

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Designing Blast-Free Opencast Coal Mine: A Socio-eco-efficient Production System

Pawan Kumar Singh

Pursuing Ph.D. Program, Department of Mining Engineering, ISMU, Dhanbad, India

ABSTRACT: Breaking of sandstone or other rocks overlying coal seams as well as coal seams in opencast coal mines is essentially required for ease in excavation. The process of breaking rocks normally involves drilling and blasting. Coal mining industry world over, for all its importance and contribution to the energy sector, is viewed with scepticism for its impacts on environment and society. Apart from other processes, blasting of rocks with explosives is a major contributor to originate several evils of coal mining like emission of noxious gases, high speed dust and fly rocks, heat, and noise and ground vibrations. Moreover, what miners get after blasting is rock wastes, lumpy coal and sometimes quality of coal also gets deteriorated due to mixing of rock wastes in blasted coal. Waste dumps also create long-term environmental problems. This paper develops a new methodology to generate sustainable value in opencast coal mining significantly increasing the inextricably-linked demand of production systems, by way of designing blast-free opencast coal mines. Mechanical method of cutting and breaking the overlying rocks and coal seams as well can replace the prevalent practice of blasting with explosives. An experiment of the designed method has been conducted using locally made simple tools and a comparative study was made to examine the benefits of the design over the prevalent practice. The method is found socio-eco-effective, economically viable and provides new business opportunity. There appears substantial prospect for applicability of the design in coal mining industry, and it deserves a high potential to become a brand CSR practice on the industry to benefit the society and improve sustainability.

KEYWORDS: Blasting, Corporate social responsibility, Environment, Opencast coal mining, Rock wastes, Sustainability

I. INTRODUCTION

Coal meets around 30% of global primary energy needs and generates over 40% of the world's electricity. Mining of coal is practiced in various nations of the world. In 2013-14, global production of coal was 7865 million ton; out of which PR China produced 46.4%, United States 11.7%, India 7.7%, European Union 7.4%, Australia 5.5%, Indonesia 4.9%, Russia 4.5%, South Africa 3.3%, Germany 2.5%, Poland 1.8% and Kazakhstan 1.5%. With a proven reserve of 867 billion ton of anthracite and bituminous coal [1], it is the most mined mineral in the world. Also, the demand curve for this sector is continuously rising. Major factors leading to a rise in the demand include the growing power sector in countries such as India and China and rising steel production. Additionally, stringent environment regulations, lead to delay in achieving production targets to match the demand from various sectors dependent on coal [2]. Coal mining industry is a critical contributor to many economies; provides employment, pays revenues to the government for providing services and infrastructure to nations, makes substantial contribution in improvement of livelihoods of communities, and is a must to sustain till other sources of energy are ensured, but the industry is struggling hard against environmental and social challenges. Abundant cheap and highly polluting energy supplies, while providing essential inputs for economic growth in the short term, result in unsustainable local, regional, and global environmental and health effects over the medium and long term, as seen throughout the industrial world and now increasingly in China and India [3].

Coal mining involves several processes like vacating the area of mining free from habits, drilling and blasting, transportation, crushing and beneficiation of coal, reclamation etc. Apart from other processes, blasting of rocks with explosives is a major contributor to originate several evils of coal mining like emission of noxious gases, high speed dust and fly rocks, heat, and noise and ground vibrations. Moreover, what miners get after blasting is rock wastes,

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

lumpy coal and sometimes quality of coal also gets deteriorated due to mixing of rock wastes in blasted coal. Waste dumps also create long-term environmental problems. Huge quantity of rocks overlying coal seams as well as coal also is blasted with explosives in opencast mines all over the world. Coal India Limited, a coal mining industry of India, alone excavated 886.53 Mm³ (million cubic meters) overlying rocks in 2014-15 [5]. For excavating this quantity of overlying rock, nearly 0.4 Mt (million ton) of high explosives were blasted. In future, the use of explosives will increase because the company has envisaged a coal production of 908.10 Mt in the year 2019–20 while it was 494.24 Mt in 2014-15 [4].

