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Abstract

Strategic Mine Planning – A Case Using MineOpt Software

Ranajit Das*

ABSTRACT

Strategic Mine Planning is often thought to be limited to pit optimisation, although pit optimisation is a major part of Strategic mine planning it encompasses much more. Optimisation techniques have been in vogue in the mining industry for over half a century for determining the ultimate pit limits and the pushbacks. The most common algorithm had been the Lerches Grossman algorithm popularly known as the LG algorithm which is now being replaced by the Pseudoflow algorithm used for determining the nested Pit shells. Optimisation in mine planning has mostly been limited to generating nested pit shells.

With the advent of modern mine planning tools such as MineOpt, the extent of strategic mine planning has been extended beyond Pseudoflow. MineOpt replicates the workflow in Mine Planning, thereby following ultimate pit generation and design it uses MILP(Mixed Integer Linear Programming) techniques to find the optimal sequence of mining and dumping, including in-pit dumping as well as hauling.

This paper explains the workflow in mine planning with special reference to strategic mine planning, followed by a case study using MineOpt mine planning software.

INTRODUCTION

Strategic Mine Planning

Strategic mine planning is a critical stage of a mining project that aims to capture the maximum economic potential of mineral resources. The decisions taken at this stage largely determine the expected cash flows of the project. For an open-pit mine, there are two important problems that the strategic planning process must address: the ultimate pit limit problem (it defines the mineable reserves) and the life-of-mine (LOM) production scheduling problem (it defines when the reserves should be extracted to maximize the net present value or NPV). (Morales, Seguel, Caceres, Jelvez, & Alarcon, 2019)

Mining companies are required to generate value and attract investment (financial and social) for their mineral assets based on a detailed strategic mine plan. A strategic mine plan must consider several parameters like geology, market price trends of the commodity, geotechnicals, cost of operation, feasibility, and more. The physical parameters of a mineral resource such as type, nature of mineralisation, and physical structure (such as depth below surface, shape, extent, dip, and surface topography) are fixed and do not change over time. However, parameters such as price, costs, stakeholders, legal, social, environmental, and infrastructural are some that may change over time with social, political, and economic evolution. This is the spatial context that encompasses location and associated operating environment. The selection of a mineral asset portfolio is affected, in the business context, primarily by the perceived financial value such as investment, returns, and mine life, arising from the mineral assets. The estimated value of a mineral asset is driven primarily by the physical nature of the mineral resource like size, content, and depth, which drive exploitation technology selection. The market demand for the products arising from the mineral assets and the accepted level of business risk in realising the perceived value contribute to the value generation. The level of complexity and possible options that arise under these circumstances increases with movement from a single commodity, single operation in one country business through to a multi-commodity, multi-operation.

To create sustainable value from mineral assets, it is necessary to:

- Optimise the composition of the mineral asset portfolio to align with strategic and business objectives.
- Create and operate long-term assets within an anticipated long-term business environment.
- Create and retain flexibility of short-term tactical response that allows an effective response to short-term shifts in the business environment.

To achieve this, it is necessary to:

- Allow the fixed physical nature of the mineral asset(s) to drive the definition of the optimal objective, which could be to attain goals such as the lowest capital

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cost, lowest operating cost, highest efficiency, maximised cash flow.

- Define and apply different business scenarios to determine possible economic viability under different conditions.

Strategic mine planning encompasses a higher-level business outlook of the project and does not detail the operational aspects. As we go into more details about implementing a strategic mine plan we come up with a Tactical plan. The line between a strategic plan and a tactical plan is often very blurry. It could also be an iterative process. Figure 1 describes the differences between a strategic mine plan and a tactical mine plan.

The strategy is the broad plan required to achieve an objective. This involves 'free' or lateral thinking to identify all possible scenarios, which could lead to the objective. Normally, for a mining project, the objective is to obtain the best economics from a particular resource. In summary: 'define the goal'.

Tactical Mine Planning in this environment is the tactics required to achieve a strategic objective to be deployed and implemented. In the mining sense, this would be the procurement and utilization of resources, such as capital and labor, to achieve the defined strategic plan. In summary: 'achieve the goal'. Tactical and Operational go together.

Workflow in Strategic Mine Planning

Strategic mine planning starts with a geological model. This job is mostly performed by a Mining Engineer after the geological model has been handed over to him by the Geologist. The workflow has been depicted in the image in Figure 2.

Figure 1 Strategic mine plan vs tactical mine plan(Ref https://ideascale.com/blog/tactical-planning-definition/)

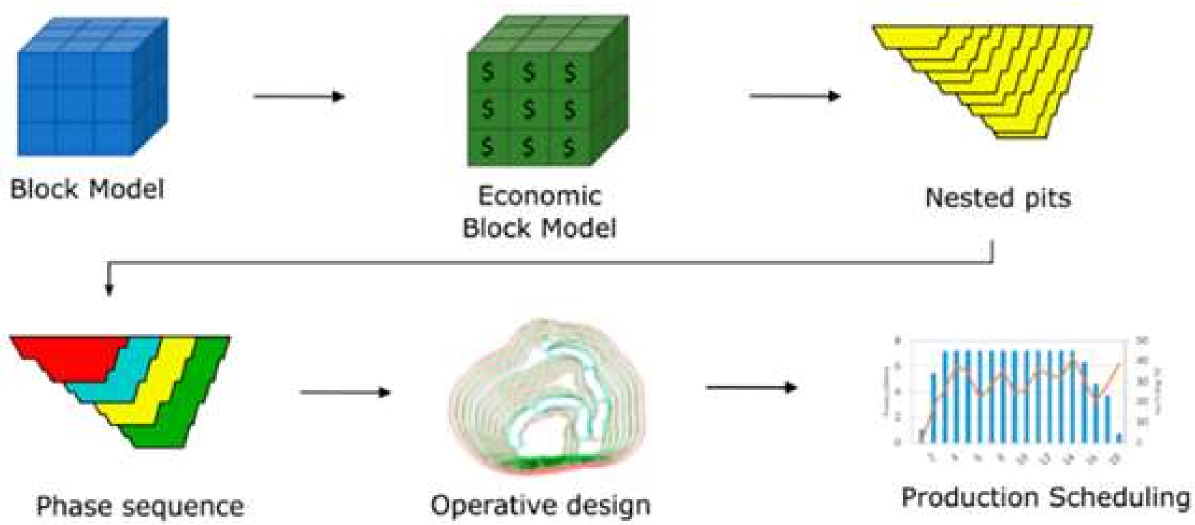


Figure 2: Traditional methodology for long-term open-pit mine planning (Morales, Seguel, Caceres, Jelvez, & Alarcon, 2019)

Block Model 

A block model is the first input required for the mine planning process, which is a representation of the inventory using generally regular block volumes. Each block of this model is assigned attributes of the deposit, such as its grade, density, rock type, and geo-metallurgical variables, among others. These attributes are conventionally estimated using geostatistical estimation techniques from available drill-hole data and sampling (Geostatistics: Modeling Spatial Uncertainty, 2009). In the case of stratified deposits, the model is based on seams or layers of ore/coal and is called a grid model. The application of estimation techniques varies to some extent in this case to domain the estimations by seams. Figure 3 shows a block model for a gold deposit and a grid model for a coal deposit side by side

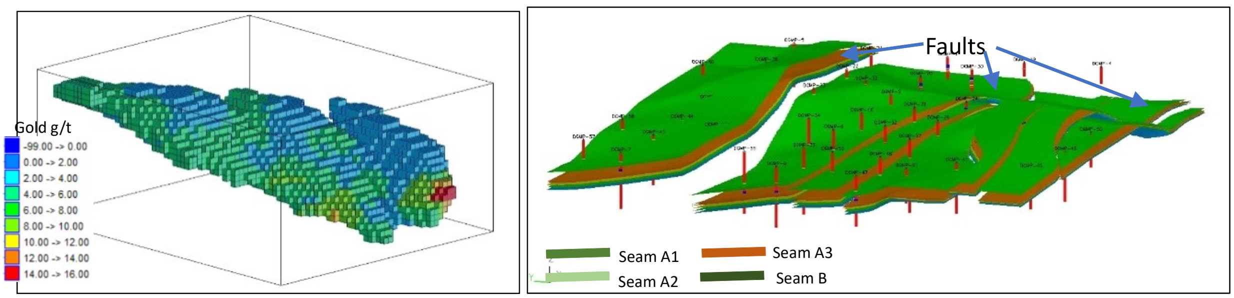
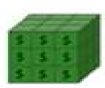


Figure 3 Example of a block model(left) vs a grid model for stratified deposits(right) (Das, Topal, & Mardaneh, 2023b)

Economic Block Model 

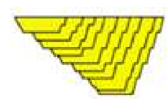
An economic block model is obtained by estimating the value of each block. Here value means the margin (Revenue-costs). Equation 1 below describes the process of value estimation of a block.

$v = (t * g * r * p) – (t * cp) – (tm * cm)$ - Equation (1)

Where,
v = value
t = ore tonnes
g = grade
r = recovery denotes mining recovery and process plant yield
p = sale price
cp = cost of processing
tm = total mined rock
cm = cost of mining. In some cases, ore and waste may have different mining costs.

Here recovery is a combination of process plant recovery and mining recovery. The value model finds the value of individual blocks; however, we are interested in the value of the entire pit, and of course, we are looking for a positive value for the pit.

It is often a practice to limit a pit to the maximum extent of the block model, or any boundary constraints such as mining lease or environmentally approved boundary etc. While this could be a possible economic limit but not always. Even if it is the economic limit, there are chances to start the mine progression in a way to compromise attaining maximum value.

Nested Pit Shells 

Finding the economic mining limits from the value model is of utmost importance. For a given price, slope, and cost, the economic pit limits are fixed.

Revenue = factor of (ore tonnages, energy, pit and wash plant recoveries or yields and product price, etc)
Cost = factor of (mining parameters, Geology/waste volumes/thickness, etc)
Slope = factor of (Geotechnical stability)
An optimum pit is a pit of maximum value.

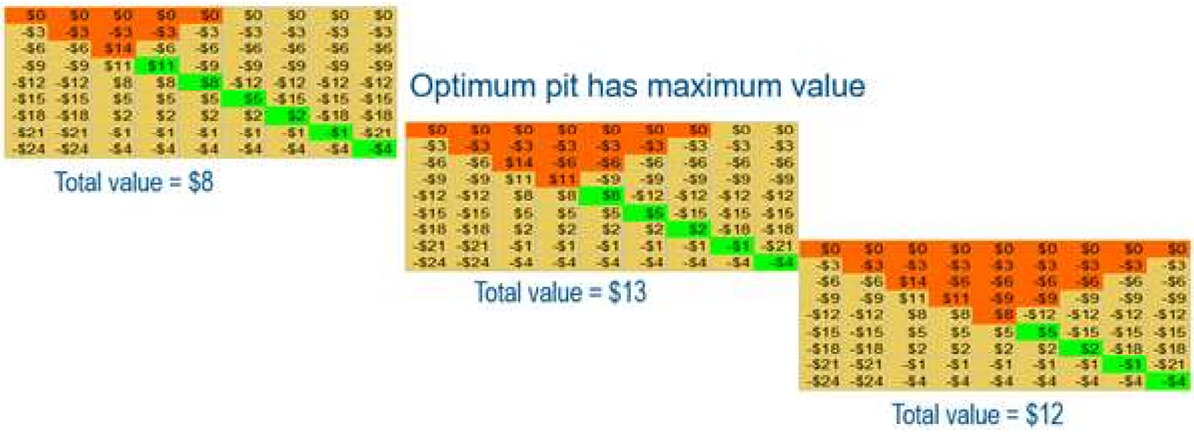
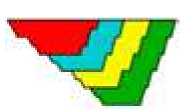


Figure 4: Optimal pit has maximum value

Figure 3 shows a value model in cross-section. There are three scenarios in the image. The green blocks are ore with a positive value and the yellow blocks are waste with a -ve value. There are 3 proposed pits shown in orange, all at a 45-degree angle. The net value for a smaller pit, the first one is sub-optimal, and the net value for the largest pit the third one is sub-optimal as well. The maximum value is obtained by the pit in the middle. This is a very simple representation of the concept. Ultimate economic pit limits are determined using pit optimisation algorithms such as Lerchs-Grossman or Pseudo Flow for a given price of the commodity, cost of mining, and other parameters. Nested pit shells or pushbacks are also created by varying the commodity price over a range as a common practice. (Das, Topal, & Mardaneh, 2023b). Keeping all other parameters the same if the price is decreased the pit size decreases. Thus, by providing a discount on the price we can generate smaller pit shells. A pit shell is a pit without any benches and berms and at an overall slope angle. To achieve practical operative pits further detailed designing is required,

Pit Phase sequencing



To obtain the best value from a mining operation the nested pit shells are often used to determine the phases of a pit over its life. Phasing involves selecting some of the nested pit shells as stages. A convention used here is by plotting a pit-by-pit graph from the nested pit shells as a stacked bar graph of the volume of ore and waste. A pit shell is generally selected as a phase where there is a significant jump in total volume from the previous pit shell. This method of selecting pit shells as phases is often manual giving rise to several possible options. Once the phases are selected then a decision has to be taken manually by the engineer on how they would be mined. Whether phase by phase – meaning complete phase 1 and then start phase 2, maintain a lead of a few benches between a previous phase and the next phase, or a mix of these two. Whittle has an algorithm in place for that known as Milawa.

However, an improved method for selecting the optimal sequence is block-level schedule optimization. There has been a lot of research in this area where Mixed Integer Linear Programming (MILP) techniques have been used. Some notable research in the area is well documented within applied literature, with notable examples including: (Johnson, 1968); (Gershon, 1983); (Dagdelen & Johnson, 1986); (Onur & Dowd, 1993); (Tolwinski & Underwood, 1996); (Ramazan & Dimitrakopoulos, 2013); (Caccetta & Hill, 2003); (Topal & Ramazan, 2012); (Groeneveld & Topal, 2019); (Mai, Topal, & Erten, 2018). Further progress on the subject was made with the inclusion of waste handling and dumping (Das, Topal, & Mardaneh, 2023b). MineOpt is one of the software that uses MILP.

Deterministic vs Stochastic Optimisation

Deterministic models are based on precise inputs and produce the same output for a given set of inputs. These models assume that the future can be predicted with certainty based on the current state. On the other hand, stochastic models incorporate randomness and uncertainty into the modeling process. (Khare, n.d.). In Equation 1 the parameters shown take precise inputs to create a value model. However, in reality, these parameters are uncertain and can vary within a range. Incorporating this range in the mine planning and optimization model gives rise to Stochastic Optimisation. (Das, Smith, Poblete, Romero, & Van Der Hout, 2021) proposes in their paper a method using the Design of Experiments to simulate a range of possibilities. (Hall & Hall, 2015) describes the Hill of Value approach as "The mine optimisation process using the Hill of Value approach is in principle no different from any other life-of-mine study that a technically competent mine planning team would conduct, except for a large number of combinations of mining options tested under a comprehensive range of input scenarios. This approach allows a thorough and rigorous assessment of the various options under the full range of likely scenarios to be investigated, and allows a robust 'optimal' solution to be identified."

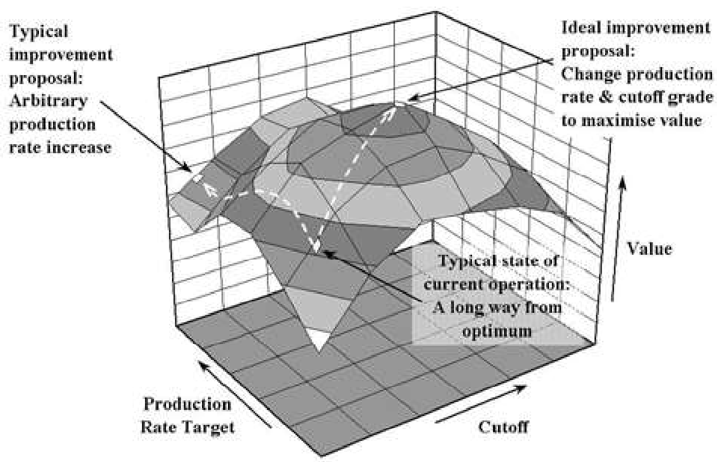


Figure 5: The Hill of Value mine optimisation technique. (Hall & Hall, 2015)

Figure 5 explains the impact on value (plotted as a surface) for changes in production rate and cut-off grade. With an arbitrary production rate increase we may achieve some improvement in value but will miss the crest of the hill. The ideal proposal is a change in both production rate and cut-off grade. Here production rate and cutoff grades can be replaced with more than two parameters.

The mine planning process described in Figure 1 has been implemented in many planning software in some form or other. For an efficient mine planning process, it is necessary to have a package that facilitates the quick development of mineable shapes and easy updating of schedules, with a quick evaluation of multiple possibilities and scenarios. Visual inspection and examination of the mine plan are also made easier by the closer integration of the scheduling and mine design software. But it's also important to be aware that these software tools have limits. Each mine planning tool, for instance, has advantages and disadvantages; some are better suited for strategic purposes, while others are better suited for creating intricate operating plans. It is required to choose the optimal instrument for the particular needs of the mine plan being created rather than applying a one-size-fits-all strategy. In this paper, we have discussed about MineOpt which is a strategic mine planning tool and covers the mine planning process discussed in Figure 1.

CASE STUDY USING MINEOPT

About MineOpt

MineOpt is a single software that covers the entire Strategic planning workflow under one umbrella. Starting with importing a block model, creating nested pit shells, creating automated pit design from the pit shell, and finally creating an optimal schedule that considers mining, dumping, and hauling simultaneously. MineOpt has features that no other software in the market has as of date – like optimizing to maximize the Net Present Value (NPV) of a project while optimizing dumping and hauling, including in-pit dumping. At the time of writing this paper, MineOpt is working on another unique solution of automated pit design which will be followed by stochastic mine planning and hill of value approach (as explained above in Figure 5).

Features of MineOpt

- Finding economic pit limits and phases to reach the ultimate pit
- Automatic/parametric pit design, including strips and blocks design
- Optimum mining and dumping sequence for in-pit and external dumps
- Considers building haulage network of shortest paths and selection of optimal haul roads for each block by period
- 3D display/schedule animation and export of end-of-period surfaces to dxf and stl formats

MineOpt provides a workflow as shown in Figure 6, where the three stages are

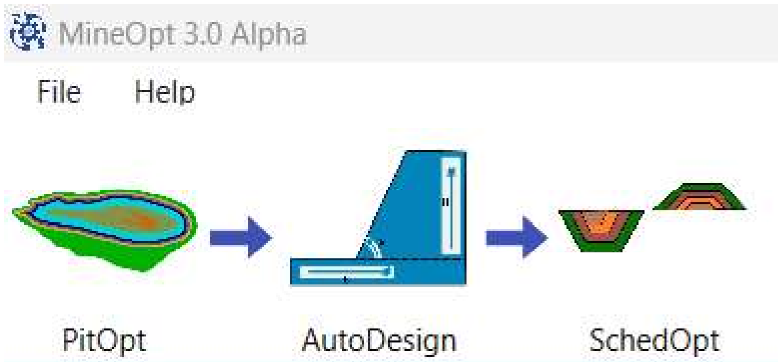


Figure 6: MineOpt main menu showing the workflow

PitOpt Module: This module builds nested pit shells from a geological model which can be either a block model or a grid model.

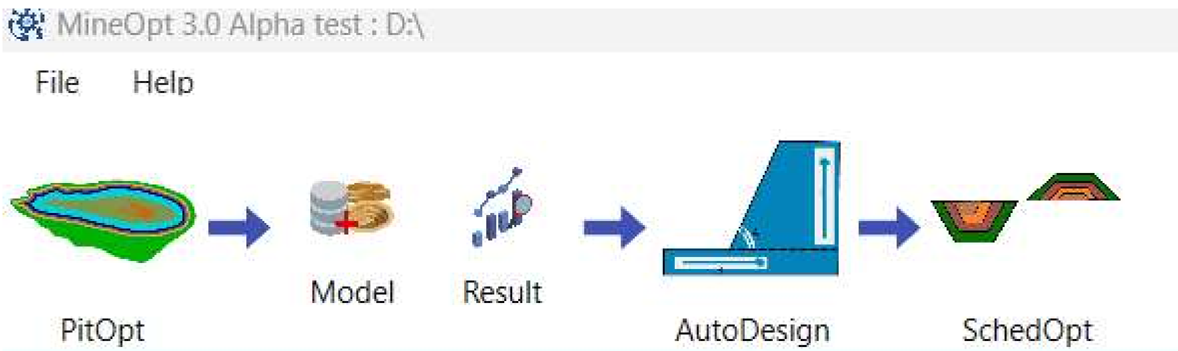


Figure 7: PitOpt Options in MineOpt

AutoDesign Module: At the time of writing this paper, this module is in development. This will design the pit automatically from a selected nested pit shell, within a boundary. It will also create strips and blocks for stratified deposit mines or will create mining blocks/units(solids) for other mines. The design attributes of bench height, berm width, and wall slope angle will be parameterized so that they can be changed easily instead of redesigning.

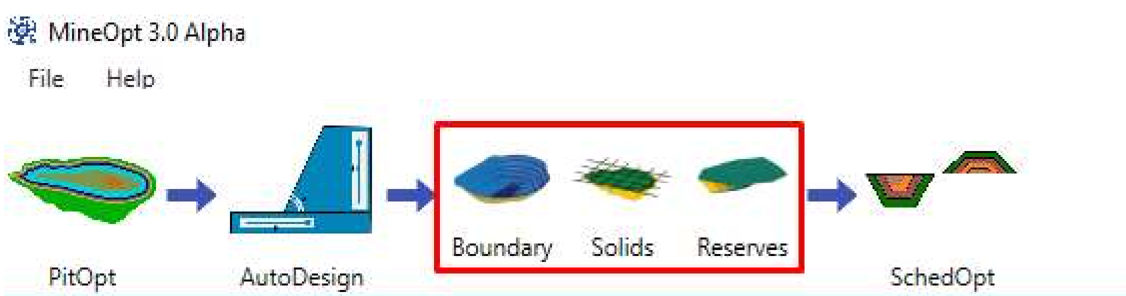


Figure 8: AutoDesign options in MineOpt

This module will also include reserving along with updating the quality of mineable blocks, considering loss and dilution. Finally, it will prepare a ROM model ready for scheduling. Once completed this will be one of the most powerful tools in mine planning.

SchedOpt Module: SchedOpt is the first software that can optimize an open pit mining schedule including optimizing mining, dumping both in-pit and external, and haulage road selection while maximizing the Net Present Value(NPV) of the project. This runs on a Mixed Integer Linear Program (MILP).

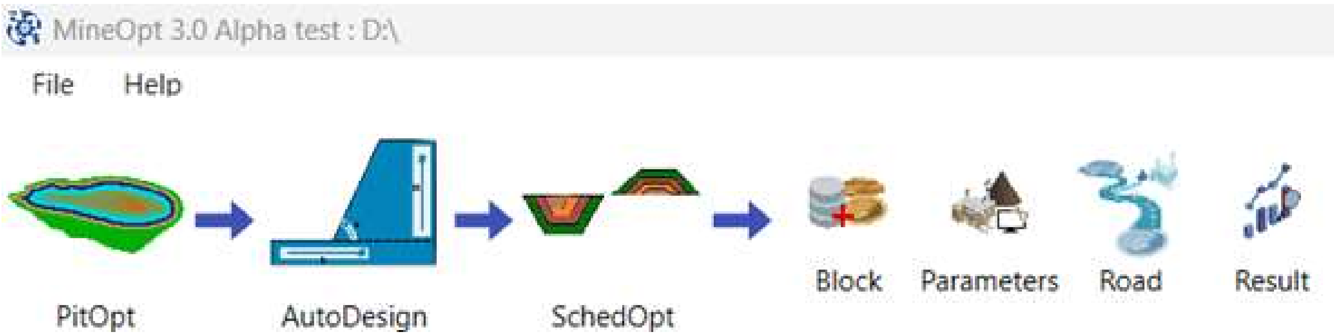


Figure 9: SchedOpt options in MineOpt

SchedOpt workflow as shown in Figure 9 starts with importing the design blocks either from AutoDesign or from external software, the parameters are defined, then road connections are created, and finally the results can be visualized. Work for the Stochastic Mine planning will start soon around mid of this year.

Case study background

Data for a coal mine in NSW, Australia was run through PitOpt and SchedOpt to obtain a long-term schedule including long-term dumping and hauling plans. The data forms part of the Minex tutorial. The next level of detail would be incorporated into tactical mine planning software.

The mine has 2 seams SW1 and SW2, which can also be viewed in cross section. The seam SW1 floor is in 3D in Figure 10.

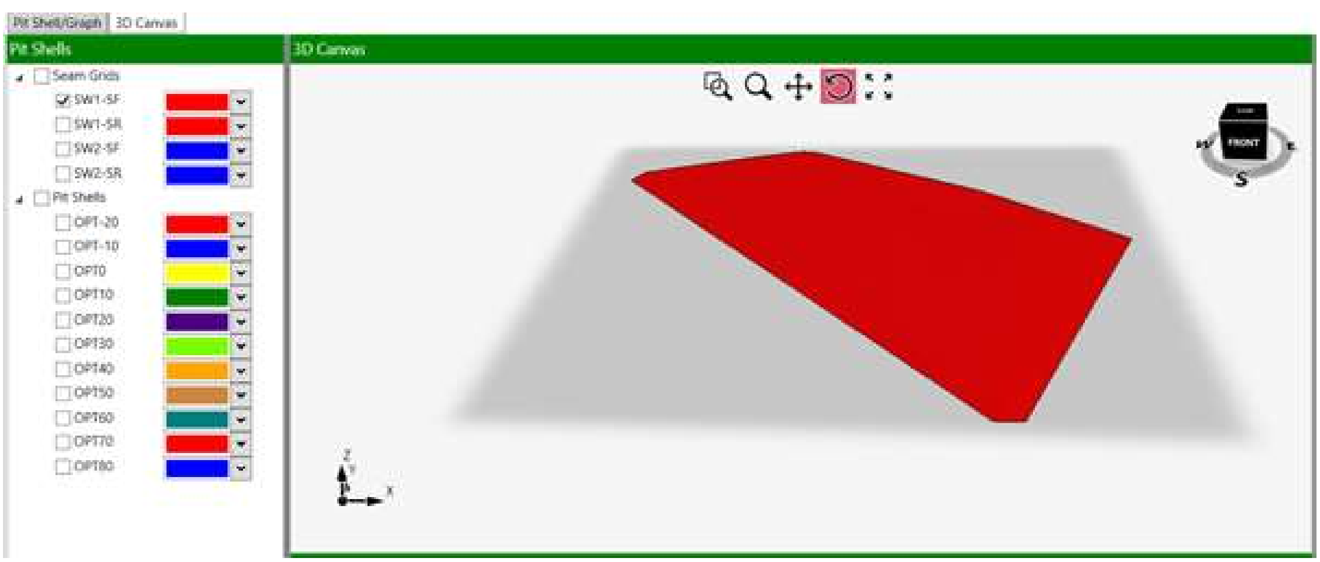


Figure 10: SW1 seam floor shown in MineOpt

PitOpt Module – To generate nested pit shells

The MineOpt interface to read the grid model data of the coal mine is shown in Figure 11. A similar interface exists for reading block model data. As soon as the data is read, the summary of the data appears on the right-hand side showing the tonnes and grade details in the two tables. The volume, tonnes, and grade for each seam are also shown graphically.

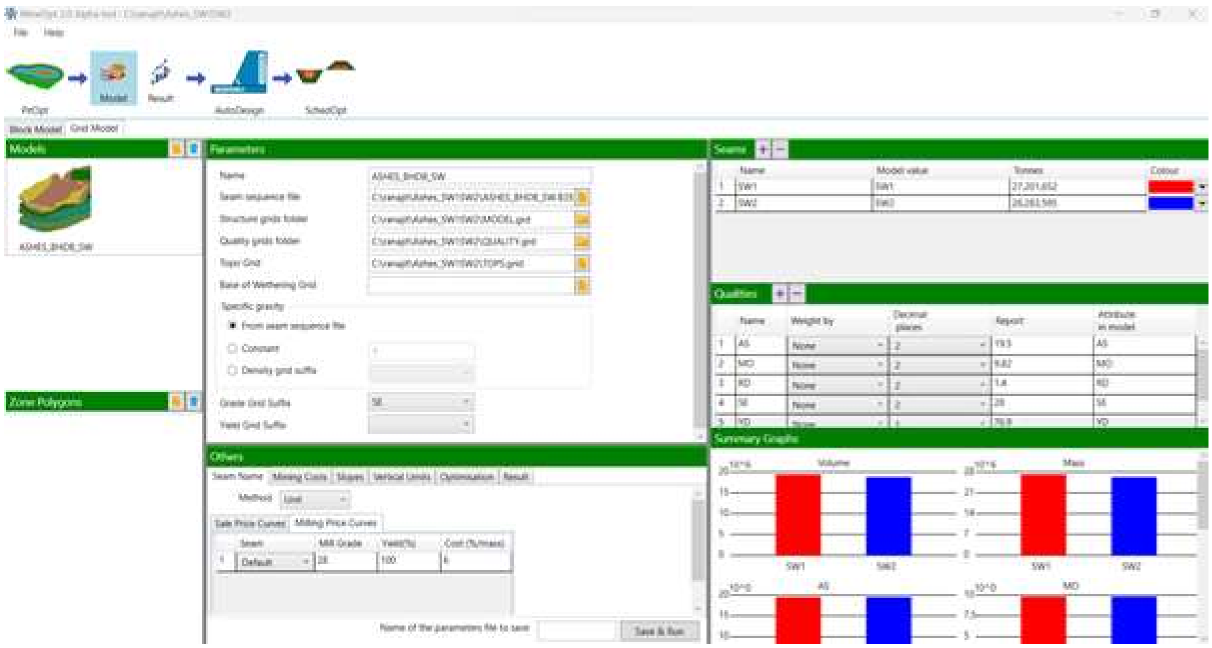


Figure 11: MineOpt Interface to read a Grid Model from Minex

There are different menu options to enter the following :

Sale price entry tab: Sale price can be specified by seams(or rock types), cut-off grade can be either manually entered or can be calculated in the software, default density, and mining recovery.

