportation road contribute **maximum** towards dust generation and its dissemination in opencast mines. Conventional method of dust suppression on the unpaved haul road include water sprinkling through mobile water tanker (28,000 ltrs capacity) and grading of the road surface to take care of the un-even surface due to spillage material as well as due to movement of tyres of the vehicles with heavy loads. Pot holes and rut holes on the haul road are filled up with gravel chips (commonly called metals) and then a layer of morrum is spread on it and finally compacted by Road Roller. Chain dozers are also applied for construction and maintenance of haul roads.

Proper care/attention is required for design and maintenance of haul road as dust generation directly depends on it.

The amount of dust that will be emitted is a function of two basic factors ;

- The **erodibility** of the material involved
- The **erosivity** of the actions to which the material is subjected

In broad terms, the effectiveness of any dust suppression system is dependant on *changing* material erodibility or erosivity. The nature and particle size
distribution of a mine haul road *wearing course* material has a fundamental influence on the tendency to form fugitive dust. Particles that become suspended for a noticeable length of time are generally *<30μm* in diameter. The amount of material in this range is therefore approximately proportional to a material's erodibility. In general, the silt and fine sand content of a material (i.e. 2-75 μm) is a good indication of its erodibility.

In most circumstances regular watering, the application of chemical dust palliatives and/or the optimal selection of wearing course materials are the only viable alternatives in controlling mine haul road dust emissions.

Several products are available for controlling dust from unpaved roads. These products work by attracting moisture, binding dust particles together, sealing the surface, or some combination of these effects.

**Chloride salts** are the first category of dust suppressant. These chemicals are moisture attractants, which work by drawing moisture out of the air during periods of high humidity, particularly at night. They also reduce the evaporation rate of water during hot dry periods. This tends to hold the dust on the road surface, although there is no physical bonding.

Calcium chloride should be mixed into a solution and sprayed on the surface at a rate of 400 to 500 gram per square meter. At this rate, it would require about 4,000 kg of dry flake to treat 1 linear km of road of 10 meter wide. A follow-up treatment at half to 2/3 of the initial rate is usually needed.
Dust Suppression Strategy for Black topped Road or Paved Roads

Huge volume of coal transportation takes place on blacktopped roads for transportation of coal to the local consumers, which takes place through trucks. Approximately 35,000 te to 40,000 te coal is transported daily and if a conservative estimate is made 2,000 to 2,500 trucks ply every day for the transportation of coal. Although, there is stricture for covering of the trucks before start of the journey, still the huge traffic of trucks on the road generates a lot of fugitive dust. Three pronged approach is required to control the dust due to this huge volume of traffic:

(A) Properly surfaced and graded roads, free of rut holes & pot holes and ramblers with proper drainage and regular maintenance of the road.

(B) Evacuation of the road side accumulated dust either through mechanical sweeper or loading and transportation for proper disposal.

(C) Water spray at required interval with sufficient pressure and efficient nozzles to create fog like mass. This will reduce water consumption as well as improve the efficacy of suppressing the air borne dust.

Currently one such Mechanical Road Sweeper, manufactured by M/s TPS Infrastructure Ltd., is being used for first time in India on coal transportation roads at Talcher coalfields which are highly dusty however its movement and operation are required to be monitored very meticulously for actually reducing the dust level.
Control of dust at CHPs

Coal Handling Plants also require three pronged approach to effectively control the dust.

(A) Proper Enclosure of the dust generating operations: Receiving Hoppers along with the chain conveyor feeding the Run of Mine Coal (ROM) to the Primary crusher should be covered with corrugated sheets and flexible material from all the three sides, this is very effective in containing the dust. Primary crusher should be fully covered. Secondary crusher and the belt conveyor should also be covered properly.

Mist Spray arrangement at the unloading hopper, discharge chute and along the belt conveyor: Normally the nozzles of the misters get choked with the dust particles in the water supply line. This must be avoided and if not possible pressure filters should be used prior to the water supply. Mist spray effectively contain the air borne dust. Dry fog system should also be considered for this purpose.

(B) Regular evacuation of the spillage coal from the CHP Circuits and the CHP Complex: There is number of leakage points for coal dust spillage in the CHP Circuits and there should be arrangement for manually feeding these spillage coal by Belcha in the belt conveyor. Spillage coal at the discharge end should be lifted by pay loaders and sent to siding at regular interval. A good housekeeping is the key to reducing dust generation from the CHP Complex.

(C) Reduce the requirement of crushing by producing more coal through surface miner, because surface miner produced coal is less than 100 mm in size and does not require crushing.
Control of dust at Railway Siding

Crushed Coal from CHP or directly from surface miner face is transported through tippers which unload the coal on the platform. Then pay loaders load the coal in the wagon. Due to the unloading, loading and movement of number of tippers and at least 10 nos of payloaders in the entire 700 m long platform, Railway Sidings becomes a major source of fugitive dust emission. Water sprinkling through mobile and fixed sprinklers and good house keeping through plying of wheel dozers are the key to control of dust at Sidings.

Silo loading arrangement is recommended for all sidings which will totally eliminate tipper and payloader movement and consequent loading and unloading operations and thereby will drastically reduce the dust generation from the sidings.

Role of Surface Miner in reducing fugitive dust emission

The conventional mining requires basically three unit operations namely Drilling, Blasting and Crushing at CHP to make the coal dispatchable for use at Power Plants. Surface Miner is a machine, first time introduced in India at MCL for cutting of coal directly and the size of cuttings are less than 100 mm, thus all the basic unit operations involved in conventional mining i.e. drilling, blasting and crushing are altogether eliminated due to use of Surface Miner and thus dust generation reduces significantly. The current share of surface miner production of approximately 45 % will have to be gradually increased to 100% for better dust control.

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