II. BACKGROUND

Methods of mining coal can broadly be classified as opencast mining (also called surface mining or strip mining) and underground mining. Which method should be used in extracting a coal seam depends upon many technological, economic, and social factors. Underground mining is comparatively better than opencast mining in view of environment and society but often more expensive. Some coal reserves where multiple coal seams are there in the world are mined first by opencast method and then underground method is used when the coal seam extends to a depth where stripping ratio increase and renders it uneconomical to continue with opencast mining. (Stripping ratio is the volume of strata overlying the coal in a specific area of the seam. A stripping ratio of 1:X means for each ton of coal production, X m³ overlying rock is removed.) An analysis of the world coal production for contributions from opencast method and underground method indicated that anthracite coal seams (less than 10 percent of world coal production) are generally mined by underground methods, bituminous coal seams (approximately 65 percent) are mined in roughly equal proportions by both methods and other inferior coal seams (25 percent) are most often mined by opencast methods. In India, nearly 90% of coal production comes from opencast mines. In near future, this is projected to increase the volume of coal production from opencast mines, requiring more removal of overlying rocks because the stripping ratio is increasing with time worldwide.

Sequence of processes in opencast coal mining generally involves (i) excavating the top layers of the unconsolidated soil (ii) drilling the hard strata over the coal seam (iii) blasting the hard strata with explosives (iv) excavating the blasted material to expose the coal seam (v) fragmenting the coal seam by drilling and blasting (vi) excavating the blasted coal and transporting to surface (vii) Crushing the run-of-mine (ROM) coal to (-) 100 mm size (viii) Despatch of coal from mine to plant, and (ix) reclamation of post-mining land. Equipment normally used includes the sets of dozer, scraper, drill, shovel, dumper, pay-loader, grader etc. At places, dragline or bucket-wheel-excavators are used. None of this equipment excluding the drill can perform their role in excavation if rock is not loose. Hard rock is normally fragmented by the way of drilling and blasting. Holes (diameter may be 25 to 250 cm) in the hard rock are drilled from top of the bench. After completing drilling of set of blast holes, drill machine is removed from the face, and the holes are charged with explosives. Use of explosives is restricted in night hours normally by law. On completion of charging the holes, all operations in the vicinity are stopped, danger zone is cleared from men and animals, and then blasting is carried out. After blasting, the blasted location is inspected and when found safe, normal works of the mine is resumed. In case, some misfires are detected, the process of dealing misfires starts discontinuing all other operations of the mine.

Blasting operations not only restrict all other operations of the mine in vicinity, but it is hazard prone if not carried out with extreme caution. Explosives when blasted in confined place create very high local pressure often exceeding 1500 bars. The pressure breaks the rock releasing blasting (nitrous) fumes, heat, high speed dusts and fly-rocks, noise and ground vibrations. Every kilogram of ammonium nitrate in explosives generates 110 litres to 600 litres of nitrous gases and 6 to 31 litres of CO in air [5] depending upon the quality of explosives, their use and situations. Nitrous fume is one of the most powerful greenhouse gases. It bears very high global warming potential (310 times that of carbon dioxide). It contributes to photochemical smog and damages the ozone layer, thus reducing the protection offered from harmful ultraviolet sun rays. Also, NO along with CO can remain in the expanded rock for a long time and NO only gradually changes to NO₂ with exposure to oxygen [6]. High speed dusts spread in surroundings and deposit upon soils, grass and leaves. Dust in atmosphere causes health problems to local population. Fly-rocks and noises make birds and animals too afraid to return to location. Ground vibrations travel long into residential places causing damage to structures, soils, flora and fauna, and creating psychological pressures on habitats.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Blasted rocks called wastes are excavated and transported to waste dumps. Wastes when dumped in mined out area, it is called internal dumps and form a part of reclamation, otherwise it is called external dumps. External dumping converts further useful land into waste dump. Waste dumps put serious impact on environment and society like land damage, loss of biodiversity, and contamination of soil, groundwater, and surface water. Wind and rainwater causes dust and chemicals from debris of mines to mix with environment and pollute air and water. Runoff of soil or rock debris - although non-toxic - devastates the surrounding land and vegetation in short-run and long-run.

On exposure of coal seam, similar process of drilling and blasting is done and blasted ROM (Run-of-mine) coal is excavated and transported to coal dump yard on surface. ROM coal is then crushed to uniform size preferably (-) 100 mm size in crushers which generate dust and consume energy.