Milling cost entry tab: The Milling cost can be a cost curve based on plant feed grade and yield. It can also vary by seams.

Mining cost tab: There are several ways of providing mining cost in MineOpt, in this case, a straight and simple fixed mining cost has been used for waste and ore mining. There are options to provide cost by depth or elevation, cost by seams or rock type, cost by zones defined by polygons, etc. Haulage cost can also be added by elevation for both waste and ore.

Slopes tab: Slopes can be simple as used in this case – a 45-degree angle on all sides. Slopes can be based on geotechnical zones and directions.

Vertical limits: The ultimate pit can be limited to a base elevation or surface. The upper limit is the topo.

Optimisation: Here the price discounts are provided for generating the nested pit shells. A -ve price discount means a premium. We often use a premium instead of a discount so that infrastructure and dumps are placed outside any future possible pit shell.

Result: As the optimization progresses the results appear here.

RESULTS AND ANALYSIS OF PITOPT

Once the Optimisation was run pit shells were generated. In this case, 11 pit shells were generated. The pit-by-pit graph generated by MineOpt is in Figure 12. and the summary table below shows the tonnes and grades of the nested pit shells.

The graph in Figure 12 shows ore and waste in a bar graph while the value and average grade are lines plotted on the secondary axis. The X-axis shows the %discount applied to the price. The 0 discount is the full-price pit shell. Normally for sequencing the shells where there is significant change happening would be chosen as phases. However, MineOpt uses block-level scheduling, and pit phasing is not used so far. Table 1 presents the data used in the graph in Figure 12

Table 1: Pit-by-pit volume tonnes, grade, and value

Pit Shells

Name	Discount Factor	Total Volume	Ore Volume	Ore Tonnes	Grade	Pit Value
OPT-20	-20	968,609,518	32,117,645	44,964,702	28	2,338,801,218
OPT-10	-10	835,328,243	30,442,264	42,619,170	28	2,035,734,776
OPT0	0	794,621,205	29,842,610	41,779,654	28	1,740,083,681
OPT10	10	735,175,879	28,894,263	40,451,968	28	1,452,394,259
OPT20	20	665,433,674	27,657,292	38,720,209	28	1,175,374,388
OPT30	30	601,199,283	26,332,049	36,864,868	28	911,200,743
OPT40	40	533,371,146	24,678,393	34,549,750	28	660,953,505
OPT50	50	449,996,130	22,235,093	31,129,130	28	431,374,213
OPT60	60	336,609,394	18,099,503	25,339,305	28	232,548,482
OPT70	70	184,875,005	11,105,641	15,547,897	28	84,242,043
OPT80	80	65,292,970	3,949,222	5,528,911	28	11,672,697

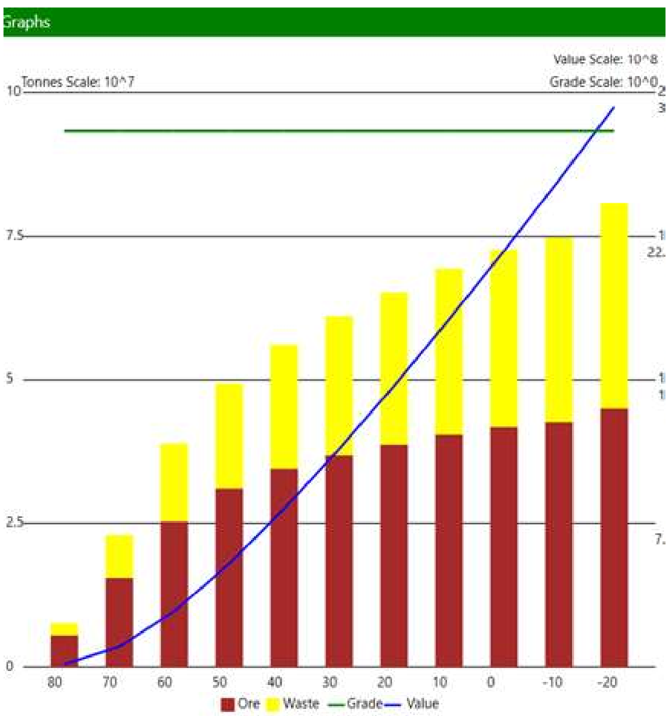


Figure 12: Pit-by-pit graph of ore, waste, value, and grade

The Pit shell at no discount or full price is shown in Figure 13. There is an option to display one or all the nested pit shells together.

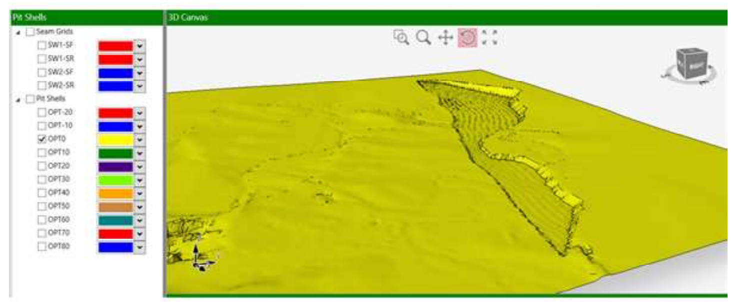


Figure 13: Pit Shell at 0% discount on price -OPT0

Figure 14 shows all the pit shells as nested pit shells on a sectional side view.

Figure 14: Nested Pit Shells in cross-section view

It is also possible to report the volume, tonnes, and grade by bench for each pit shell. Here bench height is precalculated by MineOpt to maintain the required slope. A bench-by-bench breakdown of OPT0 is shown in Table 2.

Table 2: Volume, tonnes, and grade by benches for OPT0 pit shell

Bench for Selected Pit Shell: OPT0

Bench	Total Volume	Ore Volume	Ore Tonnes	Grade
1	19,531	5,020	5,020	28
2	187,502	128,084	128,084	28
3	597,659	409,021	409,021	28
4	1,246,098	792,056	792,056	28
5	2,335,944	1,396,369	1,396,369	28
6	3,832,039	2,044,107	2,044,107	28
7	5,468,756	2,515,750	2,515,750	28
8	7,238,287	2,906,275	2,906,275	28
9	9,503,913	3,449,457	3,449,457	28
10	11,847,663	3,693,198	3,693,198	28
11	14,386,730	3,805,701	3,805,701	28
12	16,964,853	3,900,260	3,900,260	28
13	19,878,917	3,971,278	3,971,278	28
14	22,812,512	4,042,963	4,042,963	28

There is also an option to do a detailed report within a polygon with any pit shell as the bottom limiting surface.

SchedOpt module – To generate mining and dumping sequence

A pit was designed along with strips and blocks to create mining solids for the OPT0 pit. An external dump was also designed outside the OPT-20 limit and an internal dump was designed following the footprint of the OPT0 pit. These were designed in an external software, however, once the AutoDesign module is functional it will be used for this design.

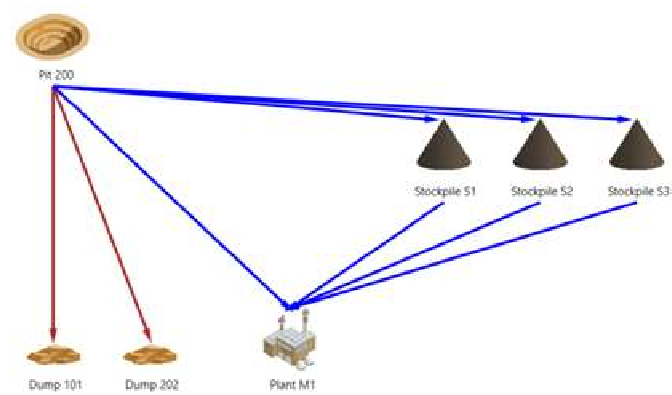


Figure 15 Graphical flow diagram from SchedOpt module of MineOpt

Two dumps 101 and 102 were designed for this data. Dump 102 has been designed as an internal dump inside pit 200 using the same footprint of strips and blocks in pit 200. A lag distance (working room) of 60 m has been assumed between the face of pit 200 and dump 102. A permanent haul road has also been imported to SchedOpt

A mining capacity and process capacity have been assumed for an 8-year life. The sale price for the coal and costs such as mining, processing, and hauling have also been provided.

Data Review

Stockpile | Plant | Resource | Cost/Price

Resource	Capacity	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Max	✓ Repeat	40000000	40000000	40000000	40000000	40000000	40000000	40000000	40000000
Min	✓ Repeat	10000000	10000000	10000000	10000000	10000000	10000000	10000000	10000000

Data Review

Stockpile | Plant | Resource | Cost/Price

Plant	Max Capacity	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
M1	✓ Repeat	5000000	5000000	5000000	5000000	5000000	5000000	5000000	5000000

Data Review

Stockpile | Plant | Resource | Cost/Price

Kind	Cost/Price	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Ore Sell Price(unit)	✓ Repeat	100	100	100	100	100	100	100	100
Waste Mining Cost	✓ Repeat	3	3	3	3	3	3	3	3
Coal Mining Cost	✓ Repeat	4	4	4	4	4	4	4	4
Wash Cost	✓ Repeat	6	6	6	6	6	6	6	6
Haulage Cost	✓ Repeat	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Stock Rehandling	✓ Repeat	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Figure 16: Input parameters for strategic schedule optimisation

SchedOpt creates a database of possible shortest paths from each source pit block to all dump blocks, stockpiles, and process plants as shown in Figure 17. The database is displayed for review. Each possible path has an identification number. Only some of these paths finally get used by the schedule. These paths travel along pit blocks to connect to the nearest main haul road, thereafter travel along road points to the required destination – all along maintaining a max gradient for each connection. Further details of how this road database has been created have been discussed in (Das, Topal, & Mardaneh, 2023a)

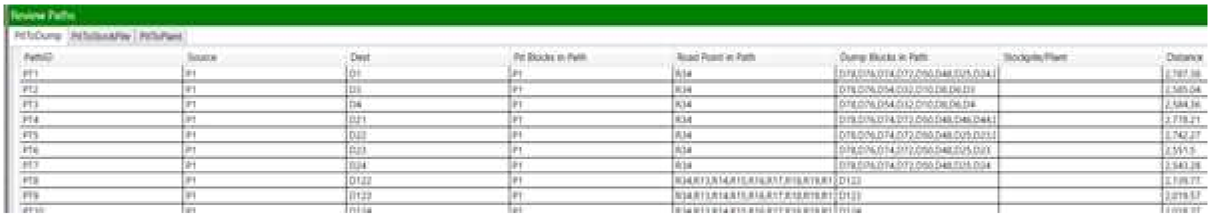


Figure 17: Sample snapshot of the paths created in the SchedOpt module of MineOpt

Once the roads are created the optimisation is run and the results are visualised as tables, graphs, and 3D visualiser. There is also an option to animate the mining schedule period by period. The end-of-period positions are shown in Figure 18. These end-of-period surfaces can also be exported as dxf into any other software for carrying forward to tactical planning.

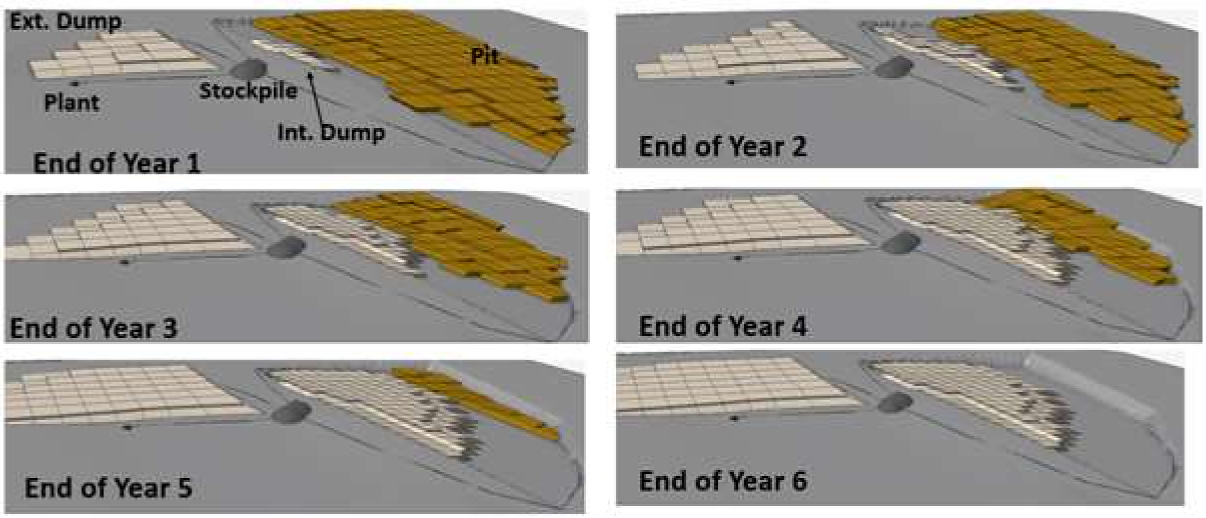


Figure 18: Pit and dump stages from SchedOpt module or MineOpt

Among several other reports generated notable is the summary report which shows the volume and tonnes of material movement to external and internal dumps, process plants, and stockpiles. There is a table of annual cash flow and NPV(Net Present Value) reported based on this cash flow as shown in Figure 19.

Period	Waste Volume	Dump(Ext)	Dump(Int)	Coal To Plant From Mine	Coal To StockPile From Mine	Coal To Plant From StockPile	Total To Plant
1	33,695,049	4,006,525	29,688,523	5,000,000	3,826,932	0	5,000,000
2	35,136,046	16,677,606	18,458,441	5,000,000	1,548,707	0	5,000,000
3	36,145,054	19,559,229	16,585,825	5,000,000	396,924	0	5,000,000
4	36,375,428	27,121,085	9,254,343	4,967,849	0	32,151	5,000,000
5	35,177,946	10,867,691	24,310,255	5,000,000	496,887	0	5,000,000
6	5,428,410	0	5,428,410	3,501,706	0	1,498,294	5,000,000
7	0	0	0	0	0	4,739,005	4,739,005
8	0	0	0	0	0	0	0

NPV 57,371,958,755

Period	Waste Mining Cost	Waste Haulage(Ext)	Waste Haulage(Int)	Coal Mining	Coal Haulage To Plant	Coal Haulage To StockPile	Coal Wash	Rehandling	Revenue	Margin
1	101,085,146	12,625	69,708	35,307,728	82,129	69,552	30,000,000	0	12,600,000,000	12,433,3
2	105,408,139	58,935	49,729	26,194,828	139,684	19,481	30,000,000	0	12,600,000,000	12,438,1
3	108,435,163	74,673	51,895	21,587,696	173,303	3,467	30,000,000	0	12,600,000,000	12,439,6
4	109,126,284	109,378	33,966	19,871,396	183,628	0	30,000,000	16,076	12,571,064,100	12,411,7
5	105,533,837	47,218	94,939	21,987,548	217,418	17,173	30,000,000	0	12,600,000,000	12,442,1
6	16,285,230	0	22,077	14,006,824	246,059	0	30,000,000	749,147	11,251,535,400	11,190,2
7	0	0	0	0	0	0	28,434,030	2,369,503	7,677,188,100	7,646,3
8	0	0	0	0	0	0	0	0	0	

Figure 19: Tables showing summary material movement and Cash flow/NPV for the schedule

Other than that, graphical results are also available such as shown in Figure 20

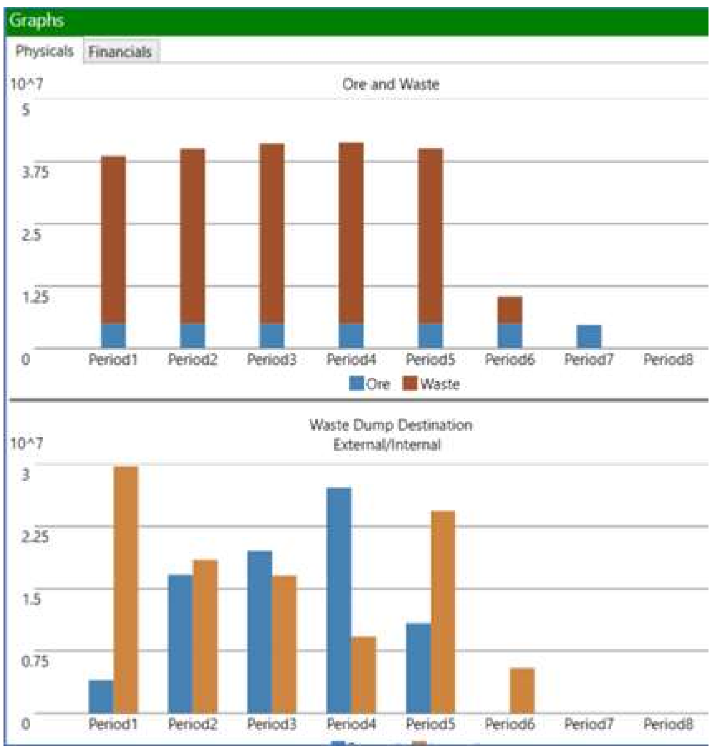


Figure 20: Graph of results from the SchedOpt module of MineOpt

CONCLUSION

Strategic mine planning is an important aspect of mine planning. Sun Tzu, a Chinese military general wrote, "Tactics without strategy are the noise before defeat." A tactical mine plan with several details like equipment productivity, shift timings, and more is unlikely to achieve the maximum potential of a project unless it follows a strategic mine plan.

MineOpt, which is still in the process of development, is a unique tool to prepare strategic mine plans. A case has been run through the PitOpt and SchedOpt modules of MineOpt and satisfactory results of a strategic mine plan were obtained. With further advancement in MineOpt designing and stochastic analysis parts will also be available.

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Transformative Maintenance Technology Opportunities and Challenges

Uday Kumar*

ABSTRACT

On-going digitalization of mine and mining operation provides enormous capabilities for the sector to collect vast amount of data and information (i.e. Industrial Big Data), from the assets in operation. Currently, focus has been to find transformative operation maintenance solutions for the new and ageing mining assets which will ensure safe and failure free mine operation at the lowest cost. This real time data driven approach to operate mining systems is expected to transform the way mine is operated and maintained ensuring high level of productivity, increased reliability and quality at reduced life cycle costs for the organization. To get useful information out of high volume of data generated by smart mining assets, advanced tools are developed and implemented so that data can be systematically processed into information and useful knowledge which facilitate correct decision making in real time regarding operation and maintenance and thereby realizing the vision of cloud based mining operations. The new and emerging technologies such as big data analytics (predictive and prescriptive analytics), industrial Internet of Things(IIoT), Cloud computing, Machine Learning 5G communication technologies, AI that offer near perfect solutions for the operation and maintenance of mining systems, are collectively termed as transformative technologies (TT) . Such transformative technologies facilitates or expected to facilitate correct decisions and actions in real time at the lowest possible cost using the power of predictive and prescriptive analytics by mining engineers and managers. Furthermore, for the successful development and implementation of new and emerging technologies and solutions, there is a spoken need for the convergence of the Operational Technology (OT) and Information Technology (IT). Without IT and OT convergence, it's difficult to get the best out of these technologies.

The presentation will be centered on the capability of enabling technologies both new and emerging that will facilitate development of transformative technologies for the operation and maintenance of a modern-day mining systema using the power of predictive and prescriptive analytics. The presentation will be an over view of matured, new and emerging technologies useful for effective life cycle management of capital intensive mining equipment with focus on new maintenance technologies incorporating big data analytics, industrial internet, artificial intelligence, etc. The presentation will cover both technological aspect and management issues based on an ongoing R&D projects with aim to develop and implement transformative technologies and solutions in Swedish mines.

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Pre-concentration and Separation of Heavy Minerals from Beach Sand by Fluidization Technique

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ABSTRACT

Indian marine sands contain about 15% heavy minerals with about 10% Ilmenite, 3.2% Monazite, 1.6% Zircon, 0.09 % Rutile, 0.4% Garnet and less than 0.2% Sillimanite. These minerals are considered to have economic importance as these are the primary ore constituents. Industries like paint, plastics, welding medical prosthetics, etc. use these materials for manufacturing their end product. The mineral deposits are mostly located in the coastal stretches of peninsular India covering the states of Orissa, Andhra Pradesh, Tamil Nadu, Kerala, and Maharashtra. From the previous literature studies on the pre-concentration and mineral separation studies, it is observed that concentrates of Ilmenite, Monazite, Zircon, and Garnet which are initially at low concentrations can be obtained. Previously Spiral concentrates are used on an industrial scale for the production of Heavy Minerals. But some constraints are to be addressed such as the rate of mineral enrichment from ore, the ratio of water to pulp density in the system, etc. So fluidization is considered to be an alternative in addressing such problems and energy efficiency which is considered to be the latest improved technique for pre-concentration of minerals. In this article, two regions of beach sand ore samples were taken, one from the Srikakulam area from the Andhra region and the other from the Orissa Chhatrapur Ganjam area for experimentation. The samples are initially separated from all other wastes by the first stage of screening and subjected to sink and float analysis to determine the initial concentration of heavy minerals in the sands. The impact of the beach sand materials on the governing parameters such as the bed aspect ratio, and minimum fluidization velocity, are studied and also the enhancement of mineral concentration by fluidization is determined.

Keywords: Heavy Minerals, Fluidization, Concentration

INTRODUCTION

India is bestowed with its mineral deposits, especially with a coastline of 6000 km. Heavy mineral deposits of Manavalakuruchi in the state of Travancore (now Tamilnadu) were discovered by Schomberg, a German chemist in 1909 which was proved richer and more economical compared to the rest of the world. Interestingly, Mineral sands then mined from rich seasonal Beach washings for only one mineral, i.e., Monazite, in a solution of thorium which produces incandescence by infusing the paraffin mantle and cerium compounds, lost its worth due to the arrival of the filament lamp.

The Atomic Energy Commission was commissioned in 1948 by Govt. of India. Indian Rare Earths Limited was incorporated as a private company as a joint venture with the then Government of Travancore, Cochin in 1950 under the Indian Companies Act, 1913. IREL became a full-fledged Govt. undertaking under DAE in 1963. OSCOM was set up in 1972; construction had been started in 1975 and mining had been started in 1984. The main objective of IREL is to emerge as a leading international player in the area of mining and separation of beach sand deposits to produce minerals as well as value-added process products.

OBJECTIVES OF THE STUDY

- Study the fluidizing behavior of different beach sands.
- Study the variation of parameters for the fluidized bed for proper fluidization of beach sand
- To analyze the pre-concentration/separation of Heavy Minerals from beach sands.
- To compare the sample characteristics before and after fluidization.
- To validate the experimental data using CFD Analysis.

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LITERATURE REVIEW

Authors& Year	Title	Remarks
J. Vaughn et.al. (1980)	Hydrodynamic Controlling the Distribution of Heavy Minerals (Bristol Channel)	Proposed that Differential mineral transport of heavy minerals depends upon. the hydraulic conditions of unidirectional and oscillatory flow, separately and in combination, acting on a seabed of certain roughness
Harel, Y, and W . Resnick (1991)	Particle Separation In Magnetically Stabilized Bed	investigated the features of Magnetically stabilized fluidized beds which provide the possibility of performing dry particle separation based on the density difference
Antoine Mulaba-Bafubiandi et. al. (2002)	Ilmenite Mineral's Recovery from Beach Sand Tailings	conducted the works on alternative routes for the extraction of the ilmenite, from Beach Sand Tailings.
W.T. Kim, Shin et.al. (2006)	Recovery of Heavy Minerals from Korean Beach Sand	investigated the establishment of the optimized recovery process for heavy minerals from beach sand, also studied the physical separation methods such as gravity and magnetic separation followed by mineralogical
C. Raghu Kumar et.al. (2006)	Effect of Process Variables on High-Tension Separation-A Statistical	Proposed use of electrostatic separators in a mineral processing plant which are effective in the separation of the conducting minerals
S. Sabedot et.al. (2009)	Mineral Processing of Low Quality Zircon concentrates and Pre-concentrates	introduced the concentrates, named zirconite B, which presents a low ZrO value and high content of contaminants, being considered a low-quality concentrate
Greg Jones (2009)	Mineral Sands: An Overview of the Industry	studied mineral sand ore bodies, which essentially fall into two categories based on the mode of deposition: alluvial or aeolian
Veerendra Singh and S. Mohan Rao (2010)	Selective Classification of Mineral Sand Slimes in an Air-Fluidized Bed	Studies were carried out for selective classification of mineral sands to remove unwanted slimes (particles of <0.63 µm in size)in an Air Fluidized bed.
Sunil Kumar Tripathy et.al. (2010)	Modeling of high-tension roll separator for the separation of titanium bearing mineral	proposed a three-level Box–Behnken factorial design combined with response surface methodology (RSM) for modeling and optimizing of process parameters of high-tension roll separator (HTRS), namely feed temperature, feed rate and roll speed for the separation of titanium bearing minerals (ilmenite and rutile) was developed.
Srijith Mohanan et.al. (2012)	Application of High Tension Roll Separator for the Separation of Titanium Bearing Minerals: Process Modeling and Optimization	employed the High Tension Roll Separator (HTRS) which is one of the main electrostatic unit operations employed to separate titanium minerals like ilmenite, rutile and leucoxene from zircon etc.
B. Nayak et.al. (2012)	Heavy Minerals and the Characters of Ilmenite in the Beach Placer Sands of Chavakkad-Ponnani Kerala Coast, India	investigated with the general character of the heavy minerals of CP with special emphasis on the characters of Ilmenite, also studied the observations on the ilmenites of CP using Optical Microscope, SEM and EPMA reveal that these are mineralogically very complex.
J. Januch et.al. (2013)	Evaluation of a fluidized Bed Asbestos Segregator Preparation Method For The Analysis of Low- levels Of Asbestos In Soil And Other Solid Media	proposed to use the fluidized bed asbestos segregator (FBAS)which is a sample preparation instrument that utilizes air elutriation to separate asbestos structures from heavier matrix particles and deposit these structures onto a filter which can then be analyzed by transmission electron microscopy (TEM)
Xiaosheng Yang et.al. (2015)	Beneficiation studies of a complex REE ore	studied the beneficiations of a complex rare earth element (REE) ore containing REE minerals of carbonates, silicate oxides, and other REE-bearing minerals by flotation and high gradient magnetic separation (HGMS) were investigated.
Sahu S . N. et.al. (2015)	Study On Mixing And Segregation Behaviors In Particulate fluidized Bed System For Mineral Processing	presented the study on the hydrodynamics of solid–liquid fluidization.

Pal SZENTANNAI et.al. (2016).	A New Design Method for Fluidized Bed Conversion of Largely heterogeneous Binary Fuels	investigated a typical example of the thermal utilization of rubber wastes. A novel design is proposed by setting up a non-mixing, non-elutriated binary bed
A. B. Nesbitt et.al. (2016)	The processing of Beach Minerals using an In-Line Pressure Jig.	calculated the particulate sizes which are typically in the sub 500- micron range, because of the nature of the geology of beach sands
Q. Dehaine, L.O. Filippov et.al. (2016)	Modelling heavy and gangue mineral size recovery curves using the spiral concentration of heavy minerals from kaolin residues.	studied that spiral concentrators are one of the most common gravity processing methods extensively used for the concentration of minerals based on their density, particle size and shape.
Dariush Azizi et.al. (2017	Liquid-liquid mineral separation via ionic-liquid complexation of monazite and bastnäsite—An alternate route for rare-earth mineral beneficiation	investigated the potential of liquid-liquid mineral separation mediated by ionic liquids (ILs) to beneficiate rare earth (RE) bearing minerals. Liquid-liquid separation tests were performed on actual RE-bearing ores.
M.J. Espin et.al. (2017)	Magnetic stabilization of fluidized beds: Effect of magnetic field orientation	proposed that fluidized beds of granular materials can be stabilized by inter particle attractive forces which confer the expanded bed an elastic modulus that stabilizes it against flow perturbations
Sunita Routray et.al. (2017)	Optimization of Mineral Separator for Recovery of Total Heavy Minerals of Bay of Bengal using Central	investigated the optimization of a mineral separator for processing beach sand minerals of the Bay of Bengal along Ganjam–Rushikulya coast
E. Cano-Pleite et.al. (2017)	Segregation of equal sized particles of different densities in a vertically vibrated fluidized bed	experimentally studied the influence of vibration and gas velocity on the density-induced segregation of particles in a pseudo-2D vibrated fluidized bed
Bo Lva et.al. (2018)	Particle mixing and separation of gas-solid separation fluidized beds containing binary mixtures	Studied the effects of different factors (e.g. gas velocity and size fraction and mixture ratio of fine coal) on the degree of mixing of binary mixture particles were studied using a combination of factor analysis method and orthogonal test method
Jana Chladek et.al. (2018)	Fluidized bed classification of particles of different sizes and density	The main objectives of this study were to quantify the classification efficiency of a binary mixture of two different particle types and to demonstrate that CPFD can be used to simulate the main features of the classification process

METHODOLOGY FOLLOWED

The beneficiation of Beach Sands for the recovery of Heavy Minerals is done by the Fluidization technique. Initially, the sands contain low concentrations of Heavy Minerals. Pre-concentration of Beach Sands is carried out to separate the Light Minerals from Heavy Minerals. A detailed explanation of the proposed methodology is shown in Figure 1.