Coalfields normally contain sedimentary strata. The sequence of geological formations of sedimentary strata in various coalfields of the world is not common but differs slightly from place to place. However, most of them contain alluvium soil, laterite, morrum, conglomerate, basalt, clay, fireclay, shale, sandstone, limestone, coal etc. Most of the rocks in these layers inevitably find some uses to humanity if mined out separately. Unfortunately, the entire mass of overburden existing over coal seams is broken and dumped as wastes which create serious long-term concern. This huge loss of sedimentary rocks in mines that have come into strata-form over ages of geological processes forming a part of our natural capital is never acceptable in the present global scenario, where all efforts are being made for sustainability.

III. SCOPE OF THE RESEARCH

Blasting of rocks with explosives, dumping of rock wastes, and crushing of coal are the most polluting processes in opencast mining. When environmental and social concerns against coal mining are on increase worldwide; air pollution levels in areas close to coal mines almost invariably exceed the permitted levels significantly and are often more than twice the permitted levels [7], this is urgent to search for a solution. The prevalent system of opencast coal mining renders huge wastage of natural capital, making all the existing thin coal seams non-extractable because they are blasted along with rocks, mixing of coal with other materials requires system improvement. Further, mining in proximity of surface structures in prevalent system of opencast mining is restricted causing the resource blocked.

In view of the above problems associated with opencast coal mining, a environment friendly, practicable, and socially acceptable and beneficial solution is the demand of time. As such, this research was conducted with the following objectives: (i) to design a method of work in opencast coal mining for excavating overlying rocks without blasting with explosives, (ii) to compare the outcome of proposed process against prevailing process, and (iii) to explore the use of removed rocks and examine whether the proposed design is useful to common people.

IV. PROPOSED METHODOLOGY OF BLAST-FREE OPENCAST COAL MINING

In this method, mechanical cutting of rock strata and coal seam is done to replace the drilling and blasting operations in opencast coal mines usually practiced to break the strata for excavation.

1. The location and area of mining operation for breaking the strata is decided as usual, and then,
2. The topsoil over the selected area, if it is there, is scraped, and preserved to be used in future for reclamation activity. If hard rock surface is not exposed just by scraping, a dozer is used to remove the unconsolidated layer, and the material is transported to waste dump. At places, in Indian coalfields, the unconsolidated layer is morrum which is a mineral widely used in road construction. It is advisable to doze it properly, and stocked separately for suitable uses.

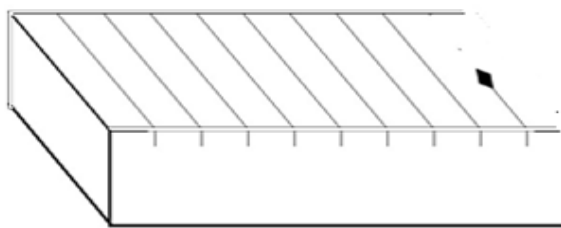
On exposure of the hard rock surface, a rock saw is deployed for line cutting resulting vertical cuts (Fig.1.a), with an ultimate aim to get the rock cut in pieces. What shall be the size of cut rock piece is decided first. The size of rock piece depends on the size of rock cutting tool, lifting or excavating machine and transporting equipment. When the rock saw is of 3 m diameter blade (Fig.1.b), the thickness (depth) of stone piece may be

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

kept 1.2 m. When the size of lifting or excavating machine is 8-12 ton or 3-5 m³, the length and breadth of the rock piece may be kept 2.4 m and 1.2 m respectively.



(a)

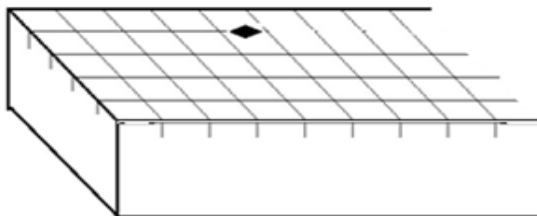


(b)

Fig.1: Line cutting to give vertical cuts across the face (a) Pattern of line cutting showing movement of rock saw across the face (b) A single blade rock saw with 3 m blade diameter available in market, Separate blade attachment is also available for getting it fit to available excavator in opencast coal mines.