CFD SIMULATIONS

ANSYS FLUENT 18.0 is considered simulation software for this study. Standard k-å dispersed Eulerian granular models with standard wall functions are used for modeling the transition nature of the bubbling fluidized bed. Air is taken as a continuous phase while solid particles are taken as a dispersed phase which are treated as continua, interpenetrating and interacting with each other and everywhere in the computational domain.

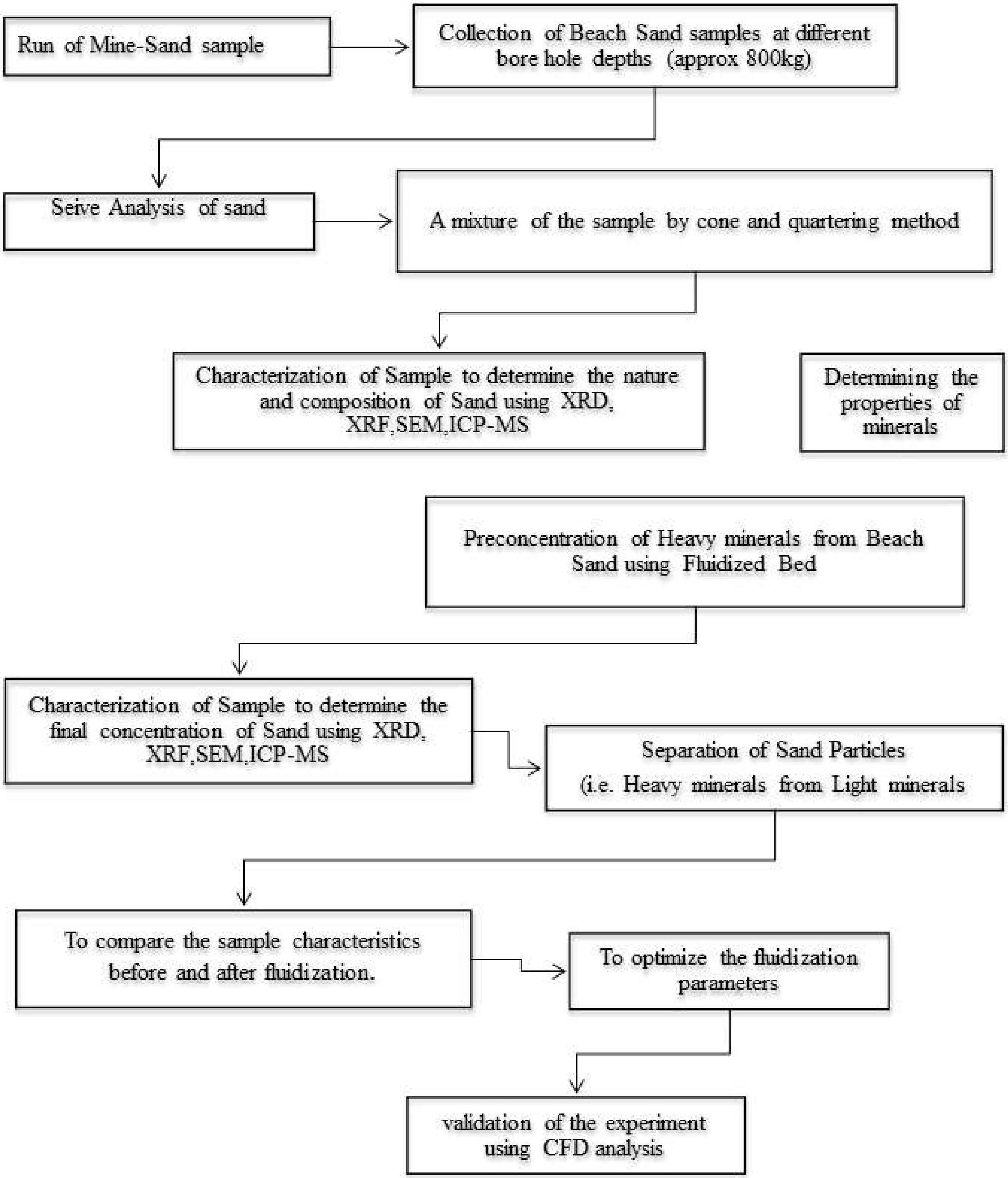


Figure 1: Methodology followed for the study

Assumptions Made

For simulating any method, few assumptions are required for initializing the computational work. The basic assumptions considered for CFD simulations are isothermal, non-reactive, unsteady state gas-solid system, no lift force, and no mass transfer between gas and solid phase for a unit. Constant pressure gradient and constant density of each phase are also assumed in the present work. The gas phase has been modeled with k-å turbulent model and solid phases have been modeled with the kinetic theory of granular flow. In this work, bubbling fluidization is observed with bed material where viscosity is considered to be negligible.

Comparisons of 2D and 3D simulated bed dynamics against velocities

The CFD modelling is performed for both 2D and 3D systems for the parameters such as Particle Volume Fraction, Expanded Bed Height, Bed Expansion Ratio, Bed Pressure Drop concerning superficial gas velocity, Static Bed height, drag models, specularity coefficient, and restitution coefficient are seen to affect the hydrodynamics of the fluidized bed. Therefore, the effects of CFD parameters on the simulations are studied by varying different system parameters viz. particle size, static bed height, and superficial air velocity. The comparisons among the model predictions and experimental measurements with the time-averaged bed pressure drop, bed expansion, and qualitative gas-solid flow pattern are carried out under different conditions. Further, the drag models in simulation studies are studied along with specularity coefficient and restitution coefficient.

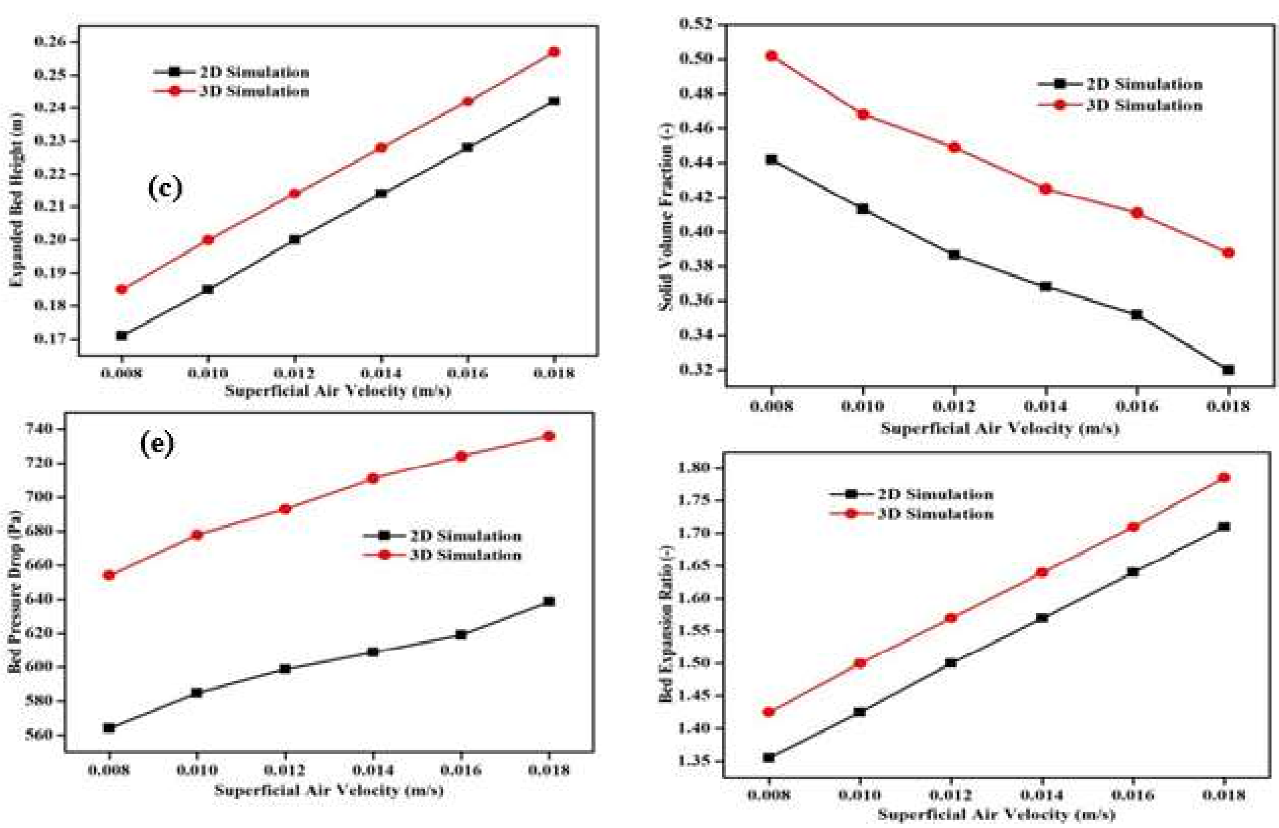


Figure 3: Comparisons of 2D and 3D simulated bed dynamics against velocities

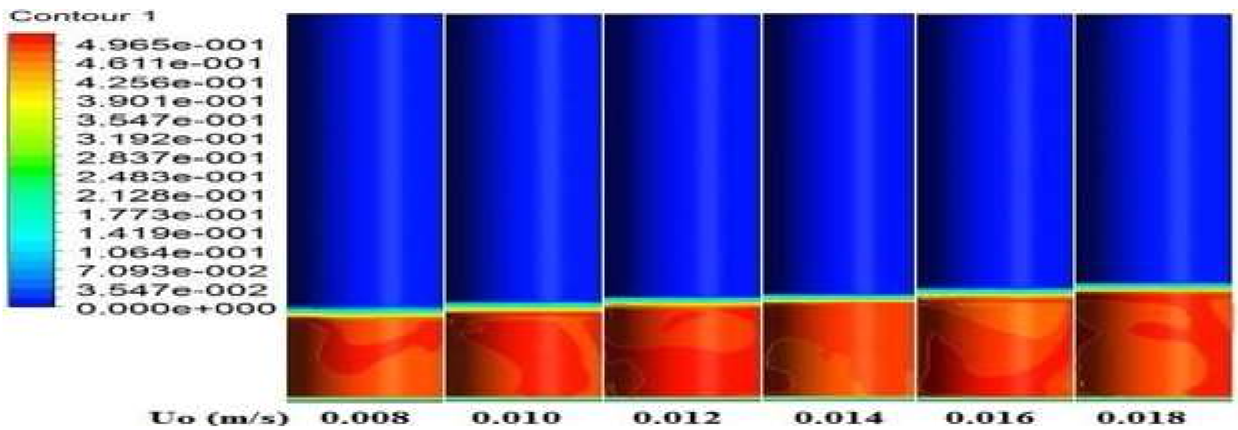
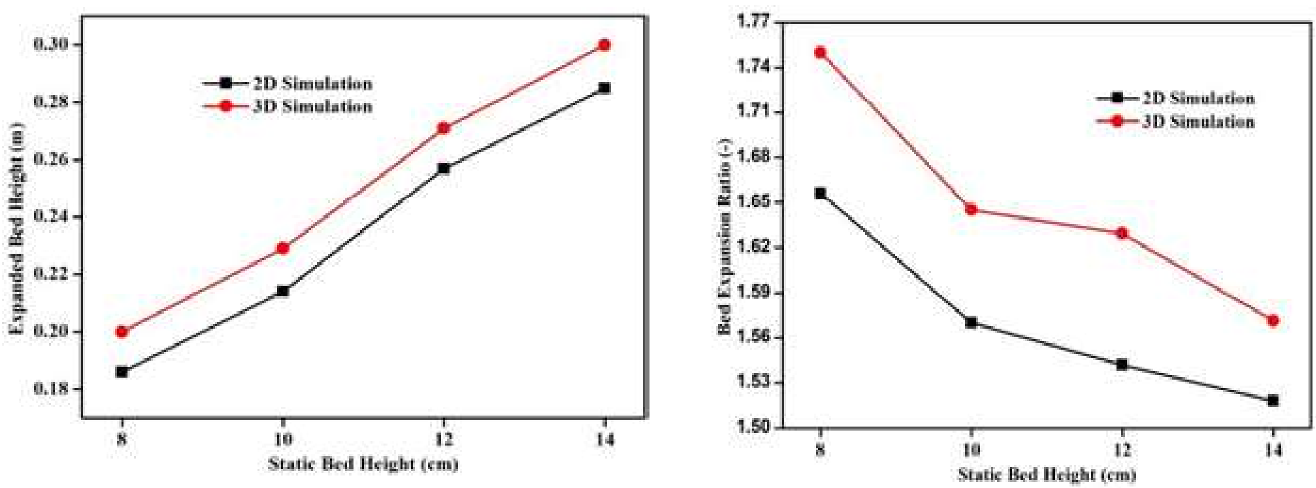
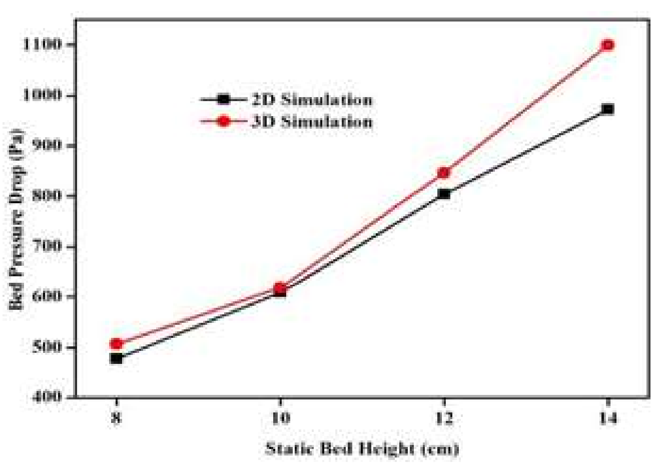


Figure 2: 3D simulated solid volume fraction against gas inlet velocities





a. **For Particle Volume Fraction**
b. **For Expanded Bed Height**
c. **For Bed Expansion Ratio**
d. **For Bed Pressure Drop**

Figure 4: Comparison between 2D and 3D simulated results for bed dynamics

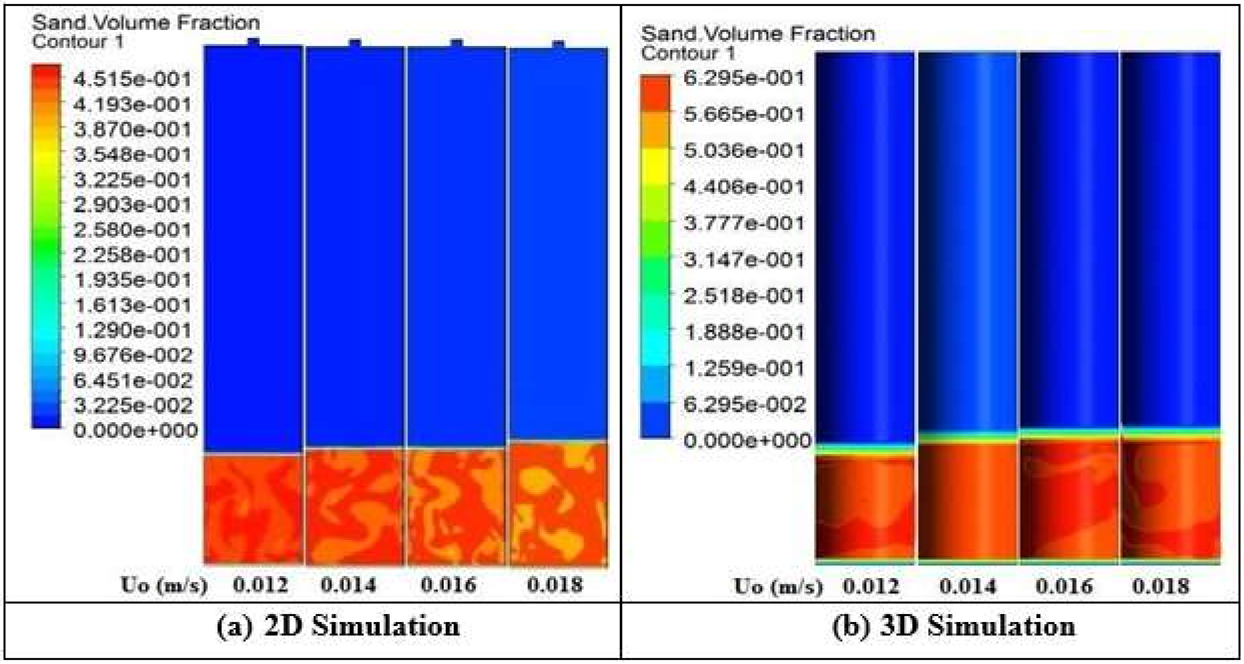


Figure 5: Contour plot of solid volume fraction for Sand particles

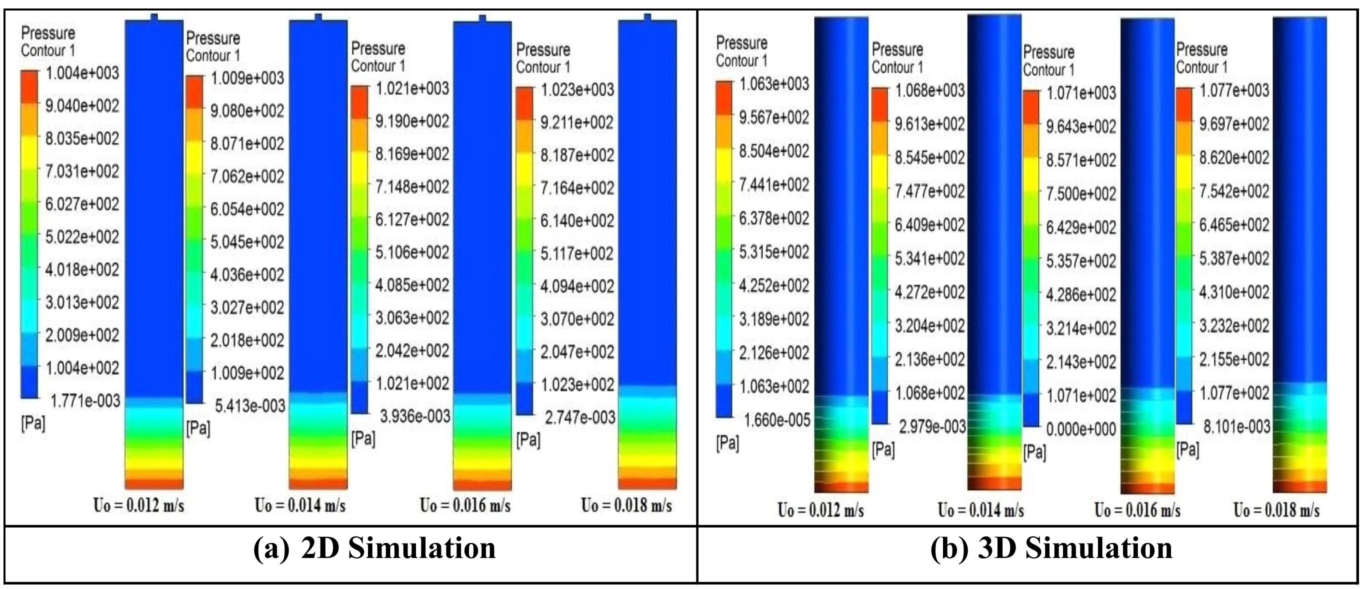


Figure 6: Contour plot of pressure for Sand particles

The above figures depict the 3D simulated solid volume fraction against gas inlet velocities, along with contour plots of both 2D and 3D models.

In this work, the hydrodynamic studies of the GSFB are carried out for the bed pressure drop, expansion/ fluctuation ratio, and fluidization index under different operating conditions. CFD simulations are also carried out for GSFB using the commercial CFD solver ANSYS/ FLUENT 18. The results yield comprehensive information concerning the bed hydrodynamics and thermal-flow behaviors existing within the FBR. CFD simulations are carried out with different CFD parameters and models. Again, the effect of different system parameters viz.

particle size, superficial air velocity, and static bed heights are studied on these CFD simulations for single-sized and binary mixtures of bed materials. The pressure effect is also studied for the gas phase and solid phase for different system parameters. Finally, a comparison is made for the results obtained in the simulations and experimental studies along with 2D and 3D models

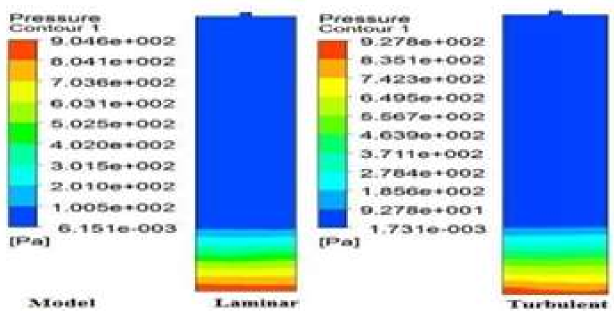


Figure 7: Comparisons of pressure drops in laminar and turbulent models

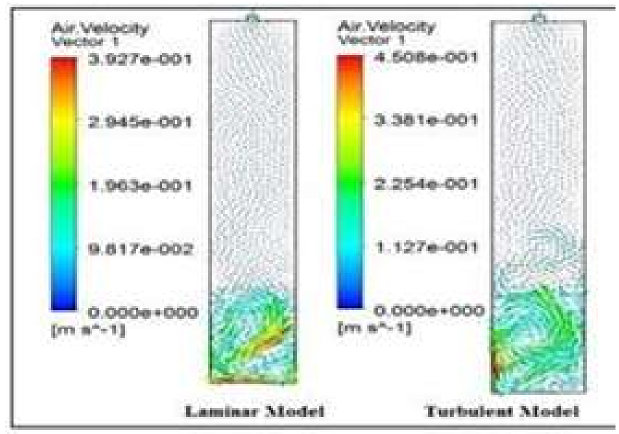


Figure 8: velocity profile for the particles

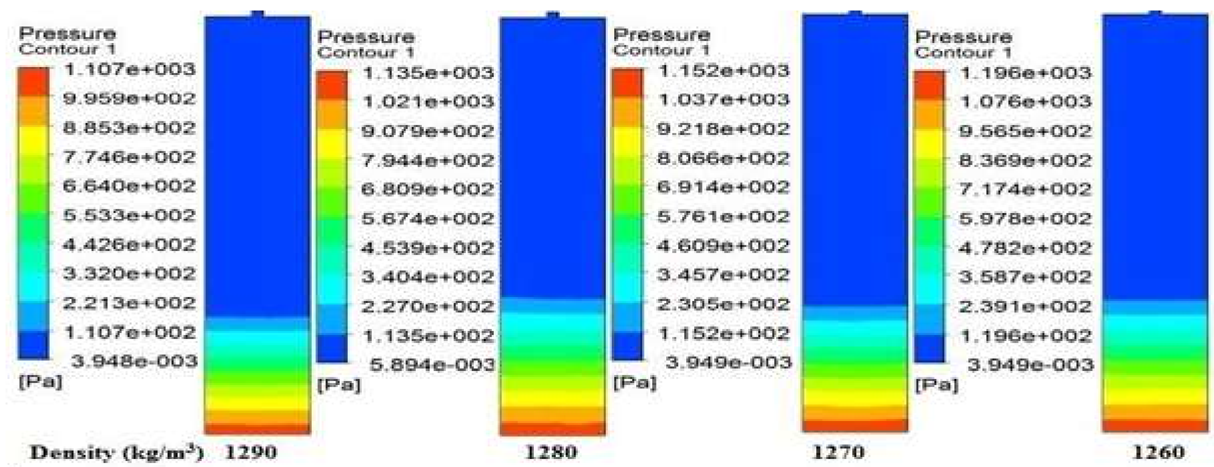


Figure 9: Contour plots for different densities of mixture of particles

CONCLUSIONS

The study was quite encouraging and the results depicted that the fluidization technique can be adopted safely on a large scale to recover heavy minerals from the rare earth deposits.

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Optimized Burden-Spacing for Improvement of Rock Fragmentation by Blasting in Limestone Mines

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ABSTRACT

Blasting with the aim to reduce oversize boulders have many hurdles. Optimized drilling and blasting parameters can lead to achieve this objective. The major challenges of the blast designers lie within deciding blast geometry which includes- drill hole diameter, burden and spacing. The general approaches covered worldwide to determine burden-spacing are based on various thumb rules. These thumb rules are based on previous experiences of blasts and its associated outcomes. However, many parameters influencing optimum burden-spacing to achieve desired fragment size are site specific. Sometimes drill geometry are decided based on associated blasting hazards rather than rock fragmentation.

Kuz-Ram model is worldwide accepted rock fragmentation predictor. The parameters associated with this predictor also includes burden-spacing for a blast. Back calculation of burden-spacing from Kuz-Ram model can be used to achieve desired fragment size. The following paper deals with burden-spacing determination with varying approaches for rock excavation in openpit limestone mining.

Keywords: Rock Blasting; Limestone Mining; Charge Factor; Kuz-Ram Model

INTRODUCTION

Productivity of excavation by blasting depends on cycle timing of loaders and indirectly on fragment size of blasted rock. Explosive quantity is considered as the main parameter for obtaining optimum fragmented rock. However, improper confinement/coupling/impedance results in to un-necessary wastage of explosive energy. Judicious design to distribute the explosives plays important role over here. This can be achieved by optimized drilling and blasting parameters. Presence of free face and properly planned drill hole geometries makes the efforts of blast designers comparatively easy. The proper planning of drill hole geometry may be approached by considering parameters like- rock factors, availability of explosive materials and sensitiveness of blast. Most of the excavation sites decides their drill hole geometry based on experimental trials and its day-to-day outcomes. Thumb rules are dominantly adopted by blasting practitioners to initially decide the burden-spacing. The existing thumb rule correlated burden-spacing of a blast with hole diameter. However, it needs to be modified based on site conditions specifically based on distribution of discontinuities, rock mass parameters etc. The empirical formulations under Kuz-Ram model for fragmentation prediction considers the rock parameters, explosive parameters and drill hole geometries as the responsible factors. The back calculation may be approached to get site specific drill hole geometry in order to achieve optimum fragment size.

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FACTORS INFLUENCING ROCK FRAGMENTATION

Output of a blast is assessed in terms of rock fragmentation. The fragmentation analysis software mostly uses image analysis techniques. The outputs from image analysis are quantified in terms of mean fragment size and desirable fragment size. Mean fragment size are not the better quantification technique, as the blasting crew are more interested in reducing quantity of oversized boulders. Percentage passing of blasted rock is better representation of fragmentation output. If result of fragmentation analysis shows X_{90} as the representation of 90% rock fragments of desired size passing through the screen of desired fragment size, then 10% oversize boulders are present in the blasted muck pile. Fragmentation outputs from a blast are dependent on many direct and indirect parameters as follows:

Blast face condition: Explosive energy tend to exhibit dynamic shock pressure along the path of least resistance. The least resistance in the path of shock wave propagation are normally along the free face or along the stemming portion. The better free face condition along with proper confinement in stemming portion will lead to effective utilization of explosive energy. The blasted rock mass along free face direction also undergo attrition to contribute improved fragment size. The free face condition lead to proper dislodging of rock mass and gives better movements.

Rock factors: Rock fragmentation by blasting are influenced by nature of in-situ rock, rock mass strength, hardness of the rock and nature of discontinuities in the periphery of rock mass. Nature of the rock mass are generally classified into- powdery/friable, vertically jointed and massive. The mean fragment size of the blasted rock will be maximum in case of massive rock mass and minimum in case of powdery/friable rocks. The vertically jointed rock mass is classified on the basis of joint sets present in in-situ rock mass. The term is named as joint factor and it can be further classified as vertical joint spacing and joint plane angle. More oversize boulders will be resulted if spacing of joint sets are nearly of drilling pattern size. Joints dipping out of the face will result in to better fragmentation, however joint sets dipping in to the face will result into oversize boulders. Density and hardness of the rock mass also have influence on rock fragment size. Low density rocks will result in to comparatively better fragmentation, similarly mean fragment size of the blasted rock will increase for harder rocks.

Rock factors for fragmentation prediction using KUZ-RAM model follows blastability index of Lilly (Lilly, 1986). The rock rating for calculation of Lilly's blastability index is presented in equation I. Rating for different associated parameters has been presented in Table 1.

A = 0.06 X (RMD + JF + RDI + HF) ……..**Equation I**

Where,
A = Rock Factor
RMD = Rock Mass Description
JF = Joint Factor
RDI = Rock Density Index
HF = Hardness Factor

Joint factor can be further represented as equation II.

JF = JPS + JPA …….**Equation II**

Where,
JPS = Vertical Joint Spacing
JPA = Joint Plane Angle

Table 1: Rating for associated parameters of Lilly's blastability index (Lilly, 1986).

Parameters affecting rock fragmentation	Variants of parameters	Rating
Rock Mass Description (RMD)	Powdery/ Friable	10
	Vertically Jointed	JF
	Massive	50
Vertical Joint Spacing (JPS)	< 0.1m	10
	0.1 m -1.0 m	20
	1.0 m to Drill pattern size	50
Joint Plane Angle (JPA)	Dip out of the face	20
	Strike perpendicular to face	30
	Dip into face	40
Rock Density Index (RDI)		25 X RD-50 RD- Rock Density (tonne/cu-m)
Hardness Factor (HF)	If Y < 50 GPa, Y= Young's modulus	Y/3
	Y >50 GPa UCS = Uniaxial compressive strength (in MPa)	UCS/5

Explosive Factors: The quantity and quality of explosive charge effects the fragmentation output from a blast. Kuznetsov's equation in KUZ-RAM model states that mean fragment size of blasted rock is dependent on quantity of explosive charge in a hole (Kansake et.al, 2016), powder factor of the blast and relative weight strength (RWS) of explosive. RWS is a measure of the energy available per weight of explosive as compared to an equal weight of ANFO Ammonium Nitrate Fuel Oil explosive). It is calculated by dividing the absolute weight strength (AWS) of the explosive by the AWS of ANFO and multiplying by 100. Indirectly, strength of the explosive is measured in terms of detonation velocity and density of explosive. These parameters evaluate detonation pressure exerted by explosive energy to the rock mass. Kuznetsov's equation showing relationship among mean fragment size of blasted rock, rock factors and explosive parameters has been presented in Equation III.

$X_m = AK^{-0.8} Q^{1/6} (115/RWS)^{19/20}$ ……**Equation III**

Where
X_m = Mean particle sixe, cm
A = Rock Factor
K = Powder factor
Q = Quantity of explosive per hole, kg

Geometry of blast: Drilling and charging patterns of blast holes plays crucial role in safety and productivity of a blast. This is completely controllable parameter, which can be planned properly by blast designers based on site conditions. Drilling geometry are decided in terms of burden and spacing. Optimum burden-spacing is decided based on rock and associated explosive parameters available at the site. Explosive energy available inside blast hole tends to provide sufficient detonation pressure to move designed burden up to predefined throw. Thumb rules associated with determination of burden and spacing normally correlates these drilling parameters with hole diameter. Hole diameter is again chosen in order to use explosive energy efficiently without causing damages to nearby structures/workings. Charging parameters are decided by blast designers to get optimum fragmentation. Explosive charges are sometimes distributed along blast hole to reduce maximum charge per delay up to desired limit. However, the fragment size is affected by distribution of explosive charges. Optimum charge length is necessary for particular blast hole length. The maintenance of proper stemming height provides proper confinement to the explosive charge to get optimum fragmentation. Deviation of drill holes also effects fragment size of the blasted rock. The drill hole deviation should be minimized up to null to get desired fragmentation. The blast hole drilling and charging geometry have been presented in uniformity index equation of KUZ-RAM model. The uniformity index equation correlating various blast hole geometrical parameters has been presented in equation IV. This uniformity index equation has been finally used for computation of desired fragment size in Rosin-Rammler equation of KUZ-RAM model. Rosin-Rammler equation has been presented in equation V.

$$n = \left(2.2 - \frac{14}{B}\right)\sqrt{\left(\frac{1+\frac{S}{B}}{2}\right)}\left(1 - \frac{W}{B}\right)\left(abs\left(\frac{BCL-CCL}{L}\right) + 0.1\right)^{0.1}\frac{L}{H} \text{..Equation IV.}$$

Where,
n = uniformity index
B = Burden (m)
S = Spacing (m)
d = Hole diameter (mm)
W = standard deviation of drilling precision (m)
L = Charge length (m)
BCL = Bottom charge length (m)
CCL = Column charge length (m)
H = bench height (m)

$R_x = \exp[-0.693 \left(\frac{X}{Xm}\right)^n]$……….**Equation V**

Where,
R_x = mass fraction retained on screen opening X.
X_m = mean fragment size
n = uniformity index, normally lies between 0.7 and 2.

ROCK FRAGMENTATION WHILE BLASTING IN JOINTED LIMESTONE STRATA

Indian limestone mine has severity of joints. The investigations on the influence of nature and orientation of joints on blast induced rock mass damage was carried out in a study at CSIR-CIMFR, Dhanbad. The study was done using numerical simulation and by comparison of experimental results. The nature of the joint was identified as frictional and bonded in this study. The orientation was classified into four types – dipping out of the face, dipping inside the face, horizontal dipping and strike of the joint normal to the face. The outcomes of the study revealed that the rock mass shows maximum damage when the joint orientation is horizontal. The order of damage to support burden movement and rock fragmentation in four cases of joint orientation is as follows:

Horizontal joint > Strike of the joint normal to the face > Joint dipping out of the face > joint dipping inside the face. Further it was found that the presence of multiple numbers of joints leads to maximum damage in the region lying between the two joints. The numerical simulation output was validated by comparing blasting output from three different limestone mines of India. The rock fragmentation output of the Injepalli limestone mine was better with a smaller charge factor than the other two limestone mines. The better results were due to the closely spaced joints having orientations horizontal and strike normal to the face. The burden and spacing practised at this mine were also larger than the other two mines. Despite large burden spacing, the rock fragmentation result was excellent as the closely spaced joints have supported the stress concentration and thereby increased the explosive energy utilisation. Further, the charge factor was predicted for each mine using Kuznetsov's equation. The predicted charge factor comes to 0.47 kg/m^3, 0.44 kg/m^3 and 0.44 kg/m^3 for Sagmania & Birhauli limestone mine, Injepalli limestone mine and Rawan limestone mine, respectively. The predicted charge factor for Injepalli limestone mine is higher than the charge factor used during the experimental blasts. The smaller charge factor for this mine was sufficient for the blast because of the closely spaced four sets of joints. Based on this study, it has been proposed to reduce the rock factor computed using blastability index (Table 1) by half in the cases when there is presence of closely spaced horizontal joints.

BURDEN-SPACING CALCULATION FOR OPENPIT EXCAVATION

Open pit working possesses safety challenges specifically in terms of fly rock ejections. Drilling geometries are often decided in order to resists fly rock ejection within safe limits and get desired fragment size of the blasted rock. Thumb rule for drill geometry design of an openpit mine suggests that diameter of blast holes should be 15 times of the bench height. Burden should be kept 25 to 40 times of the hole diameter and spacing as 1.15 times of the burden. Sometimes, subgrade drilling is required in order to get blasting upto desired depth. Subgrade drilling should be done for 3 to 15 times of the hole diameter (Dyno Nobel, 2010).

These thumb rules are used globally. However, blasting is completely a site specific phenomenon. So, geometry of the blast should be decided based on different rock and explosive parameters to get desired fragmentation size. Fragmentation analysis for the blasted rock has been performed at three different limestone mines to investigate parametric response on fragment size. The output fragment size under different geometry for three limestone mines has been shown in Table 2. It has been observed that one of the limestone mine presents 90% passing of the blasted rock under 272 mm screen size. The maximum size of fragment was 774 mm for this blast. The blast was conducted keeping hole diameter of 152 mm for 10 m bench height with burden x spacing of 5.0 m x 10.0 m. The blast face was ideal with complete free face condition. A view of blast face for this blast has been presented in Plate 1. Fragmentation output for the blast has been presented in Plate 2. Fragmentation analysis for blasted rock has been performed using wipfrag. The output of fragmentation analysis has been presented in Figure 1 & 2. Analysis of Kuz-Ram fragmentation model for this blast reveals that rock factor plays very important role for this blast face. Rock mass was highly jointed with joint spacing less than 0.1 m and direction of the joint was dipping out of the face. Nature of the rock was also friable in some cases. This resulted in to diminished boulder generation even with larger burden-spacing.

Plate 2. View of rock fragmentation resulted from blast at a limestone mine.

Table 2. Fragmentation output for three limestone mine under different blast geometry and rock conditions

Mine Name	Hole diameter (mm)	Bench Height (m)	Burden (m)	Spacing (m)	Rock condition	R_{max} (Maximum fragment size, mm)	R_{90} (90% passing through screen, mm)
Mine A	115	6	3.0	3.5	Massive	1096	865
Mine B	150	9.5	3.5	4.5	Massive	1261	964
Mine C	152	10	5.0	10.0	Highly jointed/Friable	774	272

Plate 1. View of in-situ rock mass along with blast face condition for experimental blast conducted at a limestone mine

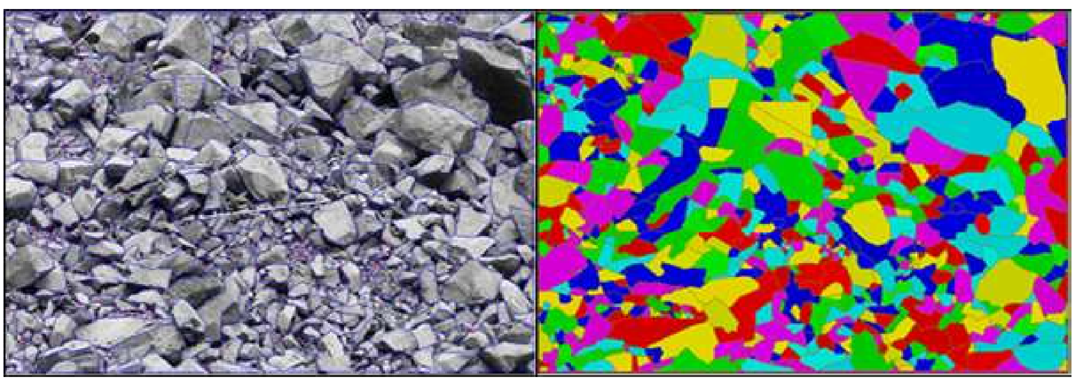

Fig. 1. Rock fragmentation analysis for experimental blast conducted at limestone mine.

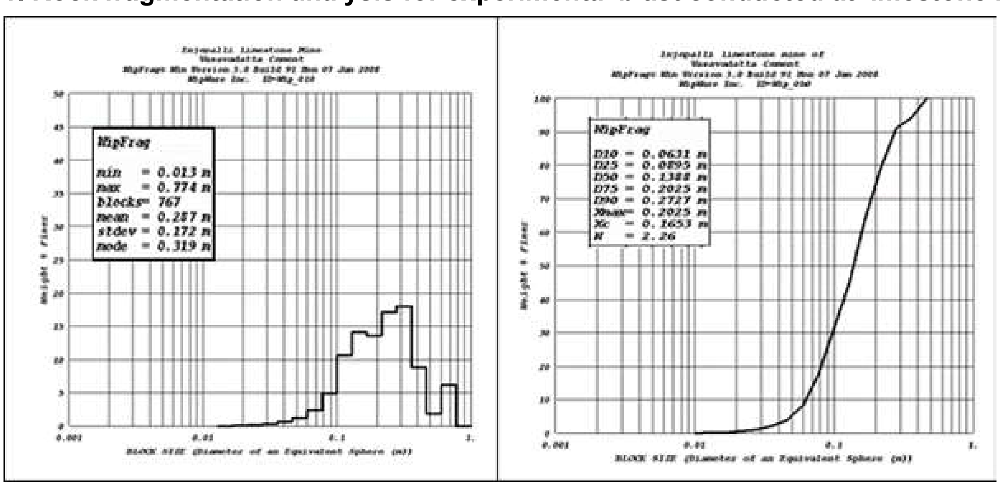

Fig. 2. Fragmentation output resulted from experimental blast conducted at a limestone mine.

Back calculation from all the three equations of Kuz-Ram model helps in getting optimum drill geometry for a blast face. Prediction module has been developed in Microsoft Excel for this purpose. Spacing of the blast has been computed based on mean fragment size of the blasted rock. Burden has been computed to get desired fragment size passing through a screen. The sample excel module has been presented in Figure 3.

Rock Factor	Powder factor	Charge per hole	RWS	Mean fragme	R90%	Fragment size	n				k	Hole dia	Burden	Charge length	Bench height	Spacing
15.12	5	61.87406106	100	40	0.1	70	2.30259	3.322634	1.200758	0.559615	2.145682	150	8.390507	7.5	10	11.32718
RMD	5	125.4364505	100	45												
10	5	236.0308115	100	50												
VJS	5															
0																
JPA																
0																
RDI=25XRD-50																
2.2																
HF																
13																

Fig. 3: Module for prediction of burden-spacing of an openpit working

CONCLUSIONS

Burden-spacing computation is approached by different methods. Rock blasting practitioners around the globe uses thumb rules for determining burden-spacing of blast holes. Kuz-Ram model is defined by three equations combine as Kuznitsov's equation, uniformity index equation and Rosin-Rammler equation. Back calculation from Kuz-Ram model has been used to compute burden-spacing for a blast based on predefined fragment size. The computed predictor has assessed the parameters with acceptable accuracy.

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Revolutionizing Occupational Health and Safety in Sustainable Mining: A Case Study

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ABSTRACT

This review article provides an overview of the occupational health and safety of the mining section against the backdrop of changes in the composition of the sector, universal trends in OHS performance, and the consensus on OHS milestones and targets among mining stakeholders. At present, with the development of technological innovations and the wide depiction of new mining equipment, research themes on mining equipment management are attracting more attention from both academic scholars and industrial practitioners. OHS performance has developed, progression is lingering, and there is a necessity for important rather than incremental variation if the targets are to be understood. The occupational health practitioners have the liability to guide management and employees on the occupational legislative obligations to protect legal consent at the workplace. Lack of training and consistency in risk management, guidance for junior, small, and artisanal miners, and holistic risk management techniques limit efforts to promote OHS and respond to developments in the sector. The continuous struggle to promote OHS and respond to changes in the sector is constrained by a lack of training, incompatibility in risk management, conduct for junior, small, and artisanal miners, and poor/ absence of holistic approaches to risk treatment. In the present review paper, sound remedial and monitoring measures are recommended to decrease the percentage of injuries and minimize the severity of accidents.

Keywords: Mining, Occupational Health & Safety, Mining Equipment Management.

INTRODUCTION

Mining remains one of the most hazardous job sectors, despite the important efforts in many countries to execute and sustain occupational safety and health. The number of deaths, injuries, and diseases among mine workers worldwide remains high. Greatly prohibitive work, in terms of health and safety, is still requisite. Over and above accidents, many of the detrimental health effects correlated with mining and the extraction industries are involving the breath of airborne pollutants that are not controlled at the genesis. Moreover, mining may require heavy work, exposure to toxic chemicals, noise, vibration, heat and cold stress, work at high altitude, shift work, etc.[1-3]. Underground mining is an important industry to considering in answering questions regarding safety, productivity, and provision [4]. Mining operations comprise a various range of actions and involve work that has an equally diverse health and safety risk profile. Implicit hazards can lead to unacceptable rates of fatalities and injuries.

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Health and safety in the mining sector can only be improved if risks are identified and effectively addressed [5]. Concerns about the environment, health and safety are increasing all over the world. Policy makers, stakeholders and interest groups are becoming more critical and rational about EHS considerations. Despite being a mineral-rich country with competitive mineral production, the industry falls well short of international EHS minimum standards. This whitepaper unfolds a key comparison of his EHS scenarios for industry leaders involved in EHS. It sets benchmarks for practices, legal frameworks and the implementation of EHS laws around the world, shows where we stand today, highlights weaknesses in existing systems and provides guidance for a better EHS compliant future in the mining sector [6]. A worker is able to all the health problems perhaps to be seen within members of the common community. However, the working population is exposed to health hazards over and above the rest of the community because of work practices, thereby providing another reasoning for special worry for their health. The world is always devised concerning climate, wellbeing, and health.

The EHS problems have been deemed more carping & become allowable among policymakers, investors, and political groups. Although a country that is rich in mineral resources and creates lucrative minerals, the sector is away from the worldwide basic standards of Health and safety. Mining seems to be the fifth fastest thriving industry but it is evincible to the environment. Financial and technological support to mining industries in developing countries capacity defeated hostile effects on the environment. Governments may also provide such incentive programs for encouraging environmental quality. Environmental degradation and health and well-being issues associated with mining activities can pose significant threats to the well-being of ethnic groups and sustainable mining activities themselves. Environmental rating systems may therefore need to address them [6]. The majority of nations lack thorough sources of information on occupational health. A large portion of the data is incomplete when combined due to its fragmentation. Particularly sparse and inaccurate are exposure data, which can predict disease. This is because to the strict and intricate regulations for representative sampling, sample analysis, and data processing, which varies depending on the countries and sectors [7].

Figure 1. Mine Safety Management Using Innovative and Technological Strategies

A worker is susceptible to all the health problems probable to be ocular among members of the common section. However, the working citizens are exposed to health hazards above and beyond the level of the community because of work practices, thus providing another cause for special concern for their health [8]. Promoting occupational health and safety in the workplace has various benefits for society; the mining organizations; the miners and their families; and socio-economic growth. Earlier studies have indicated that poor administration and implementation of health and safety measures negatively affect social and economic growth [9, 10].

The important causes of fatalities and serious injuries at underground coal mines are fundamentally the same, regardless of the area of the mine. The recommendations seized in this capacity are normally just as significant to big mines as they are to small mines. However, because of greater limitations on the work force and wealth, the substitute for solving definite types of safety problems may be more inadequate for small mines than for portly operations. The authors of this volume have been incited to focus on suggested solutions that would be practicable for execution at smallest mining companies. However, large mining operations may be able to work out certain types of safety problems via strategies that would not be feasible for most small mining operations (e.g., major changes in equipment or mining techniques) [11].

Our paper builds primarily on two literatures. One literature has investigated the link between productivity and safety in mining and other sectors[12]. Administration (OSHA) inspections lowered accident rates. Overall, we believe that we contribute to this literature by adding a novel source of identification and by quantifying the tradeoffs between productivity and safety that are implied by the current regulatory environment [4].

Another literature has determined the impact of regulation on productivity more generally. In addition to the studies on this topic noted above finds that safety regulations—such as OSHA inspections—contributed as much as 30% of the decline in productivity growth for manufacturing sectors during the 1970s [4].

Hence, this paper in the first illustration is to identify the hazards in the work place and the number of disease claims made by the workers. The analysis is made on the claims in industrial sector here because it is the biggest sector in mining. The mining sector is stated in the in consequence of part of this paper, as within the most hazardous sector [13].

This study aims to explore the impact of safety and health in the mining industry. Analyzing the implementation of operational management, the implementation of work environment management, the implementation of occupational safety management, and the implementation of occupational health, and analyzing the factors that influence the implementation of occupational safety and health in the mining industry [14].

PHYSICAL HAZARDS

Traumatic injury remnant a serious problem and ranges from the negligible to the mortal General causes of fatal injury encircle rock fall, fires, burst, mobile equipment accidents, falls from height, entrapment and electrocution. Less ordinary but recognized causes of lethal injury comprise flooding of underground workings, wet-fill release from collapsed bulkheads and air blast from block caving failure. The systematical application of risk management techniques has contributed to a substantial fall in injury frequency of vibration rates in developed nations. Further improvement, however, is required to reach rates bearable to the broader community. Safety and risk management in mining [15].

CHEMICAL HAZARDS

Crystalline silica has long been a significant hazard in mining, with the risk of silicosis at its scalp during dry drilling late in the nineteenth century [16]. Silicosis has been subject to considerable examination [17]. Axial water-fed rock drills, wet techniques, ventilation, enclosed cabins and respiratory defense have hugely controlled silicosis in developed nations. However, silicosis remnant a problem in manifesting nations and silico-tuberculosis is important in mining industry, where the high formulation. Skin plump with cyanide solutions are hazardous, though the risk is decreased by the use of low concentration solutions. Cyanide solutions are generally alkalinized to reduce the risk of hydrogen cyanide gas being evolved on contact with water.

BIOLOGICAL HAZARDS

The risk of tropical diseases such as malaria and dengue fever is substantial at some distant mining locations. Leptospirosis and ankylostomiasis were usual in mines, but eviction of rats and improved sanitation has controlled these hazards successfully in the developed world [7]. On mine sites, cooling towers are frequently seen. To find large numbers of other heterotrophic microbes or Legionella contamination, regular microbiological testing of the water is required. [18].

ERGONOMIC HAZARDS

Though mining has become increasingly mechanized, there is only a substantial quantity of manual handling. Cumulative trauma disorders pace to constitute the greatest class of occupational illness in mining and oft result in prolonged disability [19]. Overhead work is common underground, during ground support and during the suspension of pipes and electrical cables. This can cause or exacerbate shoulder disorders. Broken ground is often encountered and can cause ankle and knee injuries. Most mines operate 24 hours per day, 7 days per week, so shiftwork is very common. There has generally been a trend towards 12 hours shifts in recent years. Fatigue in relation to shiftwork has been subject to considerable investigation in the industry [20].

PSYCHOSOCIAL HAZARDS

Drug and alcohol misuse has been a difficult issue to deal with in mining, but policies and procedures are now in place in most chuckle mining operations. Confabulation continues as regards how to measure psychophysical breach. Nevertheless, mining operations commonly look at the assessment of urinary drug metabolites and respiration or blood alcohol on pre-employment and in outcome of accidents. Upland locations are common in mining. Contemporaneous finds, however, tend to be smaller and do not justify establishment of permanent townships. As a result, there has been a tendency towards ‘fly-in-fly-out’ operations, with mine employees differentiated from their families and communities during work periods. Deport allocations are also common in mining and the connected psychosocial hazards have been reviewed recently [21].

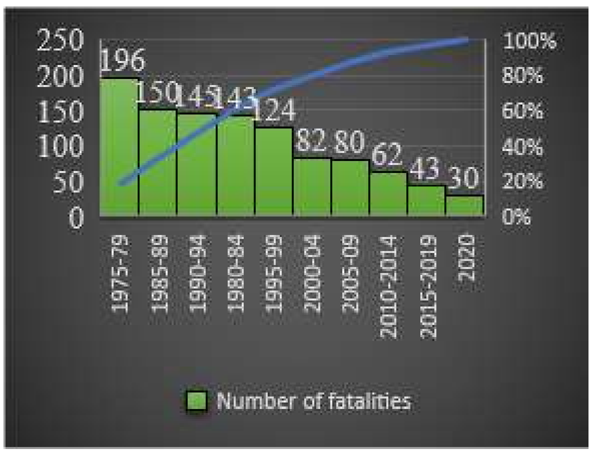
RESULT AND DISCUSSION

Table. 1: Comparative fatalities statistics of CIL 5- yearly average since 1975 to 2020 (Source: Ministry of coal, Safety in mine, India):

Year	Number of fatalities
1975-79	196
1980-84	143
1985-89	150
1990-94	145
1995-99	124
2000-04	82
2005-09	80
2010-2014	62
2015-2019	43
2020	30

In coal mines, there has been a keen decrease in the five-yearly average figure of 196 fatalities in 1975-79 to 30 fatalities in 2020. Main multiplication backward this feat is shift of mining technology from conventional underground to mechanized opencast in coal mines. In coal mines, major concern is the incident of disasters at regular intervals, mostly in the underground mines. The frequency of disasters due to fires and explosions has been alarmingly increased in the recent past. Diluvium and strata failures are common causes. This needs a focused exertion from all the stake holders. For fatal accidents concerning four or less fatalities per accident, roof fall continues to be the area of major concern pursued by accidents caused by dumpers and trucks in coal mine.

Figure 2. Comparative fatalities statistics of CIL 5- yearly average since 1975 to 2020 (Source: Ministry of coal mine, India):



The frequency of fatalities from 1975 to 2020 (Fig. 2) decreased fatality rates in the mining industry. Although the years 2000 through 2020 show a massive decrease in the rate of fatalities in the mining industry, this rate has the lowest levels recorded in 200–2020. Many mining companies have emphasized the latter in recent years [22].

Table 2. Fatalities, number of accidents, and average fatalities of different types of accidents based on 483 deadly accidents during 2015–2019, as reported by media [23].

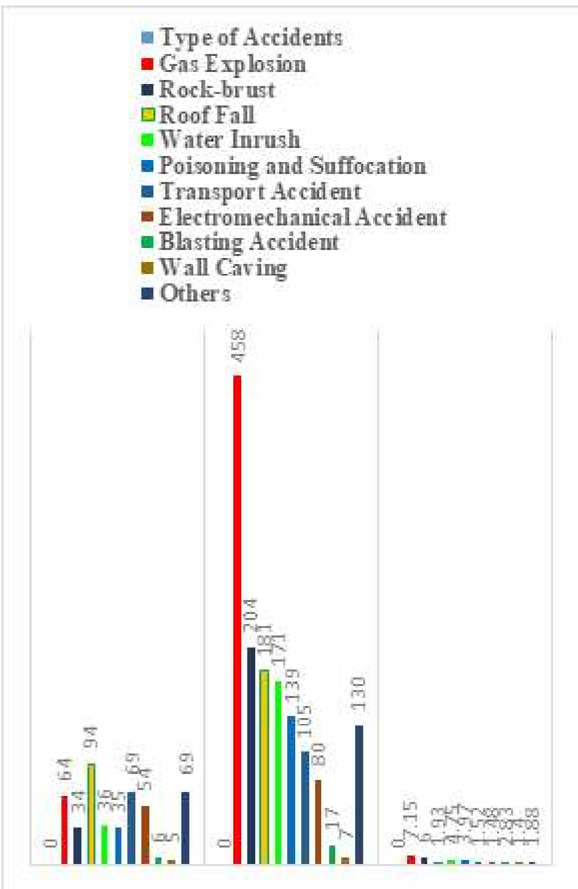
Type of Accidents	Number of Accidents	Fatalities	Average Fatalities per Accident
Gas Explosion	64	458	7.15
Rock-burst	34	204	6
Roof Fall	94	181	1.93
Water Inrush	36	171	4.75
Poisoning and Suffocation	35	139	3.97
Transport Accident	69	105	1.52
Electromechanical Accident	54	80	1.48
Blasting Accident	6	17	2.83
Wall Caving	5	7	1.40
Others	69	130	1.88

Table 2. Indicates the fatalities, number of accidents, and average fatalities of different types of accidents. Gas explosion, rock-burst, roof fall, water inrush has caused the most fatalities. Moreover, gas explosion, rock burst, coal and gas outburst, water inrush, poisoning, and suffocation are most likely to persuade, as are the above-mentioned accidents. It should be noted that these accidents tend to come up during coal cutting and roadway channeling periods. These types of accidents tend to lead to a lot of casualties and property losses. If a sensible number of coal miners are replaced by automatic machinery, it is reasonable to trust that major accidents will occur. Therefore, it is urgent to upgrade the automation and intelligentization of coal mines to polish up production capability and develop coal mine safety [23].

Figure 3. Fatalities, number of accidents, and average fatalities of different types of accidents based on 483 deadly accidents during 2015–2019, as reported by media[23].

Figure 3. Shows the fatalities, accidents, and average fatalities of various accident types. The most fatalities have been caused by gas explosions, rock explosions, roof falls, and water inrush. Additionally, the above-mentioned accidents as well as gas explosion, rock burst, coal and gas outburst, water inrush, poisoning, and suffocation are most likely to convince. It should be emphasized that similar mishaps frequently occur during coal mining and road rerouting operations. These kinds of mishaps frequently result in numerous fatalities and significant property losses. It is realistic to assume that significant accidents will occur if a reasonable number of coal miners

are replaced by automatic machinery. Therefore, it is crucial to update coal mine automation and intelligence in order to enhance production capacity and expand [23].



RECOMMENDATIONS FOR SAFETY IMPROVEMENT

The Mining Program should set its goals to take a more proactive approach to identifying and regulating hazards to sort out illnesses and injuries, especially those that climb from alternative mining situations and technologies. Associating with industry should be done more extensively so that research results can be more fruitful throughout the industry. The program should also completely utilize outside technical expertise through a vibrant extramural and contract research program.

The collection of surveillance data is highly significant in controlling worker health and safety circumstances and ascertaining the effectiveness of Mining Program action. The Mining Program should make better use of existing surveillance data on mining-related incidents, injuries, and illnesses and work to make these surveillance programs more robust. Current advances in remote sensing and diagnostic methods should be evaluated, improved, and shared with mine operators for timely detection and avoidance of mine hazards.