For a block of 30 m in length and 12 m in breadth and to obtain rock pieces of 1.2 m X 1.2 m X 1.2 m size, 24 number of line cuts are made across the length of face at an interval of 1.2 m, each having a length of 12 m and depth of cut being 1.2 m.

- After making line cuts across the length, line cuts along the length of face (Fig.2.a) are given to make vertical cuts using the same rock saw other. Rock saws which make two parallel cuts simultaneously are available in international markets (Fig.2.b).



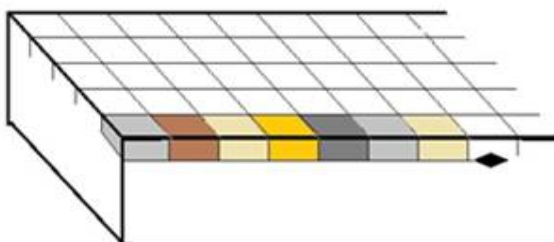
(a)



(b)

Fig.2: Line cutting to give vertical cuts along the face (a) Pattern of line cutting showing movement of rock saw along the face (b) A double blade rock saw available in market, Separate blade attachment is also available for getting it fit to available excavator in opencast coal mines

After completing these cuts, horizontal cuts along the face are started, and simultaneously the cut rock pieces are lifted out (Fig.3.a). Rock saws making vertical cut as well horizontal cut simultaneously is also available in the markets (Fig.3.b).



(a)



(b)

Fig.3: Horizontal cutting along the face to get finally cut rock pieces (a) Pattern of horizontal cutting along the face showing movement of rock saw (b) A rock saw making vertical and horizontal cuts simultaneously available in market. Swinging blade attachment is also available for getting it fit to available excavator in opencast coal mines

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Thus, a face area of bench measuring 30 m X 12 m is cut to a depth of 1.2 m into rock pieces each measuring 2.4 m X 1.2 m X 1.2 m.

4. The whole cycle is repeated to cut the bench deeper till coal seam is exposed.
5. If a soft stratum is encountered, it is scrapped or dozed out and transported to waste dump, when it is not of any economic use otherwise stacked on surface. Fireclay or shale or other layers is mined out in this method separately and brought to surface for uses.
6. When coal seam is exposed, it is cleaned properly and using a surface miner, the coal is cut in small sizes and loaded into dumpers for transporting it to surface dump. Surface miners in various sizes and designs are available in markets. Surface miners are already in use in few opencast mines for cutting soft rocks and load the cut materials into dumpers simultaneously (Fig.4.a), as well for cutting coal seams (Fig.4.b).



(a)



(b)

Fig.4: Cutting of soft rock strata and coal seam (a) A surface miner cutting soft rock and loading the cut materials in a dumper, (b) A surface miner cutting coal seam.

In this way, coal mining in opencast mines requires no blasting operations at all. All the strata overlying coal as well as the coal seam is cut and excavated.

Trial Experiment with the Method

A trial experiment with the method was conducted in one operating opencast coal mine in India. Geological borehole section indicating the nature of strata containing coal seam was studied and confirmed observing the exposed face section. It contained sandstone and fireclay layers. Both the layers had useful values. Two experimental blocks each measuring 30 m X 12 m, located side by side, were earmarked for comparing the proposed method with prevailing one.

In the first block, the prevalent practice of blasting with explosives was used for breaking the rock. On the first day, 160 mm diameter blast holes were drilled using 220 KW diesel operated drill machine. For drilling of 30 number blast holes each 5 m deep, it took 8 hour time. Next day, holes were charged with 665 Kg slurry explosives and accessories were connected. The block was blasted. The blasted rock was excavated using 3.8 m³ hydraulic shovels and 35 ton dumpers, and dumped in wastes dump. The face was cleared by next morning. Total material excavated as measured from the face was 1620 m³.