To promote training, the Mining Program should determine who will likely use the results of its research. With respect to information dissemination, a more proactive and strategic dissemination agenda is suggested, one that is possessed by research about the pervasiveness of new technologies, processes, and practices. Technology transfer could be enhanced by targeting mine operators and workers who successfully influence the decisions of others. The Mining Program should also develop demonstration projects that show the probability and utility of interventions to reduce illness [24].

Through technical changes, i.e., progressive technology, equipment, and incorporating information technology into operations, we can minimize mining accidents and diseases. The occupational health professional must be present in the mining industry, mostly in developing countries, to cover the accident [25].

CONCLUSION

Mining is a worldwide activity that employs millions of people. Mining can range from a high technology activity in big mines with a proper working environment and safety for the miners to a big, medium or small-scale activity with a very dangerous work environment. Although the fatality and diseases connected to mining, such as silicosis, and other pneumoconiosis, have been well known for centuries, together with the rates of fatalities and serious accidents, much preventive work still needs to be done. Legislation, supervision and control of the mines, good statistics of accidents and occupational diseases, and the development of safety programs and safety culture are crucial for the sound development of mining in the world.

From the case analysis, it also can be observed that many claims were turned down due to the failure to establish a strong relation between 'fatality' and 'occupation'. A need to provide occupational health services can be proposed help the work people. identifying and regulating hazards, promote training, collection of surveillance data for example. Hence, the relationship between occupation and disease can be established. It is growing and new exploitation sites are being developed, and the mining production will continue growing in the near future.

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Wireless Sensor Network Based Fire Detection and Monitoring System for UG Mines

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ABSTRACT

Underground mine poses a significant risk of fires, creating a major concern for workers and also the people live nearby. These fires erupt unexpectedly causing partial or complete evacuation of mine personnel and potential causing loss of lives. Hence, it is crucial to implement a system capable of detecting and monitoring fires promptly and trigger the alarms for immediate response. The digitalisation of mines involves the sustainable implementation with integrating advanced technologies like the Internet of Things, Wireless Sensor Networks etc. To enhance mine monitoring, data acquisition, and overall operational effectiveness. The study explores the myriad possibilities for technological interventions aimed at significantly improving safety. It briefly explains intelligent systems for sensing, monitoring, and methods for analysis to be used in particular scenarios such as underground mine fire incidents etc. In addition to that, generalized architectures were proposed which can be used to design the future research and development, facilitating applications like Underground environment analysis and mine fire predictions without requiring any alterations to existing systems i.e., mine deployment systems. The study focuses on effective connectivity, sustained deployment of real-time sensing systems, and energy harvesting to support the proper implementation of digital networks in the mines.

Keywords: Underground Mine, Fire, Monitoring, Sensors.

INTRODUCTION

Underground mines hold a pivotal role in the development of a country and its communities. They contribute significantly to environmental, economic, and social well-being. The mines are crucial for sustaining various forms of life underground and play a vital role in maintaining the ecological balance. Uncontrolled incidents, such as mine accidents or collapses, need to be promptly identified to mitigate potential damages to the subterranean ecosystem. Mining accidents, whether caused by natural disasters or human errors, result in significant loss and environmental damage. Hundreds of resources are compromised each year due to incidents in different parts of the world, leading to considerable biodiversity loss. Studies indicate that a substantial 80% of losses are attributed to these events. The fatality rate in case of an accident in underground mining environments is particularly high. Implementing the Internet of Things (IoT) in underground mines facilitates real-time monitoring of the mine environment, allowing for the timely detection of accidents or potential hazards. This technology aids in preventing and mitigating the consequences of incidents, contributing to the overall safety and sustainability of underground mining operations.

The main aim of this project is to design a system "Wireless Sensor Network based Fire Detection and Monitoring System for UG Mines" which helps in monitoring and detecting the investigation site for rescue purposes. It includes integration of different Smart Sensors, Micro Controller Units and Radio Frequency modules for monitoring Underground Mines Fire and its Environment, development of Graphical User Interface for Real Time data acquisition and alerting was done as well as conduction of laboratory and field investigations using integrated system and regression analysis on the data obtained is implemented.

LITERATURE SURVEY

The following table 1 gives the detailed reviews on WSN applications in UG Mines.

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Table 1: Literature review on UG and WSN applications

S. No	Year	Authors	Title	Publishers	Work done
1	2022	Burak Kizilkaya et al.,	An Effective Forest Fire Detection Framework Using Heterogeneous Wireless Multimedia Sensor Networks.	ACM Journals	The multimedia data transmission is an expensive operation. In this study, a novel hierarchical approach is presented for the detection of forest fires. The proposed framework introduces a new approach in which multimedia and scalar sensors are used hierarchically to minimize the transmission of visual data.
2	2022	Wahyono et al.,	Real-Time Forest Fire Detection Framework Based on Artificial Intelligence Using Colour Probability Model and Motion Feature Analysis.	MDPI	This article proposes a new framework for fire detection based on combining colour motion shape features with machine learning technology.
3	2022	Seyd Teymoor Seydi et al.,	Fire-Net: A Deep Learning Framework for Active Forest Fire Detection.	Hindawi – Journal of Sensors	In this paper they explained about a deep learning framework called Fire-Net, which was trained on Landsat-8 imagery for the detection of active fires and burning biomass. Specifically, they fused the opticaland thermal modalities from the images for a more effective representation. In addition, their network leverages the residual convolution and separable convolution blocks, enabling deeper features from coarse datasets to be extracted.
4	2022	Udaya Dampage et al.,	Forest fire detection system using wireless sensor networks and machine learning.	Springer Nature	This paper proposed a system and methodology that can be used to detect forest fires at the initial stage using a wireless sensor network. Furthermore, to acquire more accurate fire detection, a machine learning regression model is proposed.
5	2021	Rajesh Singh et al.,	Forest 4.0: Digitalization of Forest using Internet of Things.	Journal of King Saud University – Computer and Information Sciences.	IoT in the forest enables to implement the real-time monitoring of the forest environment in terms of tracking fire accidents, monitor the health of the crop, continuous assessment of the vegetation, and real-time tracking of forest logging.
6	2021	Renjie Xu et al.,	A Forest Fire Detection System Based on Ensemble Learning.	MDPI	In this paper, a novel ensemble learning method was proposed to detect forest fires in different scenarios. Firstly, two individual learners Yolov5 and EfficientDet are integrated to accomplish fire detection process. Secondly, another individual learner EfficientNet is responsible for learning global information to avoid false positives. Finally, detection results are made based on the decisions of three learners.
7	2020	Gabriel Roque And Vladimir Sanchez Padilla	LPWAN Based IoT Surveillance System for Outdoor Fire Detection	IEEE	This paper presents a low-cost IoT prototype for re-detection in outdoor environments based on sensors and Low Power Wide Area Network (LPWAN), focused on the accuracy in the temperature and gas measurement now a fire starts.
8	2019	Jinglong Liu et al.,	Underground Coal Fires Identification and Monitoring Using Time-Series InSAR With Persistent and Distributed Scatterers: A Case Study of Miquan Coal Fire Zone in Xinjiang, China	IEEE	This paper focuses on the usage of Interferometric synthetic aperture radar (InSAR) technology identifies and monitors coal fire areas by monitoring surface subsidence caused by burned out area. The distributed scatterer interferometry (DSI) technology is used to monitor the Miquan fire area in Xinjiang in this paper.
9	2018	Bin Zhou et al.,	Surface-based radon detection to identify spontaneous combustion areas in small abandoned coal mine gobs: Case study of a small coal mine in China.	Elsevier	This study focuses on a small abandoned coal mine in Shanxi Province, China, using surface-based radon detection. Three abnormal temperature areas (A, B, C) and a potential abnormal temperature area (D) were identified. Drilling was subsequently performed to measure the temperature distribution in these areas.

METHODOLOGY

The following figure depicts the detailed procedure for implementation of Wireless Sensor Network based Fire Detection and Monitoring System for UG Mines.

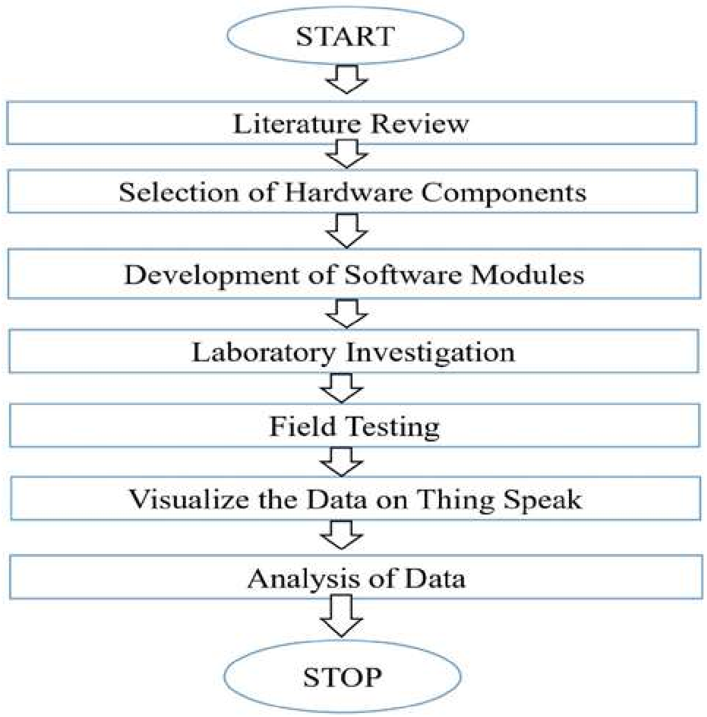


Fig 1: Methodology

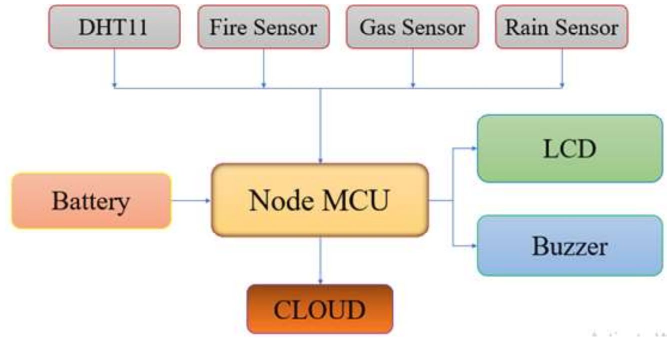


Fig 2: Block Diagram of the Project

SOFTWARE COMPONENTS

The software components used in the project are ThingSpeak and Arduino IDE. ThingSpeak, an open-source IoT platform for data collection, processing, visualization, and device management. ThingBoard Cloud, a fully managed, scalable and fault-tolerant platform for IoT applications. The Arduino Integrated Development Environment, which contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It is used to implement the code dumping into the kits where it acts as interpreter. It connects to the Arduino hardware to upload programs and communicate with them.

CONNECTION DIAGRAM

This section involves the connections with one-to-one components.

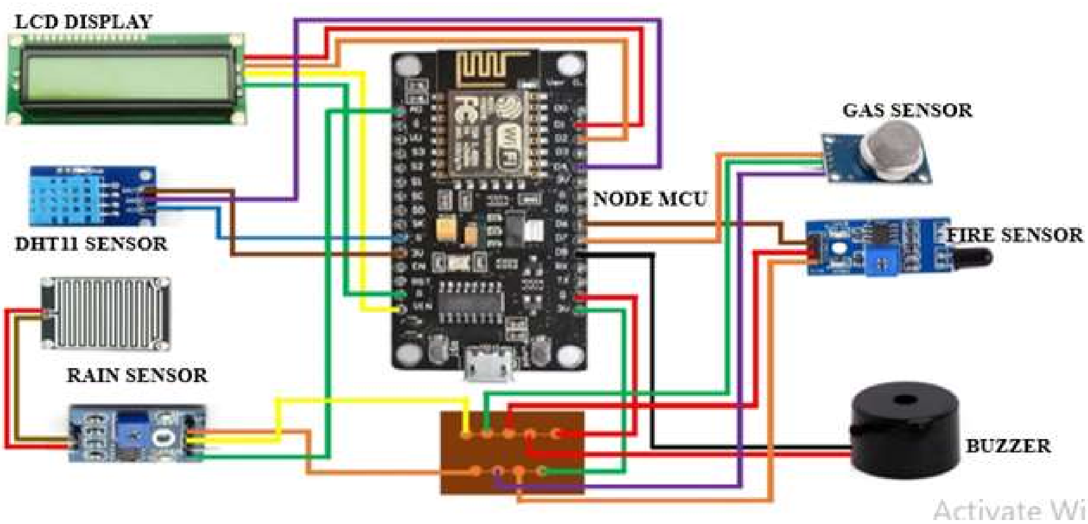
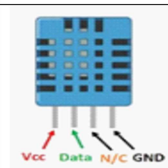
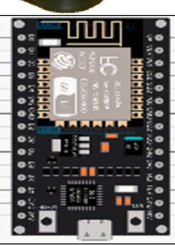


Fig 3: Connection Diagram

HARDWARE COMPONENTS

The following table 2 tells about the hardware components used in the project

Table 2: Table of hardware components

S. No.	Components	Picture	Description
1	Flame Sensor		Flame detector, a sensor designed to detect and respond to the presence of a flame or fire, allowing flame detection. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel linesuch as a propane or a natural gas line, and activating a fire suppression system.
2	DHT11 Sensor		DHT-11 Digital Temperature And Humidity Sensor, a basic ultra-low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin.
3	Rain Sensor		Raindrops Detection sensor module, used for rain detection. It is also used for measuring rainfall intensity. Rain sensor can be used for all kinds of weather monitoring and translated into output signals and AO. Raindrops Detection Sensor Module, Rain Weather Module for Arduino, etc. Rain sensor can be used to monitor a variety of weather conditions and turned into several fixed output signal and Analog output.
4	Battery		This node will be powered by a battery and will be integrated with local storage for data backup.
5	Gas Sensor		A device that is used to detect or measure or monitor the gases like ammonia, benzene, sulfur, carbon dioxide, smoke, and other harmful gases are called as an air quality gas sensor. The MQ135 air quality sensor, which belongs to the series of MQ gas sensors, is widely used to detect harmful gases, and smoke in the fresh air.
6	Buzzer		A buzzer or beeper, an audio signaling device which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.
7	Node MCU		Node MCU, an open source platform based on ESP8266 which can connect objects and let data transfer using the Wi-Fi protocol. In addition, by providing some of the most important features of microcontrollers such as GPIO, PWM, ADC, and etc., it can solve many of the project's needs alone.
8	LCD		LCD, a basic 16 character by 2 line Alphanumeric display. Black text on Green background. Utilizes the extremely common HD44780 parallel interface chipset. Interface code is freely available. You will need Minimum 6 general I/O pins to interface to this LCD screen. Includes LED backlight. Works in 4bit and 8 bit Mode.

All the sensors are connected to Node MCU with their respective node connections which has their own properties.

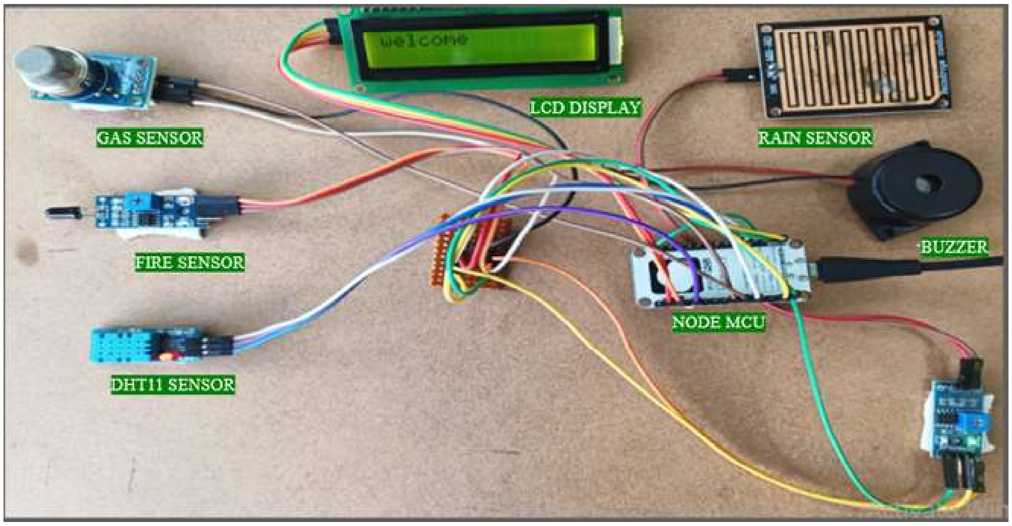
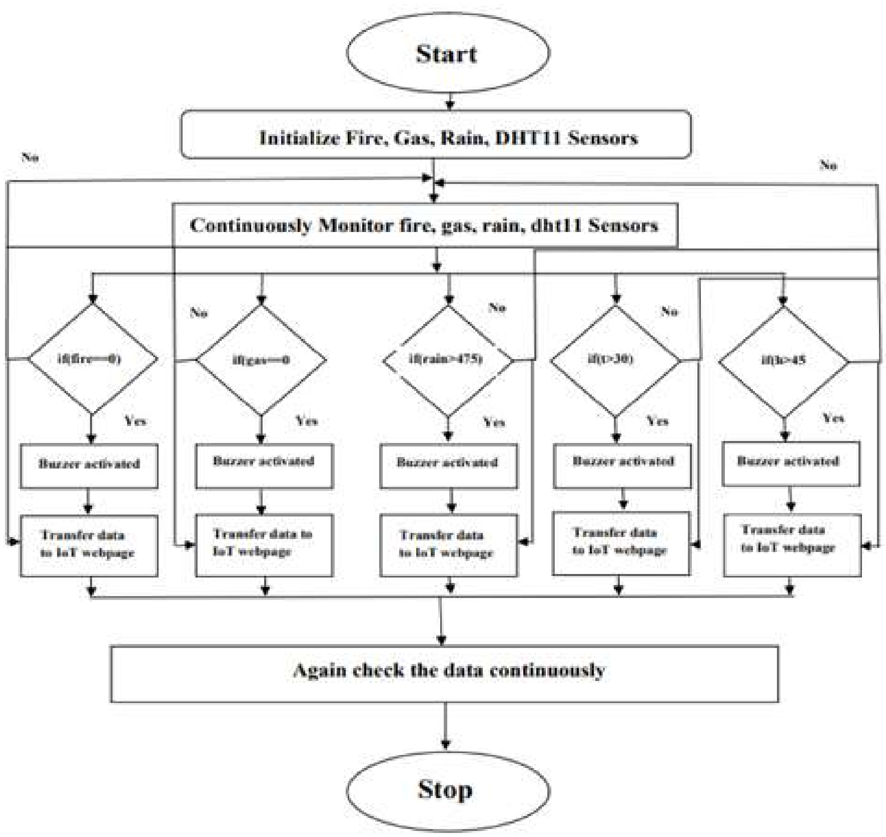


Fig 4: Hardware connection of the Project

Connections are given from the power supply to NodeMCU which directly connects to the rain sensor, temperature sensor, DHT11 sensor, gas sensor, LCD and buzzer.

SOFTWARE IMPLEMENTATION

The flowchart explains the implementation of our project code.



We have done with the implementation of code with different conditions for every sensor unit. Firstly, we initialized all the sensors which we connected to the main controller. After initializing of the parameters, we initiated the dumping of code into the controller. Continuous monitoring of sensor unit is done in this system. Every parameter has its own conditions said as threshold values, to recognize the system cross hold. We initiated fire, gas, rain, temperature and humidity sensors. For fire sensor, we gave a condition stating if (fire=0), then there is no intimation of fire. But if (fire=1), then the system detected the fire and gives alert. The same will be initiated to the IoT webpage where we are going to monitor the surroundings continuously i.e., real time monitoring. The same goes with the gas sensor, if (gas=0), then there is no detection of spreading harmful gas. If (gas=1), then the gas is detected and alert is initiated. Rest rain, temperature and humidity have threshold values which are 475, 30 and 45 respectively. If the system is detected the parameters above the threshold values then alert is generated for safety purposes. Every parameter is real time based monitoring, so that even a little fluctuation in the readings may help us in providing the safety cautions in advance. This system helps us in real time safety to help the people, or resources and more, to be saved without any high destruction cost. It helps in reducing the destruction held by the fire in the site area by prioritizing the surroundings and its conditions

RESULTS & DISCUSSION

Actually, our aim of the project is to design a prototype in order to detect underground mines fire and environment monitoring using IoT to develop Graphical User Interface for Real Time data acquisition and alerting.

Fig 5: Laboratory implementation of our Project

Table 3: Output data set obtained from the implementation

Date	Temperature	Humidity	Rain	Gas	Fire
11-12-2023	28	24	459	1	1
11-12-2023	25	61	436	1	1
11-12-2023	30	59	421	0	0
12-12-2023	30	29	416	1	1
12-12-2023	24	47	412	0	1
12-12-2023	28	48	462	1	1
13-12-2023	21	83	436	1	1
13-12-2023	22	58	457	0	1
13-12-2023	26	55	413	1	0
14-12-2023	28	47	402	1	1
14-12-2023	33.8	31	456	0	1
14-12-2023	33.8	31	466	0	1
15-12-2023	33.8	31	429	0	1
15-12-2023	33.8	31	439	0	1
15-12-2023	33.8	30	452	0	0
16-12-2023	33.8	30	991	0	1
16-12-2023	34.2	31	648	0	1
16-12-2023	34.2	31	605	0	0
17-12-2023	34.2	44	609	0	1
17-12-2023	34.7	34	480	0	1
17-12-2023	35.6	30	605	0	1
18-12-2023	35.6	31	590	0	1
18-12-2023	35.6	30	581	0	1
18-12-2023	35.6	30	585	0	1
19-12-2023	35.2	29	474	0	1
19-12-2023	35.2	29	400	0	1
20-12-2023	35.2	29	473	0	1
20-12-2023	35	28	445	0	1
20-12-2023	34.7	30	440	0	1

The above data set was taken from the implementation of our project. And this set only used to implement the rest of our project.

The hardware design has been done and the results are explained below:

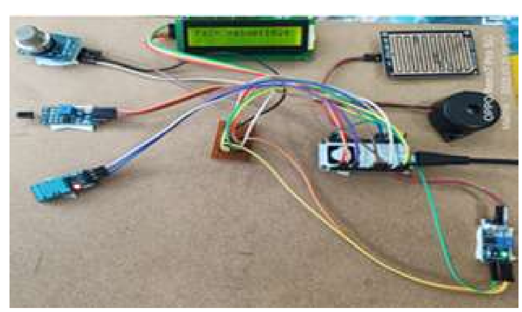


Fig 6: Rain sensor output

Rain sensor senses the presence of rain when it is raining it will be displayed as “rain value” on the LCD screen and also it gives the warning signal by buzzer.

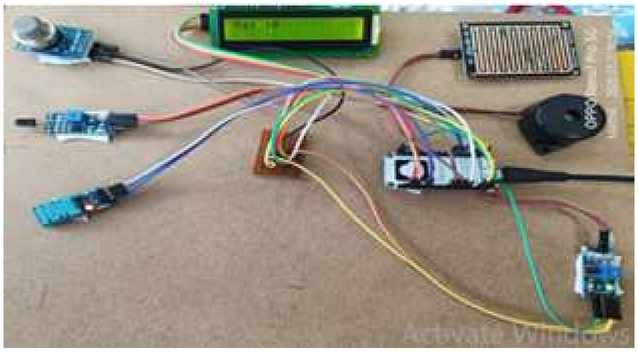


Fig 7: Gas sensor output

Gas sensor senses the presence of any kind of gas/smoke when it is burning over the mines and it will be displayed as “gas: 0” on the LCD screen and also it gives the warning signal by buzzer. Mines growth is well known to increase the environmental impact of fossil fuel usage.

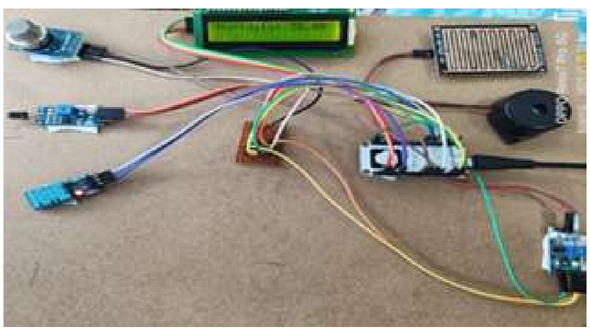


Fig 8: Humidity sensor output

The humidity sensor module is sensitive to environmental humidity, generally used to detect ambient humidity by adjusting the potentiometer and it will be displayed as “Humidity: 38” on the LCD screen and also it gives the warning signal by buzzer.

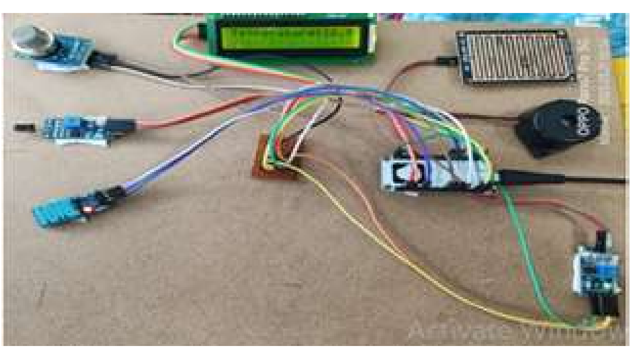


Fig 9: Temperature sensor output

Temperature sensor is used in various applications such as measuring temperature values in heating, ventilation and air conditioning systems. This sensor senses the presence heat when the mines are burning and it will be displayed as “Temperature: 28.9” on the LCD screen and also it gives the warning signal by buzzer.

The below graphs are implication of the dataset which we obtained during our implementation of the system.

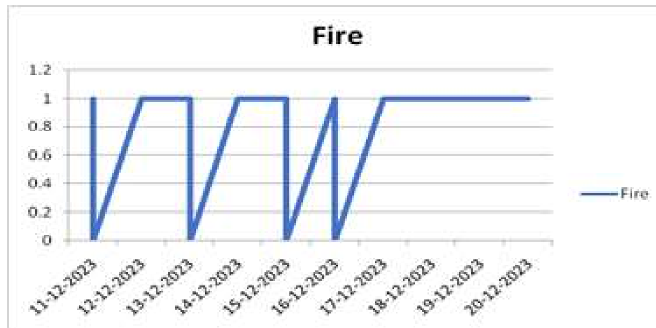


Fig10: Graphical representation of Fire Sensor Outputs

The output of the x and y axis values of the fire sensor whether any firing is identified or not is defined in the graphical manner.

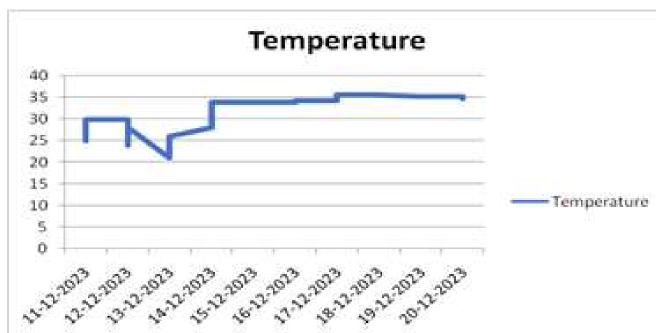


Fig11: Graphical representation of Temperature Sensor Outputs

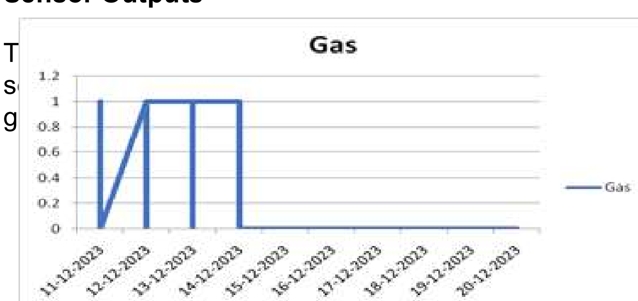


Fig12: Graphical representation of Gas Sensor Outputs

The output of the x and y axis values of the gas sensor whether any type of smoke of burning over the mines is identified or not is defined in the graphical manner.

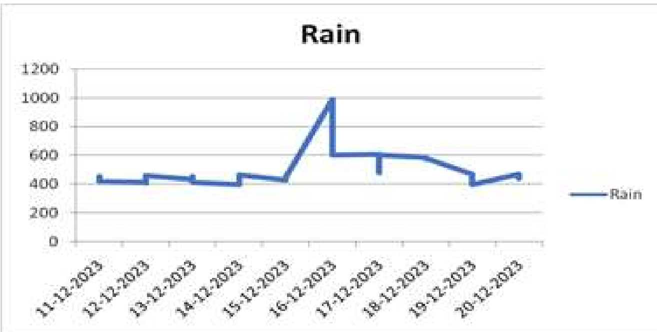


Fig13: Graphical representation of Rain Sensor Outputs

The output of the x and y axis values of the rain sensor whether it's raining or not is defined in the graphical manner.

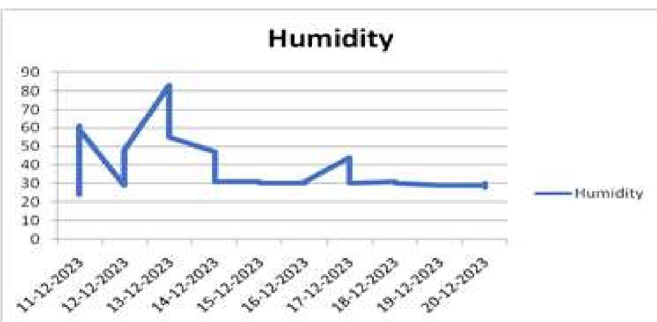


Fig14: Graphical representation of Humidity Sensor Outputs

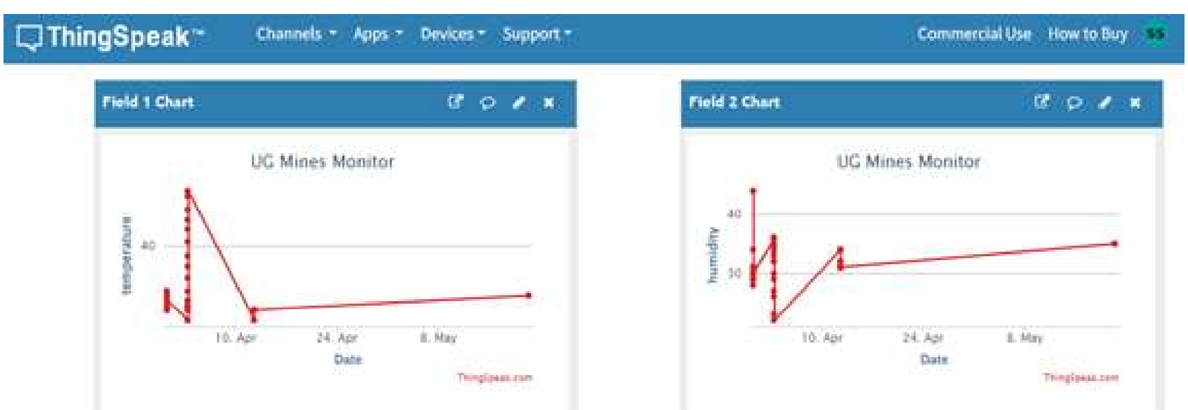
The output of the x and y axis values of the humidity sensor whether the humidity is identified or not is defined in the graphical manner.

THINGSPEAK

ThingSpeak, an IoT analytics platform service that allows us to aggregate, visualize and analyse live data streams in the cloud. It provides instant visualizations of data posted by our devices to ThingSpeak. With the ability to execute MATLAB code in ThingSpeak we can perform online analysis and processing of the data as it comes in. It is often used for prototyping and kept as proof of concept for IoT systems that require analytics.

We create channels for each and every single sensor data. These channels can be set as private channels or we can share the data community through Community channels.

ThingSpeak is an IoT platform that allows us to connect and save sensor data in the cloud and increase IoT applications. Sensor data can be easily integrated and sent from Arduino or Raspberry Pi or any additional IoT gateway. Every sensor connected will have a separate channel as stated above. These channels helps us in visualizing and analysing the collected and stored data. In this project, we used an LDR to plot its light Intensity level on ThingSpeak using Node MCU. We programmed the Node MCU to read and store the LDR data into a variable and then upload it to ThingSpeak using its channel name and API key. The Node MCU should be connected to the internet via Wi-Fi.



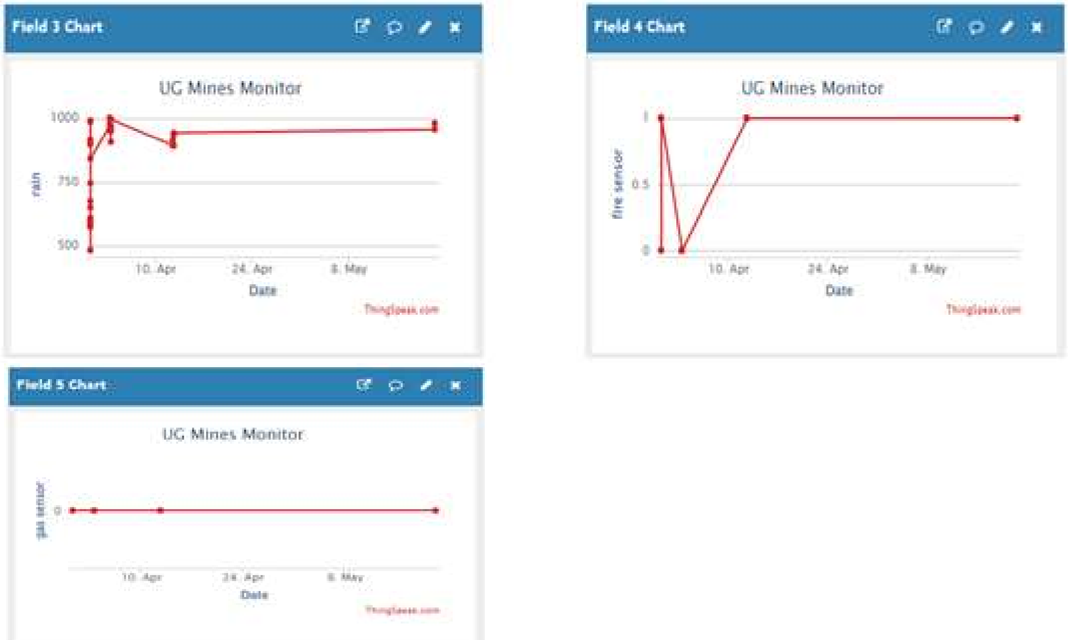


Fig 15: Thing Speak graphs of the project

The above graphs represents Things speak output with 5 initiated channels. Those are temperature sensing data, rain sensing data, humidity sensing data, gas sensing data and flame sensing data. All the values recorded by the sensors were represented in graphical manner.

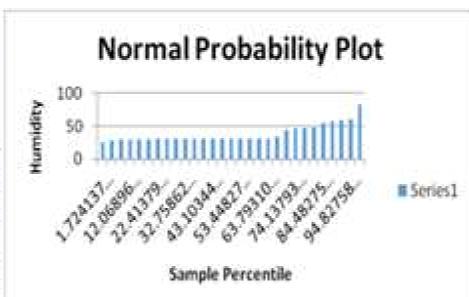
Regression Analysis

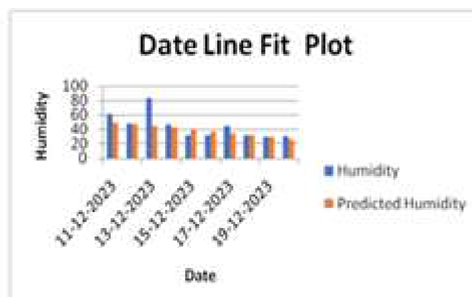
Advance technique in Data Analysis for ML Platform in Prediction. This regression analysis is done using EXCEL platform. This regression is Supervised Learning.

SUMMARY OUTPUT

Humidity

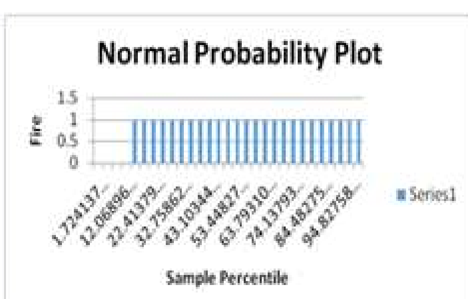
Regression Statistics	
Multiple R	0.932951729
R Square	0.893808583
Adjusted R Square	0.870255397
Standard Error	7.933818961
Observations	29

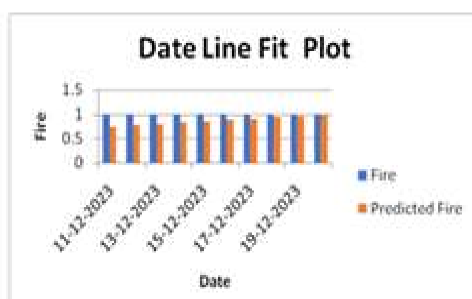


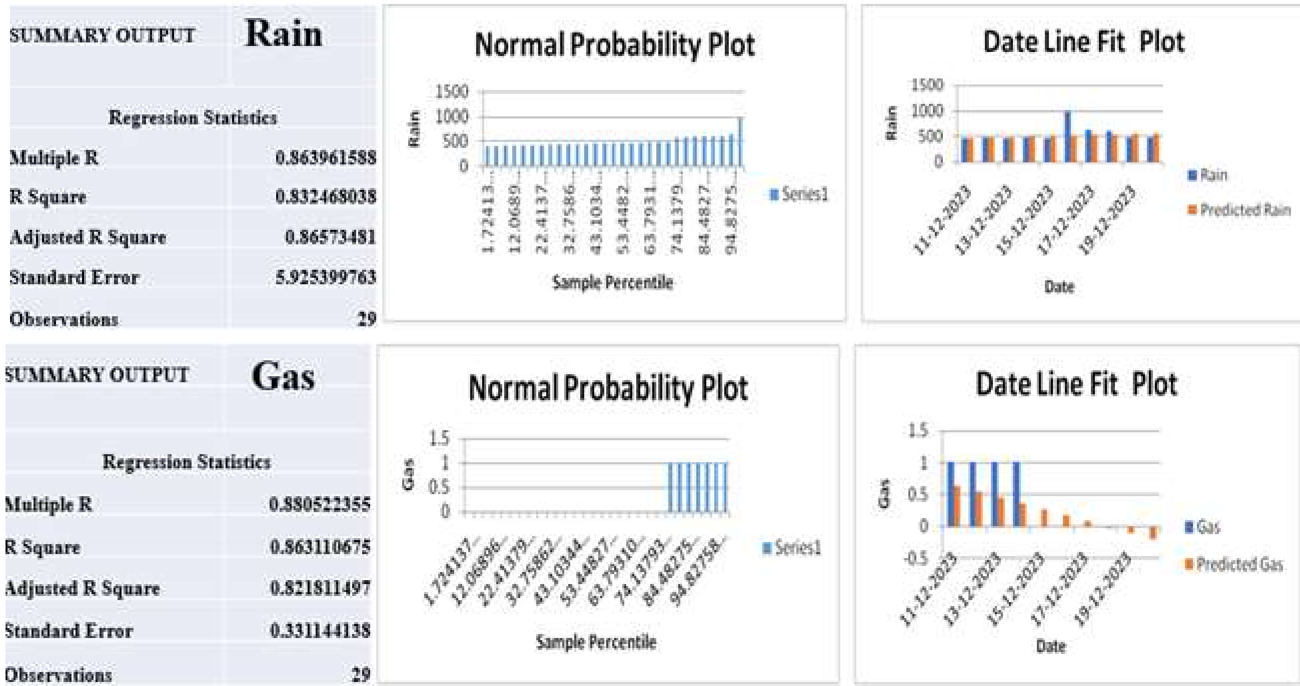


SUMMARY OUTPUT **Fire**

Regression Statistics	
Multiple R	0.884588565
R Square	0.880990651
Adjusted R Square	0.810297624
Standard Error	0.649119649
Observations	29







Advance technique in Data Analysis for ML Platform in Prediction. This regression analysis is done using EXCEL platform. This regression is Supervised Learning. Prediction of our project is shown in the form of graph (above). As part of analysis the statistics gives the range percentage of analysis above 80% which indicates it can be used for further more complicated predictions in the implementation of the prototype.

CONCLUSION

The system was successfully integrated without any modifications. The integrated system was successfully tested on laboratory conditions and results were presented. The single node module can give data for one location. The real-time implementation requires many nodes for underground mines fire identification. The integrated system can send and receive the data wirelessly to any nearest node or office. The regression analysis of the data obtained is also implemented and studied accordingly. For real time implementation a large network and multiple nodes can be designed in one system. And a setup can be designed for location tracking also. As part of innovating in real time it can be further designed in ML technology. As part of de-signaled area, implementation of LoRa can be taken part.

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Watershed Management of Odda River Sub-Basin, Mauganj District, Central India

Kalpana Mishra*

ABSTRACT

The study deals with the watershed management of the Odda River Sub-Basin situated in Mauganj District, Central India. The Odda river is tributary of Tons river basin and characterized by dendriritic drainage pattern. The area lying in the north eastern part of of Mauganj district comprises of Mauganj and Naigarhi Blocks. The normal annual rainfall of Mauganj District is about 1100 mm and received maximum rainfall during south west monsoon period i.e. June to September. The area has hot summers and cold winters. The study adopts an integrated approach, combining hydrogeological investigations and the implementation of recharge structures to address the challenges of water scarcity and declining groundwater levels in the region. The objectives of this study encompass hydrogeological investigations involve mapping aquifer characteristics, analyzing groundwater quality, and evaluating the potential for artificial recharge. The study proposes the implementation of specific recharge structures tailored to the geological and hydrological conditions of the Odda River Sub Basin. These structures include contour trenches, subsurface dams, and percolation ponds strategically placed to optimize water infiltration. The outcomes of this research are expected to provide valuable insights for policymakers, local communities, and water resource managers. By integrating eco-hydrological principles with community-driven strategies and targeted recharge structures. Besides these, active participation of stakeholders as well as various awareness programs are urgently needed for the watershed management of the area.

Keywords: Watershed Management, Odda River Sub-Basin, Mauganj District, Central India,

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Noise and Vibration Control of Vavious Mining Machinery in Opencast Mines

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ABSTRACT

Sonic crystals (SCs) are structures made of sound scatterers periodically arranged in a square or triangular lattice. Recent research on sonic crystals has demonstrated that they are efficient materials for controlling the propagation of sound. They attenuate sound in certain frequency bands due to Bragg scattering across the periodic scatterers. This range of frequencies is known as the bandgap, and it is found that sound propagation is significantly reduced in this bandgap region. Belt conveyors connected in series to form routes stretching for many kilometres in surface mines are an important source of noise. Noise emission standards are typically exceeded in the locations where belt conveyors are operated, particularly during the night time. Conveyors largely account for the noise generated by the entire technological system. Therefore, reducing their noise emissions is of particular importance. So, to attain elevated noise reduction, various intuitive periodic designs made of sonic crystals such as rigid scatterers, resonant scatterers, and multi-resonant scatterers were suggested and followed by the calculation of free-field insertion loss (IL). Insertion Loss (IL) is the reduction of noise level at a given location due to the placement of a noise control device in the sound path between the sound source and that location. The novelty of research work is that a class of periodic structures, called the radial sonic crystals are presented, in polar coordinates. The initial investigation indicates that dominant noise originates from the contact between the conveyor belt and the guided idlers. This belt-idler interaction generates lateral belt vibrations which result in vibration-induced noise by the rotational movement of the idlers. An attempt is also made to solve such a problem by referring to some novel isolation methods developed based on nonlinear dynamics theory. These methods have excellent isolation performance when applied for vibration isolation over a wider frequency range. Noticeably, a quasi-zero stiffness (QZS) mechanism has been studied where the negative stiffness realized by the proposed design counteracts the positive stiffness to achieve the desired isolation.

Keywords: Sonic crystals (SCs); Radial Sonic crystals (RSCs); Periodic scatterers; Bragg band; Resonant scatterers; Multi resonant scatterers; Free field insertion loss (IL); Quasi-zero stiffness (QZS).

INTRODUCTION

The evolution of the noise barrier took place from the time when primitive humans used to live in forests. The forest which is the crudest form of a periodic or random array of trees is equivalent to cylindrical scatterers, and an array of periodic scatterers is known as a sonic crystal at present. In another way, it can be said that the periodic scatterers are one of the oldest sciences which is created by nature and evolves the physics of multiple acoustic scattering. The sound attenuates significantly due to the periodic arrangement of scatterers and the frequency range of attenuation in general lies in mid-range frequencies, however, specifically depends upon the geometry and the periodic arrangement of the scatterers. The sound wave is a kind of pressure fluctuation, which can exist in a compressible fluid. Sound is a pressure wave, where, the particle of the fluid medium vibrates in the direction of wave propagation. The audible frequency range is between 20 Hz and 20 kHz, which is a combination of direct sound from the sources and indirect reflection from other surfaces. The frequencies which lie below and beyond the limits of hearing are known as infrasonic and ultrasonic sound waves. The frequency of wave propagation is:

$$f = \frac{c_0}{\lambda} = \frac{1}{t_\lambda} \qquad (1)$$

Where f = frequency of the sound wave.

c_0 = speed of sound in m/s.

λ = wavelength

t_λ = time required to travel a wavelength.

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SCATTERING

Scattering is the diffraction of the sound wave into multiple directions due to physical interaction with a scatterer. When sound waves radiated from the expected path and spread out in many directions is called scattering. The amount of scattering is affected by the size and geometry of the scatterer and the wavelength of the sound. When a sound wave propagates in a homogeneous medium like air, it gets scattered interacting with a barrier known as a scatterer and expanded out from scatterers in multiple directions. Periodic scatterers can attenuate sound at certain frequency ranges due to Bragg diffraction and those frequency bands are known as Bragg bands. The acoustic performance of periodic scatterers is measured by the Insertion Loss (IL) and expressed in Decibel (dB). The periodic array of trees, which is equivalent to periodic cylindrical scatterers is the best nature-inspired example, as shown in Figure 1.

Figure 1: Periodic array of trees; a nature inspired noise barrier

First, the array of cylinders has been presented as a sound sculpture [1]. The sound attenuation via periodic rigid cylindrical scatterers has received significant attention from various researchers due to its simple geometry.

Figure 2: The sculpture, was exhibited at Juan March Foundation in Madrid [1]

However, extremely large size of cylindrical scatterers is required to attenuate noise at a low-frequency regime. Therefore, substantial research has been conducted to enhance the potential of periodic scatterers in controlling the sound in a low-frequency regime. The phenomenon of resonance has been demonstrated by researchers for controlling sound in lower frequency regimes. The scatterer which can individually resonate in the particular frequency band is known as a resonant scatterer.

LOCATION OF THE STUDY AREA

On Panchpatmali hills of Koraput district in Odisha, a fully mechanized opencast mine is in operation since November 1985, serving feedstock to Alumina Refinery at Damanjodi located on the foothills. The present capacity of Mines is 68.25 lakh TPA. Panchpatmali plateau stands at an elevation of 1154 m to 1366 m above Mean Sea Level. Bauxite occurs over the full length of the Panchpatmali plateau, which spans over 18 kilometres. Transportation of bauxite ores from the mine to the refinery is carried out with the help of a 14.6 km long, single flight, multi-curve cable belt conveyor of 1800 TPH capacity. Belt conveyors connected in series to form routes stretching for many kilometres in surface mines are an important source of the noise. Noise emission standards are typically exceeded in the locations where belt conveyors are operated, particularly during the night-time. Belt conveyors largely account for the noise generated by the entire technological system. Therefore, reducing their noise emissions is of particular importance. Analysis of the noise level demonstrates that the dominant noise originates from the contact between the belt and the idler. This belt-idler interaction generates lateral belt vibrations, as well as vibrations-induced noise, generated by the rotational movement of the idler.

PROBLEM STATEMENT

Figure 3: Belt Conveyor System of the mine & location of the village

SCHEDULE

(see rule 3(1) and 4(1))

Ambient Air Quality Standards in respect of Noise

Area Code	Category of Area / Zone	Limits in dB(A) Leq*	
		Day Time	Night Time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Note:- 1. Day time shall mean from 6.00 a.m. to 10.00 p.m.
2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. Silence zone is an area comprising not less than 100 metres around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority
4. Mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

* dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

A "decibel" is a unit in which noise is measured.

"A", in dB(A) Leq, denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

Leq: It is an energy mean of the noise level over a specified period.

Figure 4: Air Quality Standards in respect of Noise

Since the belt conveyor is running continuously for 21 hours a day, nearby villagers complain about the noise generated from it. Noise emission standards are typically exceeding particularly during night-time. Due to irritation from noise sometimes villagers are also responsible for the breakdown which leads to the stoppage of transportation of bauxite ores from the mine to the refinery.

Objectives of the study

- Mine visit, data collection, comparative study, and literature review of all the noise-related issues faced by villagers due to continuous running of Cable Belt Conveyor at Panchpatmali Bauxite Mine.
- Design and Development of Acoustic enclosure using radial sonic crystals using rigid scatterers, resonant scatterers, and multi resonant scatterers arranged in polar coordinates.
- Design and Development of mechanical damper made of QZS metastructures to reduce vibration when there is a contact between the conveyor belt and the guided idlers which result in vibration-induced noise.
- Condition monitoring of guided idlers using Thermal Imaging.

Mine visit and Data collection

I along with my Co-supervisor went to the mining site during the daytime as well as during night-time to measure noise data from different locations.

SOURCE NOISE

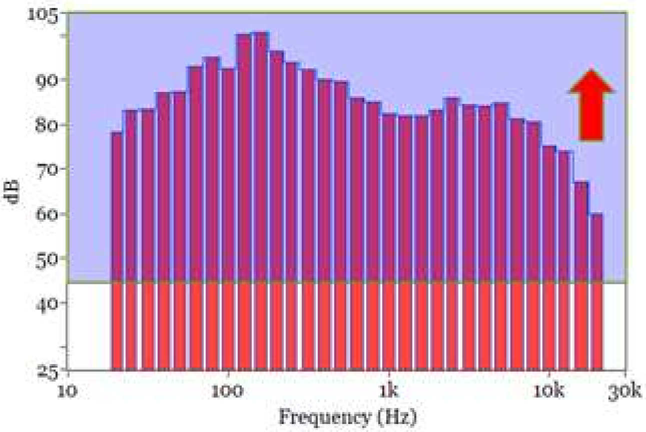


Figure 5: A field test was conducted when the conveyor was running at a maximum speed of 3.7m/s at around 3:00 pm and got the value of noise around 97.7 dBA.

Location: Watch Tower

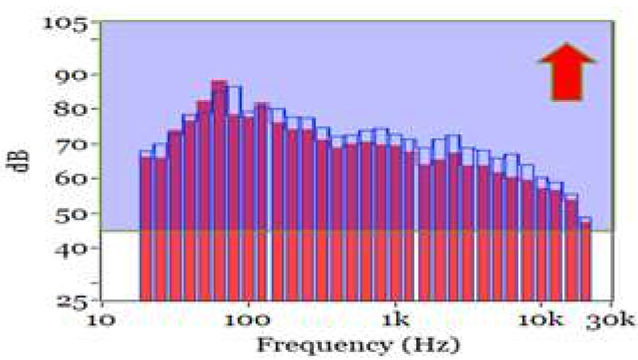


Figure 6: Conveyor Details: RPM: 3.7 m/s @ 7 PM # 3.0 m/s @ 4 AM (Measurement ~2.5 m from Noise Source) 83.0 dBA (4 AM) ## 79.7 dBA (7.30 PM)

Location: Light Post of the Village

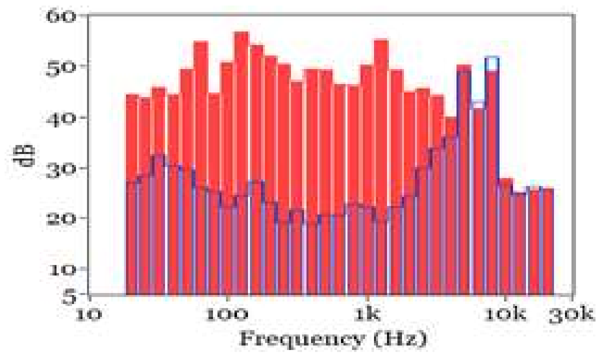
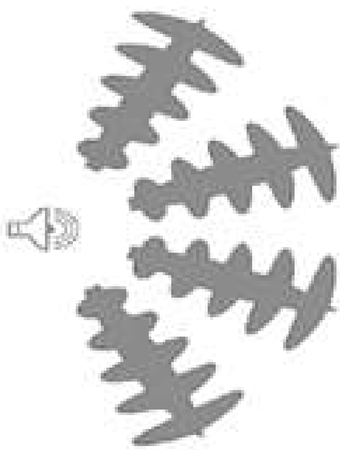


Figure 7: Conveyor Details :60.5 dBA (4 AM) (3.7 m/sec) 53.95 dBA (4 AM) (Off)

From the exhaustive literature review, it has been found that most of the authors have used square lattice and triangular lattice configurations for the arrangement of the sonic crystals. The novelty of the work is that a class of periodic structures, called the radial sonic crystals are presented, which are periodic structures in polar coordinates as shown in figure 13a. The radial sonic crystal turns out to be a structure that resembles a fish-bone structure as shown in Figure 13c. The radial sonic crystal grows in size as it goes away from the source, which is due to the inbuilt divergence in the polar coordinates. The scatterers appear like elliptic scatterers.

(a)

(b)



(c)

Figure 8: Periodic arrangement of scatterers in Polar Coordinates (a) Circular cylindrical scatterer (b) Elliptical Scatterer (c) Fish bone like structure.

CALCULATION OF INSERTION LOSS

The applied boundary conditions for calculating IL are:

a) The plane wave radiation boundary condition is applied with pressure amplitude p_{in} = 1.0 Pa (peak to peak) or of root mean square (RMS) value 0.707 Pa. The

$$20\log\left(\frac{p_{in}}{p_{ref}}\right) = 90.9 \text{ dB.}$$

Where, $p_{ref} = 20\mu Pa, p_{in} = 0.707 Pa$ (RMS value).

b) The perfectly matched layer of length (l_3) is applied on the right side of the domain to simulate acoustically non-reflecting boundary conditions.

c) Floquet periodic boundary condition has been applied on the top and bottom walls of the domain to simulate the infinite periodic arrangement in the Y-direction.

d) The walls of the scatterers have been made acoustically rigid.

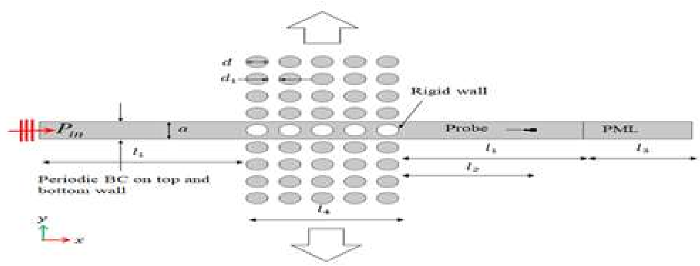
e) For meshing, the triangular element meshes are generated.

The Insertion Loss (IL) has been calculated with help of a sound pressure probe. The sound pressure without scatterers denoted as SPL_{NS} is subtracted by sound pressure with scatterers denoted as SPL_{WS}.

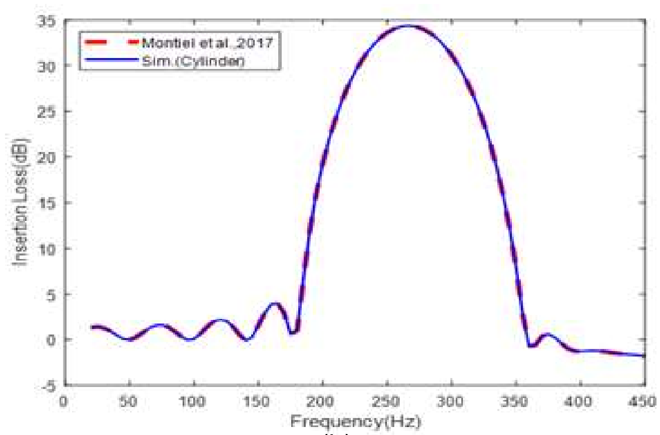
$$\text{IL} = SPL_{NS} - SPL_{WS} \quad (2)$$

$$\text{IL} = 90.9 - SPL_{WS} \quad (3)$$

Cylindrical scatterer



(a)



(b)

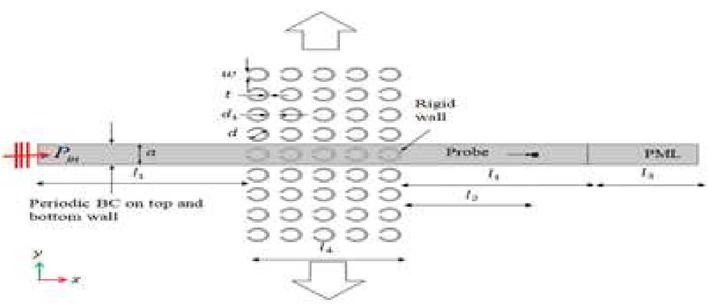
Figure 9: (a) Simulation domain for calculating IL of Cylindrical Scatterer, (b) Calculated IL of Cylindrical Scatterer.

From the figure 14b, it is clearly found that a bandgap has been observed between frequencies of 190 Hz to 280 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 190 Hz and the upper boundary of the Bragg band is 380 Hz. The maximum amplitude of insertion loss (IL) is found to be 34.5 dB at 265 Hz.