Next day, one locally arranged 10 KW electric operated rock saw having blade diameter of 70 cm was used for making cut across the length of face. It took 5 hours to complete the cutting of 12 m long, 24 line cuts across the length of face at an interval of 1.2 m, each having depth of cut 30 cm. Pouring of water on saw blade was done continuously to keep the blade cool and to suppress the dust generated. Then, the operation of cutting along the length of face was started. 30 m long, 39 cuts at interval of 0.3 m, each having depth of cut of 0.3 m could be cut in 18 hours. (One another similar rock saw had to be arranged for use but at a time only one was used). After that, horizontal cutting started. In next 20 hours, the complete block of 30 m X 12 m could be cut to a depth of 0.3 m. 15 more such operation were required to

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

completely cut the block to the depth of 4.8 m, the depth to which blasting had been done in previous experimental block.

V. RESULTS AND DISCUSSIONS

Rock cutting is an extremely slow operation as observed through the experiment. What volume of rocks were blasted and excavated in one day could have taken nearly one month by using the experimental small rock saw for cutting. Had a larger size rock saw (of 100 KW power) been used and having design for making two vertical cuts simultaneously and having provision of both vertical and horizontal cutting simultaneously, the time could have been reduced a lot. A rock saw of 3.0 m diameter blade having capacity to make 1.2 m deep cut in sandstone at a rate of 200 m per hour with attachment of two vertical cutting blades could have made 24 cuts across the length of face at 1.2 m interval within one hour only, and the cuts along length of face at interval of 1.2 m, vertical as well as horizontal well within 2 hours. Thus, the 30 m X 12 m size bench could have been cut into pieces to a depth of 1.2 m in 3 hour only. Only 3 more such cycles would have been required to completely cut the block to the depth of 4.8 m, the depth to which blasting had been done in previous experimental block. Total time taken could have been reduced to only 12 hours, making the method faster than the prevalent blasting practice. (Rock saws of various types like wire type, blade type, chisel type etc. in various designs and sizes are available in international markets, well capable to cut any soft or strongest rock masses in coalfields.) The prevalent practice of drilling, blasting and excavation in opencast mining are cyclic operations, whereas the blast-free method of rock cutting and excavation is a continuous one.

Blast-free design is a clean and safe production process. The faces after cuts are clean, providing a good look to the working place and thus improve the working environment. Wastes generation is reduced considerably. Sandstone pieces cut in sizes of 1.2 m X 0.3 m X 0.3 m obtained from the experiment when brought to surface as outcome was an attraction to all who could see them because these pieces bear potential for uses. They were cut to smaller size using chisel and hammer by local people for use of their own. Of course, some of the pieces had got broken either during loading into dumpers and unloading.

Handling of explosives and their uses in blasting is a highly skilled job, whereas cutting of rock could be done by providing only two hours training to operators. No noxious gas, no ground vibration, no fly rocks make the method safer over the prevalent practice.

All rocks in layers are cut separately in this method, and stacked as per their economic uses, while in blasting; all rocks in layers get mixed and dumped as wastes. Even, coal sometimes gets mixed with stones in blasting, deteriorating the quality. Multiple thinner seams which are unworkable in prevailing process of opencast mining become workable by application of the blast-free design, and thereby total reserve of coal will increase. Moreover, the design enables selective mining; as a result quality of coal improves.

Cutting operation can be continued in night hours also but blasting not. In the same mine, the cutting process can be done on various benches and even on single bench, more than one cutting machine can be deployed. All other operations in the mine does not discontinue when cutting of rock is going on. All other operations in the mine are stopped during blasting.

Advance of opencast mine towards public property, residence etc. is restricted to some distances by law when blasting with explosives is practiced in opencast mines. The distance in blast-free design is well reduced because it does not create any ground vibration or excessive noise or polluting gases. Dust generation in cutting process is well suppressed with water as done in drilling blast holes.

The size and cost of these saws are comparable with drilling machines in uses in opencast coal mines. Existing excavators can also be used as rock saws by way of some modifications and replacing its bucket with a rock cutting blade or saw attachment. The industry can adopt the design easily.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

VI. CONCLUSIONS AND RECOMMENDATIONS

Application of the blast-free designed methodology for breaking overlying rocks to replace the prevalent practice of blasting in rocks and coal seams in opencast mines will make the production system socio-eco-effective. The entire mass of overburden existing over coal seams that have come into strata form over ages of geological processes can be put into good uses if mined out properly, while it is converted into rock wastes in prevalent mining system. This huge wastage can be substantially reduced by the blast-free design and the industry can increase the local production capacity, reduce the environmental risks of mining by eliminating blasting with explosives and reducing waste dumps. Moreover, the thin coal seams which are considered non-extractable can be mined out on application of the proposed design. Mixing of coal with other materials, restriction of mining in proximity of surface structures and other several environment-related problems that are associated with blasting practice can easily be dealt with by the industry simply by switching over to the blast-free design methodology.