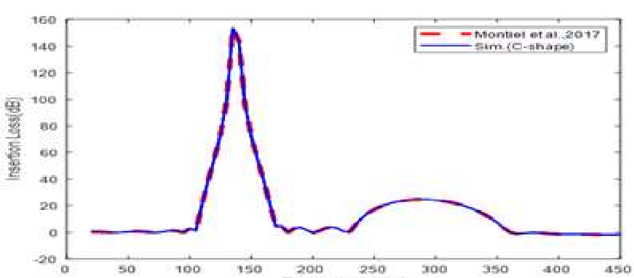
(a) (b)

Figure 10: Fabricated sample of (a) Cylindrical Scatterers, (b) C-shaped Scatterers

C-shaped cylindrical scatterer



(a)

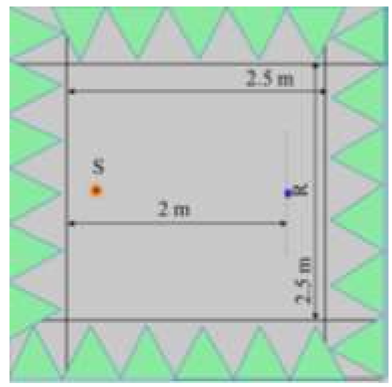


(b)

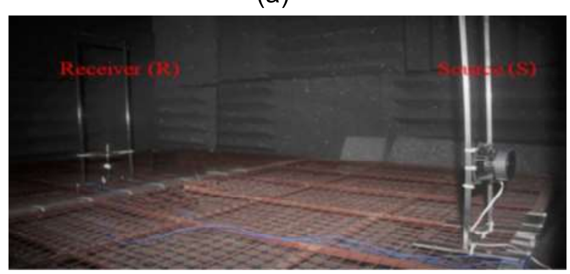
Figure 11: (a) Simulation domain for calculating IL of C-shaped Scatterer, (b) Calculated IL of C-shaped Scatterer

From the figure 16b, it was clear that bandgap has been observed between frequencies of 230 Hz to 365 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 230 Hz and the upper boundary of the Bragg band is 365 Hz. The maximum amplitude of insertion loss (IL) is found to be 25 dB at 290 Hz. Apart from the Bragg band, another peak has been observed at 135 Hz which is due to the local resonance of the C-shaped scatterer.

EXPERIMENTAL VALIDATION



(a)



(b)

Figure 12: Experimental setup; (a) schematic of the experiment, and (b) source and receiver inside an anechoic chamber.

Figure 13: Source and receiver location from the sample.

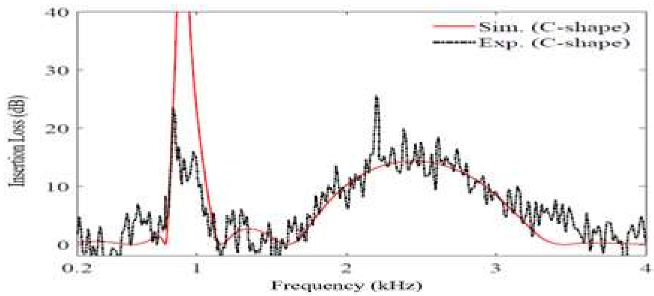


Figure 14: Calculated and measured IL of C-shaped scatterer

PERIODIC SCATTERER IN POLAR COORDINATES

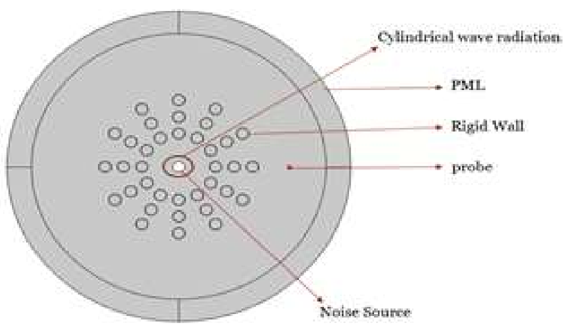


Figure 15: 2D schematic of simulation domain periodic scatterers in polar coordinates.

(a)

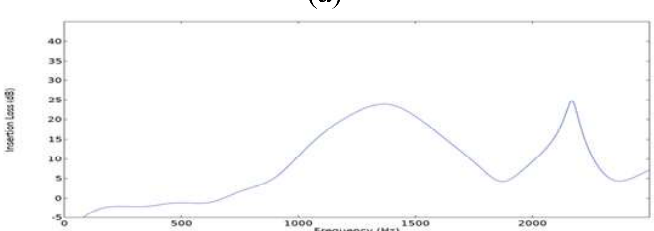
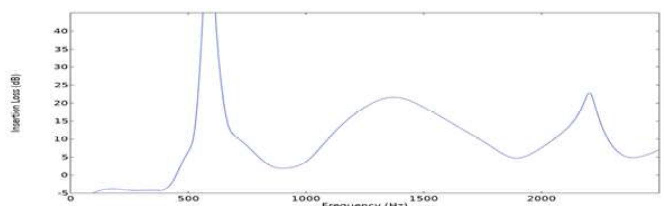


Figure 16: (a) 3D view of cylindrical scatterer in polar coordinates (b) Calculated IL of cylindrical scatterer

From the figure 22b, it is clearly found that a bandgap has been observed between frequencies of 850 Hz to 1820 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 850 Hz and the upper boundary of the Bragg band is 1820 Hz. The maximum amplitude of insertion loss (IL) is found to be 23.8 dB at 1390 Hz.

(a)



(b)

Figure 17: (a) 3D view of C-shaped cylindrical scatterer in polar coordinates (b) Calculated IL of C-shaped cylindrical scatterer

From the figure 23b, it is clearly found that a bandgap has been observed between frequencies of 970 Hz to 1820 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 970 Hz and the upper boundary of the Bragg band is 1820 Hz. The maximum amplitude of insertion loss (IL) is found to be 21.6 dB at 1380 Hz.

INTEGRATED QZS VIBRATION ISOLATION DESIGN

After a thorough survey of literature, the latest achievement in vibration isolation with QZS has been done with very few model. The few available prototype has multiple number of elements and has complex geometry which leads to unstability in the system and also results in degrading of system performance. Thus nested ring quasi zero stiffness design with minimum number of element reliable and simple design is developed. In this nested ring design quasi zero stiffness characteristic is investigated in integrated single element. The schematic model of proposed design shown in figure 17. QZS nested ring design is developed from optimization of single nested ring with rectangle groove and without groove. Schematic model is shown in figure 18.

Figure 18: Schematic nested single ring QZS model

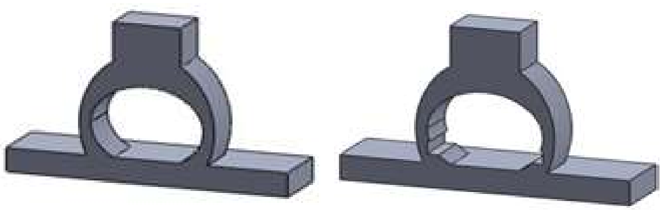


Figure 19: Schematic nested single ring and ring with rectangle groove QZS model

STATIC PERFORMANCE ANALYSIS OF IQZS

Mechanical properties of the proposes QZS design investigated using ANSYS 2020R2 simulation soft- ware. Design geometry is modeled in SOLIDWORKS 2020. The boundary condition is applied in bottom surface of model is constrained in all six degrees of freedom and top surface is constrained five degree of freedom only prescribe vertical displacement is allowed. Compression test with prescribed displacement performed in static structure module. Quadrilateral meshing is used for simulation and TPU material is taken. Material properties is density 1235 kg/m3, Poisson ratio = 0.3, Young modulus = 29.3 MPa and considering isotropic material. The force displacement characteristic mainly investigated in figure 20 which depicts the variation of reaction force with respect displacement. It can be observed that after some rang of displacement quasi zero stiffness mechanism is found also constant force characteristic is analyzed.

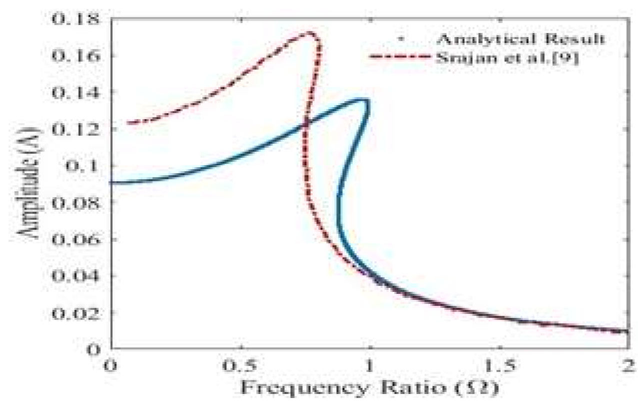


Figure 20: Frequency response curve from hybrid method

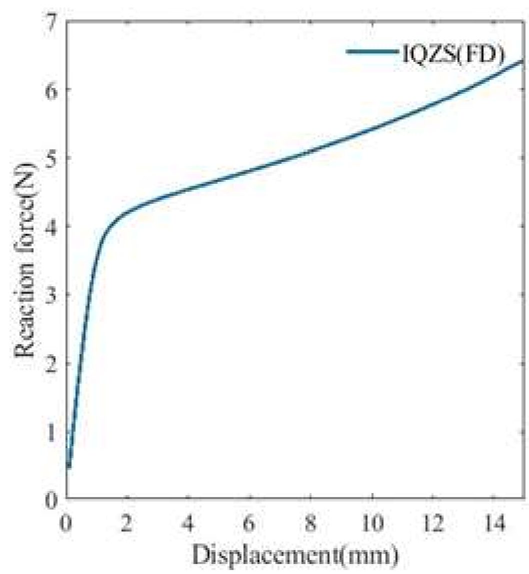


Figure 21: Force displacement curve of IQZS model

CONCLUSIONS

In this study, we proposed a sonic cage made up of sonic crystal as well as hybrid configuration of sonic cage using melamine foam for noise reduction at targeted frequencies. The unique design of the sonic cage makes it suitable for noise shielding with a provision for ventilation. The following observations have been made from this study.

It is found that a bandgap has been observed between frequencies of 850 Hz to 1820 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 850 Hz and the upper boundary of the Bragg band is 1820 Hz. The maximum amplitude of insertion loss (IL) is found to be 23.8 dB at 1390 Hz. It is also clearly found that a bandgap has been observed between frequencies of 970 Hz to 1820 Hz which is due to its Bragg diffraction. From IL, the lower boundary of the Bragg band is noticed at 970 Hz and the upper boundary of the Bragg band is 1820 Hz. The maximum amplitude of insertion loss (IL) is found to be 21.6 dB at 1380 Hz. It is observed that a hybrid sonic cage has more insertion loss value as compared to a simple sonic cage made up of cylindrical scatterers by 1.86 dB. Further, it is observed that a hybrid sonic cage has more insertion loss value as compared to a simple sonic cage made up of c-shaped cylindrical scatterers by 2.37dB. The obtained insertion loss peak demonstrates the feasibility of the sonic cage concept for various applications. A sonic cage design with only periodic scatterers can be used for low-frequency noise mitigation while a hybridized sonic cage with melamine foam can be a better choice for mid-to-high-frequency noise mitigation.

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Techno-commercial Benefit of Utilization of Waste Recycled Lubricants Oils in Manufacturing of ANFO Explosives – A Case Study at Shree Cement Limited

Lalit K Agarwal[1] Pankaj Agarwal[2] Manish Bohra[3] Pankaj Sharma[4]

ABSTRACT

It is the need of todays for mining industry to adopt cost efficient technologies while caring for environment, quality of product, health and safety of workers, and strict government regulations on many facets of their operation. A mine that does not meet these stringent criteria will be pushed out by other competition that can produce at lower cost. Two products used at nearly every mine are Oil & Explosives that affect all these situations, and with proper management mines can realize cost-reduction and a viable solution to reduce waste.

Many Mines uses massive machines that expend sizeable amounts of lubricants oil in daily operations. This oil is then changed on a regular basis during preventative maintenance procedures and is then sent away for recycling or waste. This typically is an added expense, as the mine will have to pay to handle these used oil products in an environmentally friendly manner. Smartchem Technologies Limited (STL) has worked collaboratively with Central Institute of Mining & Fuel Research (CIMFR) to bring new technology to the processing of site-based waste oil and blending with Diesel fuel oil for the onsite manufacture of ANFO Explosives. The result has been a reduction in Explosive's cost of up to 5% for customers using this new technology. STL succeeded in replacing the use of diesel fuel with used oil. Used oil is chosen as a substitute for several reasons:

1. Waste oil is available in mining locations and quantity is very abundant.

2. The value of used oil is very small, even close to zero. Used oil is categorized as Hazardous waste and other waste (Management & transboundary Movement). Based on regulations, it is required to be processed and sent to a designated waste treatment center.

These recycled lubricating oils ("RLO") can be mixed in a 50/50 ratio with diesel oil, in the manufacture of ANFO Explosives. In this respect, it should be noted that this process offers ecological and economic advantage, as it allows the efficient utilization of polluting waste (burnt at a very high temperature in an explosive reaction) and halve the needs of diesel fuel oil for the manufacture of ANFO.

This paper describes the in-hand experiences of usages of waste oil in manufacturing of ANFO, blending procedures with pure diesel oil, blast result monitoring & cost saving in blasting. This also describes the basic conceptual design of a machine to recycle used oils, a summary of standards and technical characteristics, control procedures and tests of compatibility and performance.

BRIEF INTRODUCTION ABOUT ANFO MANUFACTURED WITH RECYCLED OIL

ANFO (Ammonium Nitrate/Fuel Oil) is a widely used bulk industrial explosive mixture in mines & quarrying operation. It consists of 94 % porous Ammonium Nitrate (NH_4NO_3), (AN) and 6 % fuel oil (FO) High Speed Diesel (HSD). This forms a reasonably powerful commercial explosive. In Nimbeti Limestone Mine of Shree Cement Limited, the waste oils, which mainly comes from the mining machinery, are previously treated to remove the impurities available inside. This processed waste oil is then replaced with diesel fuel oil up to 50% without affecting the performance of the blast. Nimbeti Limestone mine produces around 25 million tonnes of Limestone & waste rock together to meet the requirement of the Cement plant.

The Trials of Recycled Fuel oil in ANFO Manufacturing in different – different proportion were conducted by Scientist

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of M/s CIMFR Dhanbad in the Month of Jun 2019. After successful trials, CIMFR submitted the report stating the suitability of the products.

ADVANTAGES OF USING RE-PROCESSED WASTE OIL IN ANFO

i) Reduction in the cost of Blasting – The direct replacement of up to 50% of the Diesel in ANFO with waste oil delivers an immediate reduction in AN Explosives Fuel Cost to Mining operations.

ii) Significant contribution to the environment through the efficient disposal of highly polluting waste products and thereby not only reducing the cost of discarding polluting material but adding value to it. Usages of waste oil in ANFO help saving in additional cost for burning this waste oil in cement clin.

ii) Savings in clean fuel that help in building the nation.

PROPERTIES OF FUEL OILS USED FOR MAKING ANFO

Diesel Oil

Diesel oil is combustible liquid which is used as fuel for diesel engines. It is also used for making ANFO in the mines. Its density varies from 820 to 860 kg/m^3 @15^{o}C or 0.82 kg/ltr. The flash point of diesel is min 35^o C.

Recycled Lubricant Oil (RLO)

Recycled used oil is the waste oil generated in the Mines & plant from the massive heavy equipment which consumes sizeable quantity of fuel. This oil is then changed on a regular basis during preventative maintenance procedures. The density varies in between 850 to 950 kg/m^3. It cannot be used as such because of impurities and suspended solids in the oil. The flash point of recycled lubricant oil is around 150^o C to 170^o C.

Mixture of Diesel Oil & Recycled Lubricant Oil (RLO)

Maximum recommended proportion is to use 50:50 RLO/FO blend. The most common practice worldwide is using a 50/50 blend. The Reason of this may be read as follows:

1) Higher content of RLO blends can eventually be too viscous and may causes jamming of spray nozzle in BMD mixing unit.
2) Flash point of blended oil may go beyond 52^o C and this may cause improper combustion of the explosive's column. In commercial use, it is always not possible to follow strict vigilance and that may issue in blasting, so it is advisable to restrict the usages by 50: 50 Ratio.

The following should be the properties of Blended oil before puts in use for ANFO Manufacturing

Table No. 1

Parameters	Standards
Density, g/cc	0.84 – 0.90
Flash Point, ^{U}C, Min	52
Water, % Max	2.0
Viscosity, cp, Max	250
Suspended Solids, > 50micron	NIL
AN oil Retention, Min	8% w/w
ANFO Cap Sensitivity	NO

PROJECT GOAL

Establish Cost saving with usages of Reprocessed oil in Manufacturing of ANFO while maintaining blast performance in current scenario when diesel cost is exorbitantly high.

The main aim of this project was to:

1. Establish blast cost saving with usages of Blended Fuel oil in ANFO Mixing
2. Establish Reprocessed Lube Oil Machine (RLO) at mine site and maximize use in ANFO Mixing
3. Determine effect on blasting with ANFO manufactured with blended oil.

COST SAVING ANALYSIS WITH REPROCESSED OIL IN ANFO MANUFACTURING

The table no 2 shows the approximate reduction in cost when recycled fuel oil is blended with diesel oil in 50:50 ratio.

TABLE-2

Component	Cost of ANFO with Diesel oil (in Rs/MT)	Cost of ANFO mixed with Waste oil (In Rs/MT)
Ammonium Nitrate (1000 Kg) Cost	33380	33380
Diesel Oil Cost (70 Litre) @ Rs 75 per Litre	5250	2625
Waste oil cost @ Rs 23 per Litre	0	805
Total cost for 1058 Kg of ANFO	38630	36810
Cost of 1 kg of ANFO explosives (Rs/kg)	36.51	34.79
Savings in ANFO Cost (Rs/kg)		1.72
Diesel Cost saving (Rs/MT)		1820
% saving in Diesel cost wrt AN Cost		5.45%

There are distinct savings of Rs 1820 per MT in ANFO cost directly while considering Rs 75 per Liter of Diesel oil cost & Rs 23 per Liter of waste oil cost (Rate at which waste oil is being sold to authorize recycler by Shree Cement Limited)

APPROVALS/PERMISSION REQUIRES TO USAGES OF WASTE/USED OIL

Permission has been obtained from the Region Pollution control Board before start of the Operations. It is recommended to get permission from concerned department to use waste oil in ANFO Mixing.
Shree Cement Limited, RAS, Nimbeti Limestone mine has obtained such permission from Rajasthan State Pollution Control Board wide letter no. F16(PA) RPCB/HAZ/SWMC/Pali/41-44 dated 08.04.2019.

TECHNOLOGY APPLIED - THE MIXING PROCESS

STL has developed a purpose-built proprietary equipment based on Advanced Processing and blending technology to enable the safe, reliable, and consistent processing of waste oil to a standard where it can replace 40% - 50% of the diesel in blasting. The equipment is containerized and modular to facilitate ease of use, transport, installation, and customization to specific site needs (see Picture)

After the oil has been drained from equipment, it must first be placed into a tank/barrel that will store all used oil at site. Oils of various grades can be mixed altogether and stored in the tank. Once settling finished, this stored used oil, after removing eventual solids like dirt, sand, small iron pieces etc., can be taken and poured into the waste oil compartment of the reprocessed lube oil machine.

The virgin or fresh Diesel can be filled with the help of diesel bouser in "Diesel Storage compartment" of the RLO Machine.

The used oil is filtered and metered when being pumped to the oil/diesel blend mixing storage tank. The virgin fuel (Diesel oil) is also metered when being pumped, to assure the proper proportions of the Final mixture. Once both oils have been fed to the blend tank, the mixture is re-circulated through a low-pressure stirrer for its homogeneous mixing and finally pumped to the BMD truck for mixing into explosives.

ADVANTAGES OF RECYCLED LUBE OIL (RLO) MACHINE

Recycling of oil is a procedure that is designed basically to restore or bring used oil back in condition for reusable. Oil recycling machine is a utility that can easily and successfully can handle this and also can blend it with

other fuel oil in desired proportion. Now a day's machine is available in the market which can Process this waste oil and blend with diesel oil in various proportion like 20:80, 30:70. 40:60 or 50:50 ratio of waste oil: Diesel oil as per desired requirement. STL has supported Nimbeti Limestone Mine to install this machine at site.

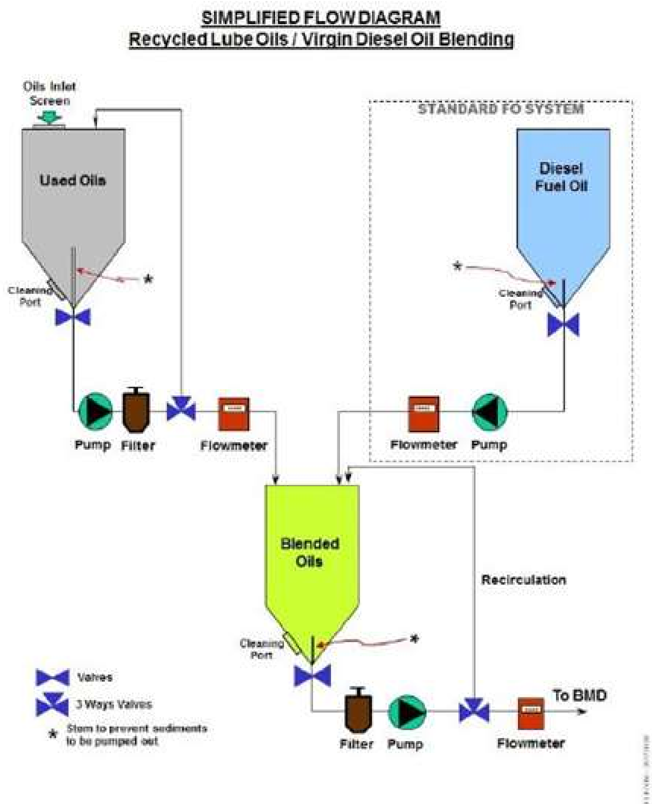
a) This machine (as shown above) has two numbers of storage tank for storing of Waste oil & diesel oil. It is provided with the requisite oil filters to process the waste oil.
b) This machine processes & filter the waste oil with the help of filters provided. The processed oil is then mixed with Diesel oil in desired proportion of 20:80, 30:70. 40:60 or 50:50 ratio of waste oil: Diesel oil. A Variable frequency Drive (VFD) is being fitted with ensure the homogeneous mixing of waste oil & diesel in desired proportion.
c) The Final blended oil can be directly loaded in the BMD Truck.
d) Mixing machine uniformly mixes the Blended fuel oil with ANFO (photographs of final products)
e) This machine reduces the manual operations of handling/mixing/loading of blended oil in BMD.
f) Machine can be installed very near to Maintenance workshop where, waste oil which generates from maintenance activities can directly be loaded in this machine after filtering.

SOP FOR SAFE UTILIZATION OF RLO IN ANFO MANUFACTURING

a) Material Safety Data Sheets (MSDS) should be prepared for mixing of blended oil. These MSDS's should be maintained at the mine site.
b) Proper training must be provided to all the personnel assigned for the job.
c) Used oil shall be filtered properly and stored in dedicated storage tanker only.
d) Used engine oil to be utilized in ANFO mixtures should not be modified in any way that could change the basic properties of the used engine oil. For example, heating and addition of additives are not acceptable.
e) Blended oils should not be used for ANFO mixtures for underground blasting operations.
f) The use of blended oil in ANFO mixtures is intended for ANFO mixed on-site at the blast site and loaded directly into the blasthole. ANFO mixtures made with blended oil should not be stored.
g) A responsible mine employee or a responsible person designated by the mine should be in charge of the oil blending operation and should make sure that all analyses, tests, operating procedures, and record keeping are performed in accordance with these guidelines.
h) The use of these Recycled Oils is recommended only for large diameter boreholes (> 100 mm). It is not

recommended for use in small diameter applications.

i) Blended oil should be transported, handled and used in such a way as to minimize skin contact.

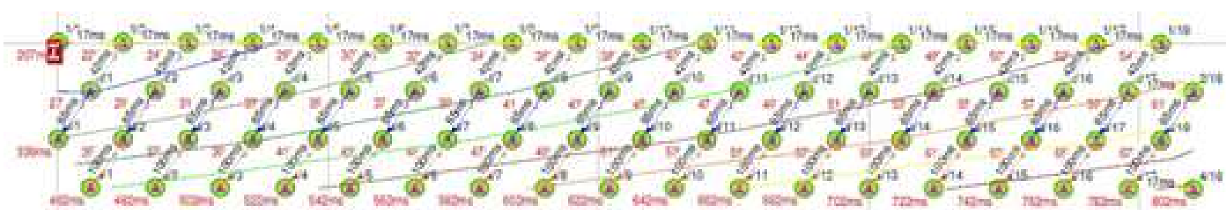


METHODOLOGY TO CALCULATE SAVINGS WITH RLO: FIELD TRIALS

In order to fulfill the objective of the study many trial blasts were conducted at Nimbeti Limestone mine under various strata conditions with Ammonium Nitrate Fuel Oil (ANFO) explosives & shock tube initiation system (density being 0.8 gm/cc and VOD ~3700 m/s) to access the performance of the blast vis-à-vis cost saved on account of usages of reprocessed oil in blending with diesel oil. Details of few blast conducted in the Month of Jul 19 has been listed below to make analysis of Cost Saving.

The blasts were designed using JK Sim Blast software and considering the mine existing blast pattern. The following parameters of the blast were closely monitored and recorded in the field day to day basis.

Pattern Design – All the blast pattern were drilled on staggered pattern and used with ANFO explosives & Emulsion cast Boosters as primer. The blasts were initiated by shock tube system with surface delay sequencing of 17ms, 25ms, 42ms and 65ms and down the hole delay of 200ms. Figure below shows the pattern designed using JK Sim Blast design software.



Fragmentation - Digital image analysis technique (wip frag software) was used in the present study to by capturing the image of the blasted muck & calculate the percentage size of fragment passing at various size of screen. The fragmentation of the blast was similar to the normal blast generally carried with pure diesel oil.

Good fragmentation within the muck pile with excellent displacement & good wall

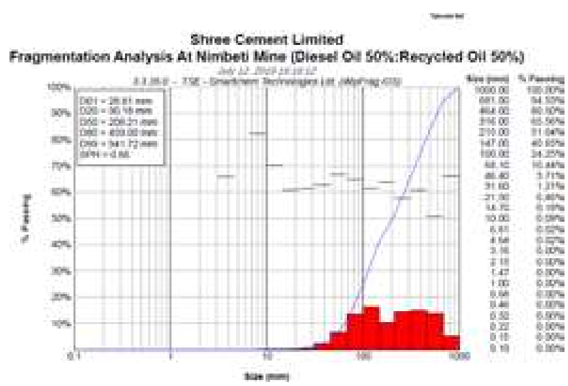
(Summarized blast data of five no of blast conducted in the month of Jul 2019)

S NO	1	2	3	4	5
Date of Blast	11th Jul19	12th Jul19	13th Jul19	14th Jul19	15th Jul19
Location - Bench RL	420	396	384	444	432
No of Holes	64	72	37	42	72
Burden (m) X Spacing (m)	4.5 x 6.0	4.5 x 6.0	4.5 x 6.0	4.5 x 6.5	4.5 x 6.5
Hole Depth (meter)	12.8	13.2	13.1	12.4	13.2
Drill Diameter (mm)	165	165	165	165	165
Ammonium Nitrate Used (kg)	7250	9750	4250	5000	9000
Total Explosives (kg)	7792	10550	4526	5595	9578
Polymer Beeds used	14%	14%	14%	14%	14%
Diesel Oil (L)	272	366	159	188	338
Reprocessed Oil (L)	272	366	159	188	338
Total Fuel Oil (include RLO)	543	731	319	375	675
Ratio of Diesel oil: waste oil	50:50	50:50	50:50	50:50	50:50
Limestone Production (ton)	55283	64294	32839	38190	69377
Powder Factor	7.09	6.09	7.25	6.83	7.24
Blast performance	Excellent	Excellent	Excellent	Excellent	Excellent
a) Fragmentation	Good	Good	Good	Good	Good
b) Throw (m)	25	28	27	26	30
Cost of Ammonium Nitrate (Rs)@33.38/kg	260097	352159	151078	186761	319714
Cost of Diesel Oil in Rs @75/Litre	20400	27450	11925	14100	25350
Cost of Waste oil Rs @23/litre	6256	8418	3657	4324	7774
Savings in Diesel Cost (Rs)	14144	19032	8268	9776	17576
% cost saving*	5.44%	5.40%	5.47%	5.23%	5.50%

* - % Cost saving has been calculated with cost of Ammonium Nitrate landed at Mine exclusive of GST.

Fragmentation plays most crucial role in affecting the productivity of the loading equipment and hence fragmentation of all the blast were monitored very closely to assess the impact of RLO blending in Diesel oil. The blast muck profile parameters in term of throw, drop & lateral spread were excellent and were as per mines requirement. There was no visible change in the blast results.

Wip frag analysis has been enclosed to understand that there are hardly any big size boulders. 95% of the material passed through the 1000 mm size.



BLASTING COST

The experimental blast gave significant savings in blast cost using recycled lubricant oil in ANFO.