Integrating CSR and sustainability measures in core operations of the industry

In response to global call for sustainable development, business organizations all over the world are making efforts for integrating corporate social responsibility (CSR) and sustainability practices in their core business operations. Even if a few percentage of rocks broken by the coal mining industry for excavation which are dumped as wastes, is mined out by applying the blast-free method, and the cut pieces of rock is offered to local population for further processing, it will create a huge employment opportunity. For example, if Coal India Limited had mined out its 20% of total overlying rocks excavated last year, nearly 180 Mm³ rock would have been available to local population annually and nearly 16500 persons per day would have got employment, each with 3.5 m³ rock to reshape it as per requirement. With providing a few tools and some training to the local population and offering cut rock pieces to them, they will get employment. This may become an excellent integration of CSR in core operations of coal mining industry. Sedimentary rocks cut in sizes bear a good market as construction material. Sandstone pieces obtained from blast-free opencast coal mines can be cut and split into smaller sizes. Although, the sawing of rocks allows greater degree of control in the finished size and uniformity, but splitting sandstone is generally much more efficient in terms of time and labour. Splitting sandstone is a semi-skilled job of boring a row of holes or carving a trough across the area to be parted, and then wedging the material apart. Dry wooden wedges into the trough are inserted, and then wood wedges are soaked with water, which subsequently expand and split the blocks in two. Alternatively, chisel and hammer are used to split and shape the smaller units of sandstone. Rectangular pieces of sandstone like bricks are more hard than conventional burnt clay bricks, compact, fine, and possess good compressive strength and low absorption property. They are used for making fencing walls (Fig.5.a), paving walls and hard surfaced floors. Sandstone strips bear good resistance against chemicals and reflect natural beauty wherever used in wall cladding (Fig.5.b), roofing and flooring etc. These forms of sandstones had earlier been used extensively in the world.



(a)

(b)

Fig.5: Utilization of cut rock pieces (a) Fencing walls made of rough shape rock pieces cut through chisel and hammer (b) Sidewall made of good quality rock pieces cut through saw

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Involvement of less competent local population with mining for generation of their livelihood is considered urgent for obtaining the social license to operate. For the purpose, the paper suggests integration of corporate social responsibility and sustainability measures with core business operations of the industry by way of providing some tools and training and offering cut rock pieces to local population for shaping them into useful forms and sizes. This may generate employment opportunities on large scale and can turn around the public image of the industry from the destroyer to the creator.

The study will pave ways for further research into development of novel ideas of uses of materials mined out, and design of new machines and equipments.

REFERENCES

- [1] BP Statistical Review of World Energy, 2015
- [2] ICC Coal Report, The Indian Coal Sector: Challenges and Future Outlook, 2013
- [3] Human Development Report, United Nations Development Programme, 1 UN Plaza, New York, NY 10017, USA, 2011
- [4] Directors' Report, Coal India Limited, 2015
- [5] Persson, P., R. Holmberg, and J. Lee: Rock Blasting and Explosives Engineering, CRC Press, New York, 1994
- [6] Krivtsov, N. V., and N. S. Miroshnichenko: Assessment and Expedient Monitoring of Nitrogen Dioxide Emissions During Industrial Blasting Operations: Metall. Gornorudn. Prom-st, pp. 67 - 69, 1999
- [7] Black and Dirty: The real challenges facing India's coal sector- A report by Prayas Energy Group, 2013

BIOGRAPHY

PAWAN KUMAR SINGH

BORN: 27th July 1959

Education:

1. B.Tech. in Mining Engineering, Banaras Hindu University, Varanasi, U.P., India, 1984
2. Pursuing Ph.D. Program in Mining Engineering, Indian School of Mines University, Dhanbad, Jharkhand, India, continuing since 2014

Professional Qualification

First Class Certificate of Competency to Manage Coal Mines, 1988
Working in Coal India Limited as mining engineer, continuing since 1984