Component	Blast 1	Blast 2	Blast 3	Blast 4	Blast 5
Quantities of AN (Kg)	7250	9750	4250	5000	9000
DIESEL (L)	272	366	159	188	338
USDED OIL (L)	272	366	159	188	338
Diesel cost @75 Rs/L	20400	27450	11925	14100	25350
Waste oil cost @23 Rs/L	6256	8418	3657	4324	7774
Fuel Cost - Diesel & RLO (Rs)	26656	35868	15582	18424	33124
Fuel Cost if used, only pure Diesel (Rs)	40800	54900	23850	28200	50700
BLAST TONNAGE (Tons)	55283	64294	32839	38190	69377
Fuel Cost when RLO used with Diesel oil (Rs/ton)	0.48	0.56	0.47	0.48	0.48
If only diesel oil used, then cost of Fuel (Rs/ton)	0.74	0.85	0.73	0.74	0.73
Fuel Cost Saving (Rs/Ton)	0.26	0.30	0.25	0.26	0.25
Average Saving	0.26 Rs/Ton of rock excavation				
	5.41% of AN Cost				

ANNUALIZED SAVINGS ON ACCOUNT OF REPROCESSED OIL USAGES - PROJECTION

Rock Excavation Basis

There is overall Savings of Rs. 0.26 per ton of rock Excavation. Considering the Mine production of 25 Million ton of Limestone & waste rock production, the total annualized savings will be around 44 Lakhs Rupees.

Savings	Figures
Savings in Cost (Rs/ton)	0.26
Rock Excavation (in mt)/Year	25
Rock Excavation involve Blasting(80% of Total excavation) - mt/Yr	20
Total Saving in Blasting (Rs/Year)	52,00,000

Cost of AN Basis

There is overall Savings of Rs. 5.41% on Ammonium Nitrate Cost. Considering the Mine Consumes 2691 MT of Ammonium Nitrate in FY 2019-20 for meeting excavation targets of production of 25 Million ton of Limestone & waste rock production, the total annualized savings will be around 40 Lakhs Rupees.

Savings	Figures
Savings in Cost of AN	5.41%
AN Used in FY 2019-20	2691
Cost of AN @Rs 33380/MT	89825580
Total Saving in Blasting (Rs/Year)	48,59,564

VALUE ADDITION FOR NIMBETI LIMESTONE MINE

Total Saving in FY 2019-20 at Nimbeti Limestone Mine with the utilization of waste oil in ANFO Manufacturing.

a) Nimbeti Limestone Mine saved Rs 9.46 Lakhs on account of usages of Reprocessed lubricant oil. The mine started using waste oil from Jun 2019 and continued till Feb 20.

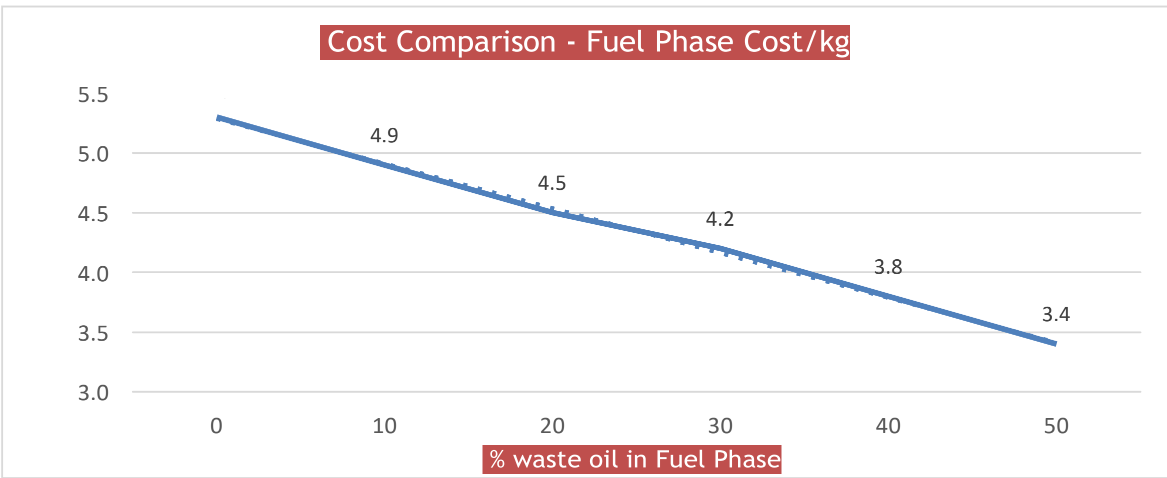
b) Restricted waste oil availability at mine also results in low waste oil utilization.

component	Figures
Total Waste oil utilized in FY 2019-20 (only 9 Months)(in Liters)	22000 Litres
Total Savings (Rs) at Mine on a/c of waste oil utilization	11,44,000 Rs

Relation in Cost saving between ratio of Diesel Oil & Processed Lubricant Oil in ANFO

A graphical representation has been shown in below chart drawn between percentage of Reprocessed oil and Fuel Cost.

1. The cost analysis shows that there is reduction in cost by Rs 0.40 per kg of every 10% increase of blending of recycled lubricant oil in ANFO Manufacturing.
2. If we use 100% pure diesel oil then the Fuel cost is around 5.30 Rs/kg and decreases by Rs 0.40 per kg with every 10% increase in Recycled oil quantity and it comes around Rs 3.40 per kg with 50%:50% ratio.



CONCLUSION

The following conclusion have been proved from the study:

1) Usages of waste recycled lubricant oil in Ammonium Nitrate Explosives (ANFO) provides an opportunity to cut significant costs (Rs 1800/MT of AN Cost) by halving the needs of Diesel oil at most operations that use heavy equipment.
2) It also provides environmentally friendly remedy for disposing of used oils as it burns at very high temperature in an explosive rection.
3) It not only reduces the cost but adds value to it by removing the cost associated with transport and disposal of waste at site.

ACKNOWLEDGEMENT

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Water Resource Management in Amarpatan Block, Satna District, Madhya Pradesh, India

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ABSTRACT

The present study was carried out to determine the assessment and management of groundwater resources of Amarpatan block, Satna district Madhya Pradesh, where water scarcity poses a significant challenge to sustainable development. The study employs a multi-faceted approach, integrating watershed management, hydrogeological investigations, and Geographic Information System (GIS) technologies to comprehensively address the complexities of water resource dynamics in the region. Therefore, the purpose of this study was to generate information which may help in choosing recharge zone sites. Many appropriate recharge structures including percolation ponds, check dams, and nala bunds have been suggested which may be off immense use to solve the water scarcity.

Keywords: Water Resource Management, Amarpatan Block, Satna District, Madhya Pradesh

INTRODUCTION

As population, urbanization and industrialization have increased, more water is needed for production of food as well as generation of electricity for supply to urban areas in ever-increasing amounts. Central and State Governments are always focused on increasing water supply to meet higher demands, no serious efforts have ever been made to manage, and efficiencies of water uses in domestic, agricultural and industrial sectors can be significantly improved through better management practices, including the use of economic instruments, adoption of new technologies and instilling a conservation ethos among all Indians to value, preserve and protect water. The study area Amarpatan block has a geographical area of about 65231 Ha or 652 KM2, with 187 villages and a population of 224762 at a density of 328 inhabitants per km2 (20011 Census). The average annual rainfall of the area is 1050 mm, the southwest monsoon being more dominant in this region. The major agricultural crops cultivated are wheat, rice, and oilseeds. As per CGWB (2017) report the net sown area is 58.77%, in which 23.44% is irrigated under groundwater and surface water. The water sources are: canals (274 ha); tube wells (13205 ha); dug wells (1804 ha). The Water management of the different part of country have been carried out by various researchers (Tiwari and Kushwaha, 2022).

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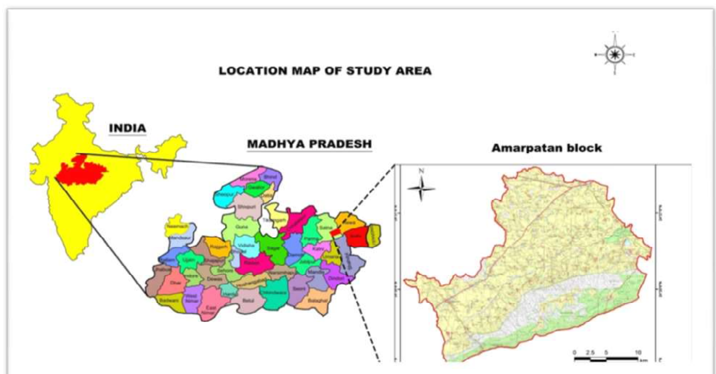

Fig 1: Location map of the study area

STUDY AREA

Amarpatan is a block in the Satna district of Madhya Pradesh which is choosing for the study. Satna district is situated in the Vindhyachal Plateau of Madhya Pradesh State. The district takes name from Satna, the head quarters town, which is in turn takes it's from Satna River which flows near the town. The district is located in between the Vindhyachal and Satpura range of hills. The Amarpatan block is having the boundaries of Rampur baghelan North, Rewa districts in the east, Maihar district in the west and Ramnagar block in the south. its lies between north latitudes 24°12'44.261"N to 24°31'20.03"N and eastern longitudes 80°54'21.627"E to 81°17'32.433"E . It falls in parts of Survey of India Toposheets No 63H/ 2, H/3, H/4, H/7 H/15 and H/16.

The major geological formations are Sirbu shale, Nagod limestone and Simrawal/Ganurgarh shale belonging to Bhander Group and Upper Rewa Sandstone and Jhiri Shale belonging to Rewa group exposed in the area. The study area does not show any major tectonic evidences except few geomorphic lineaments parallel to drainage courses mainly in the Bhander Group formations covered by pediplain. Joints and fractures of structural origin are noticed in the Kaimur hill range trending NE-SW in the southern part. Study area is falling under the Ganga basin area. The area is mainly drained by river Beehar and its tributaries. Beehar is a perennial river, which flows in north and north-east direction.

WATER RESOURCE MANAGEMENT

Traditionally, water is stored through various water conservation and harvesting techniques for the dry seasons of the year (Tiwari R.N. 2017). Numerous schemes initiated by different departments at country as well as at state level, like IWMP, National Project for Repair, Restoration and Renovation of Water Bodies, River Valley Project and Flood Prone River Programme, MNREGA, Hariyali, DPAP, MPDPIP were very useful to enhance the groundwater. Increased sustainability of existing abstraction structures, increase in irrigation potential, revival of springs, soil conservation through increase in soil moisture and improvement in groundwater quality are among other benefits of the schemes.

ARTIFICIAL RECHARGE STRUCTURES

The technique of distributing or impounding water on the ground to boost infiltration through the soil and percolation to the aquifer or of injecting water directly into the aquifer through wells is known as artificial recharge. Artificial recharge primarily serves the purpose of storing extra water in subterranean aquifers so that it may be retrieved during dry spells. In India, the development of the watershed includes artificial recharge procedures (Jain S.K 2012). If these activities are carried out with good scientific planning, their performance can be greatly boosted. The technique of accelerating the natural migration of surface water into subsurface formations through the use of artificial means is known as artificial recharge. Building infiltration facilities or generating recharge from surface water bodies are two ways to do this. The underlying lithological units in hard rock regions lack the necessary porosity and permeability. In some regions, groundwater recharge is insufficient to replace the water being withdrawn from the aquifers. Therefore, groundwater cannot meet the need for irrigation or drinking water (Garg S.K. 1973). To make up for the water shortage, extra recharge by artificial means becomes essential. The rate of percolation varies from location to location and is influenced by rainfall, soil and lithological features, the type of landforms, temperature, and humidity. Consequently, subsurface water supply will differ from one location to another. Due to siltation and farmer encroachment for agricultural uses, the existing ponds and tanks have lost their capacity to store water, and the natural groundwater penetration from these water bodies has decreased significantly. There are several such communities with ponds or tanks that are in poor shape. The heavy siltation and damaged village tanks can be fixed or adapted to function as a recharge structure (percolation tanks). Village ponds and tanks will be transformed into recharge structures by desilting and the installation of suitable waste weirs.

In the study area, there are many of these sorts of village ponds or tanks that can be modified to increase groundwater recharge. In the locations where excessive development has drained the aquifer, artificial recharge techniques often help to increase the sustainable yield while preserving the surplus surface water for future needs. Therefore, the purpose of this study was to generate information to aid in choosing recharge zone sites. Effective artificial recharge methods for groundwater exist, but only if they are selected in line with the unique site conditions. A total 75 numbers of recharge structures including percolation ponds (15), check dams (38), and Nala bunds (22) are suggested after thorough study and analysis depending on the current field situation. Based on geological and geomorphological characteristics of the area following recharge structure suggested.

NALA BUND

Nala Bunds, which are inexpensive structures built over drainage or nala in higher water catchment zones, are employed. For first- to second-order drainage, the Nala bund is built with boulders or uneven stones. The groundwater storage should be increased by building Nala bund structures in the area. A total 22 numbers of nala bund is suggested the location shown in Table-1 and in Figure 2. Nala bund in the sloping terrain specially in hills of Upper Rewa sandstone of the places like Pathra, Bheesampur, Bhogam, Gorsari Itma, etc. can be very effective in controlling rainwater runoff velocity since such structures would break the free flowing nature of rain water during the monsoon period.

CHECK DAMS/STOP DAMS

A small-scale structure called a check dam/stop dam is placed across a slope to stop runoff and hold back water to improve subsurface infiltration. Check dam is a suitable construction in the research area's somewhat favourable zone to increase the groundwater potential. These structures are built over the third or higher order of drainage and a gradual slope of the ground to stop increased runoff during the monsoon season. These structures are the most commonly constructed structure in all the said programmes for water and land conservation. It is a masonry barriers built across the direction of water flow on shallow rivers and streams for the purpose of water harvesting for irrigation as well as for domestic and animal use. Stop dam facilitates irrigation and also provides water for human and animal consumption. The sites suitable for check dam (38) in the study area are Mukundpur, Dinapur, Pagra, Sannehi, Ghuisa, Bajwahi etc.

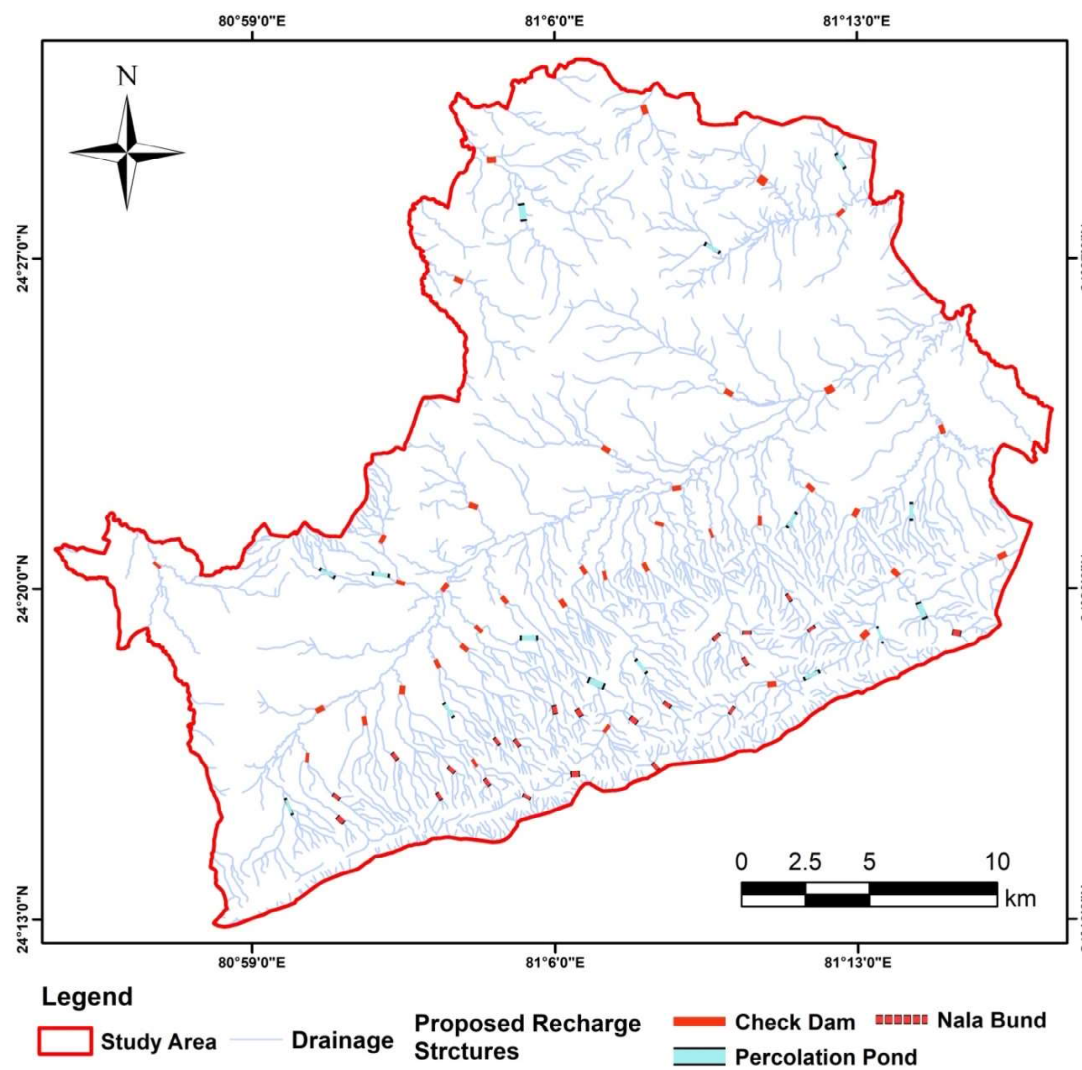

Figure 2. Suggested artificial recharge structures map of the study area

PERCOLATION POND

A percolation pond is a small tank- or reservoir-like structure built to store runoff from the surface and enable it to seep into the ground. Percolation ponds are multifunctional structures that serve as water gathering systems and may also address irrigation issues. These built-up areas act as huge reservoirs, catching more precipitation and letting it seep through them. To maximise the potential groundwater recharge, these structures were built downstream of the region. These structures are built above the drainage, usually on the second or third order. The location of suggested percolation tank shown in figure no. 2 while numbers of tanks in table-1. Raikwar, Mauhariya, Kharamseda, Kumhari, Papra are suitable sites for construction of percolation tank.

Table1.: Suggested artificial recharge structures in study area

S.No	Type of structures	No. of structures to be constructed
1	Nala Bund	22
2	Check Dam	38
3	Percolation Pond	15

RAIN WATER HARVESTING STRUCTURE

In this method, rain water collected from the roof of the building is diverted to a storage tank. The storage tank has to be designed according to the water requirements; rainfall and catchment availability**.** In urban areas, houses and buildings have large area of roofs which have planned drainage outlets. Large quantity of rainwater goes waste through these outlets. The recharge wells with injection pipe are employed in areas where top layer is of clay which occurs up to great depth and water table in unconfined aquifer at a greater depth. The lateral recharge shaft are suitable for recharge of groundwater in unconfined aquifer where sandy In the study area, where no existing structures are available, the roof top water can be recharged into ground through recharge shafts / trench. The recharges well without injection pipe are useful in the areas where groundwater in the top unconfined aquifer need to be augmented. The depth and diameter of the recharge shaft depends upon the depth of aquifer and volume of water to be recharged. Soil strata of high permeability with greater hydraulic conductivity is available at shallow depth and water table is within this permeable material.

CONCLUSION

Tanks or ponds in rural areas need proper attention in terms of renovation and maintenance to increase groundwater recharge. In locations where excessive development has drained the aquifer, artificial recharge techniques often help to increase the sustainable yield while preserving the surplus surface water for future needs. Therefore, the purpose of this study was to generate information's which may help in determine the recharge zone sites. Effective artificial recharge methods for groundwater exist, but only if they are selected in line with the unique site conditions. Many appropriate recharge structures including percolation ponds, check dams, and nala bunds have been suggested which may be off immense use to solve the water scarcity. Appropriate institutional arrangements are required for this purpose. Now it is well known that for sustainable management of water, peoples adequate participation in the programmes is essential. Community organizations and non-governmental organizations (NGOs) should be suitably involved. Apart from this, awareness programmes for watershed management is highly required to manage the water resources of the area.

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Optimum Utilization of Low-Grade Limestone During Mining Operation, Maihar

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ABSTRACT

Ore Recovery refers to the percentage of valuable minerals that can be economically extracted from a deposit during mining operation. Geological resources can be estimated of any deposit based on the recovery percentage and exploratory data. To calculate accurate reserves and resource of any deposit, it is very important to have proper exploration of area as per Minerals (Evidence of Mineral Contents) Rules 2015. Mineral exploration is the process of searching for mineral resources beneath the Earth's surface. This is a crucial activity in the mining industry, as it helps identify and assess the presence of economically viable mineral deposits. Recovery of low-grade mineral and continuous monitoring, data analysis and technological advancements playing a primordial role in the economic viability and sustainability of mining operation. Recovery of the deposit can be calculated as quantity of mineral recovered divided by total quantity of mineral deposit multiply by 100.

Keyword: Mineral exploration, Deposit evaluation, Ore recovery, Utilization of low-grade recoverable mineral, Mining operation.

INTRODUCTION

Mineral exploration is the systematic and multidisciplinary process of searching potential mineral deposit or other Geological parameters that can be economically extracted from the Earth's crust while minimizing environmental impact and ensuring the well-being of local communities. It is a critical first step in the mining industry, as successful exploration efforts lead to the development of new mining operations. This activity is crucial for the mining industry and involves a combination of geological, geochemical and geophysical techniques to locate areas with indication of economically valuable minerals. Roger Marjoribanks 2010 discus the ultimate goal of mineral exploration is to assess the deposit quantity, quality and its economic viability before starting the mining operation. The Mineral exploration process involves several stages like Prospecting, Survey, Drilling, Data analysis, Feasibility study etc.

DEPOSIT EVALUATION

Deposit is an anomalous portion of earth's crust where natural incidence of minerals is high enough over the normal crustal abundance to be economically mineable. Deposit evaluation is a crucial step in the lifecycle of a mining project. It provides the foundation for decision-making by mining companies, investors and regulatory authorities, helping ensure that mineral resources are exploited in a sustainable, responsible and economically viable manner. The primary objective of the deposit evaluation is to estimate the quantity and quality of the mineral resources and reserves, understand the geological and metallurgical characteristics of the deposit and assess the technical, economic and environmental feasibility of mining. The cut-off grade in mining refers to the minimum grade or quality of mineral reserves that must be met or exceeded for a deposit to be economically

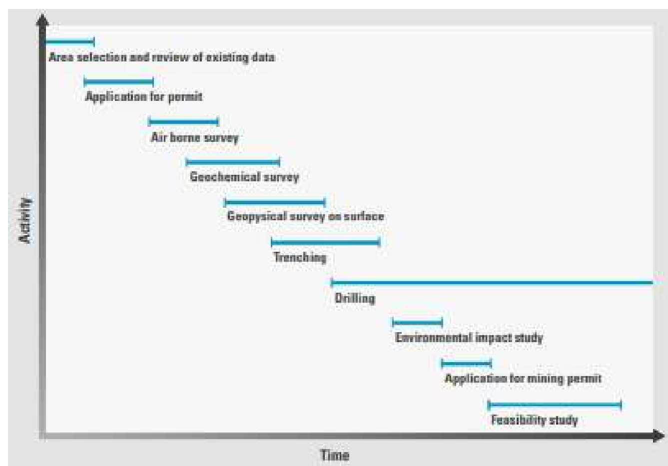

Figure 1: Exploration activity sequence in general. (Source: Atlas copo)

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viable for mining or processing. It is a critical parameter in the evaluation and development of mining project. MCDR key components of deposit evaluation include Resources & Reserves Estimation, United Nation Framework Classification (UNFC), Total Mineral Resource (Measured Mineral Resource -331, Indicated Mineral Resource-332, Inferred Mineral Resource-333), Total Mineral Reserve, Reconnaissance Mineral Resource-334, Prefeasibility Mineral Resource-221 & 222, Feasibility Mineral Resource-211.

Method of deposit evaluation

Several methods are used to estimate mineral reserves including –

Block Modelling: This method divides the deposit into a grid of blocks, with each block representing a volume of the deposit. The grade and tonnage of each block are estimated based on available geological and assay data.

Kriging: Kriging is a geostatistical technique used to interpolate data points and estimate grades at unsampled locations within the deposit. It considers the spatial correlation of data.

Geological Cross-Sections*:* Geologists creates cross-sections of the deposit to visualize its three-dimensional structure. These cross-sections aid in estimating the shape and continuity of ore bodies.

ORE RECOVERY

Ore recovery refers to the percentage of minerals that can be economically extracted from the mineral deposit through mining operation and processing. It is a critical factor in evaluating the economic viability of a mining project. The process of ore recovery involves several stages -

Mining: Ore recovery begins with the extraction of ore from the Earth's crust. This can involve surface mining or underground mining methods, depending on the depth and characteristics of the deposit.

Ore Processing: Once the ore is extracted, it undergoes processing to separate the valuable minerals from the surrounding rock or waste material. Common ore processing methods include crushing, grinding, and various separation techniques such as flotation, gravity separation or magnetic separation.

Concentration: After initial processing, the ore is often further concentrated to increase the content of valuable minerals. This step is crucial for improving the overall recovery of valuable metals. The case of metals, the concentrated ore may be undergo smelting or refining processes to further separate impurities and obtain a purer form of the metal.
Formula of ore recovery percentage:

$$\text{Ore Recovery \%} = \frac{\text{Quantity of mineral recovered}}{\text{Total quantity of mineral in deposit}} \times 100$$

High ore recovery rates are desirable for a mining project as they indicate efficient extraction and processing operations, leading to better economic returns. However, achieving high ore recovery rates can be challenging due to factors such as ore complexity, ore grade, mineralogy, processing technology and environmental consideration. Our main aim is to optimize ore recovery by using the Geological data during mining operation and minimize losses. Sustainable mining practices also emphasize responsible ore recovery to minimize environmental impact and ensure long term resource availability.

UTILIZATION OF LOW-GRADE RECOVERABLE MINERAL

The utilization of low-grade recoverable minerals poses both challenges and opportunities for the mining industry. Low grade minerals contain a lower concentration of valuable elements compared to high-grade deposits, making their extraction and processing less economically viable. However, with advancements in mining technologies, processing methods, and a growing emphasis on sustainable practices, there are strategies to enhance the utilization of low-grade recoverable minerals like

Advanced Processing Technologies: Develop and implement advanced processing technologies that can economically extract valuable minerals from low-grade ores. This may involve innovations in process.

Improved Recovery Methods: Enhance recovery methods to maximize the extraction of valuable minerals from low grade deposits.

Innovative Mining Techniques: Develop and adopt innovative mining techniques that minimize waste and selectively target higher grade sections within a low grade deposit.

Resource Characterization: Conduct thorough and detailed geological and mineralogical studies to better understand the characteristics of low-grade deposits. This information can aid in designing targeted and efficient extraction and processing methods.

Economies of Scale: Leverage economies of scale by processing larger volumes of low-grade material. This can help spread fixed costs over a larger production volume, potentially improving the overall economic feasibility of the operation.

Collaborative Research and Development: Foster collaboration between mining companies, research institutions, and technology developers to invest in research and development projects aimed at improving the recovery of low-grade minerals. Public-private partnerships and industry collaborations can accelerate technological advancements.

***Environmental Considerations*:** Develop and adhere to environmentally sustainable practices when extracting and processing low-grade minerals. Minimize the environmental footprint by adopting responsible mining techniques, reclamation plans, and waste management strategies.

***Market Demand and Prices*:** Consider market demand and commodity prices when evaluating the economic viability of extracting low grade minerals. Fluctuations in market conditions can impact the feasibility of extracting and processing these materials.

***Regulatory Compliance*:** Ensure compliance with environmental regulations and community expectations. Responsible mining practices are increasingly important for gaining social license to operate, and adherence to regulatory standards is essential.

The utilization of low-grade recoverable minerals requires a holistic and integrated approach, involving technological innovation, environmental stewardship, and economic considerations. Sustainable and efficient utilization of these resources is key to ensuring the long-term viability of mining industry.

LIMESTONE DEPOSIT OF MAIHAR

Limestone deposit of Maihar district falls in geological formation of Vindhyan System. The Vindhyan system is a group of sedimentary rock formations that in age from Late Precambrian to Early Palaeozoic era (approximately 1.7 billion to 500 million years ago) and extends across several Indian states, including Madhya Pradesh, Uttar Pradesh, Rajasthan, and parts of Bihar and Chhattisgarh. Limestone is one of the prominent rock types and having significant economic value and used as a raw material in various industries like Cement manufacturing, construction & Chemical industries etc.

The present research work discusses the use of limestone in Cement manufacturing. It requires large quantities of limestone and limestone deposit play a crucial role in meeting this demand. Thickness as well as quality of the limestone vary in the study area even after high inter-burden good quality of limestone occurs in this region. Extraction of this second band limestone will play the crucial role in the Cement Manufacturing units. Estimation of reserves and resources and determining the mine life considering the whole depth of limestone may less economically viable while extracting minerals from a deposit but it will be sustainable mining. Approx 82 Bore Holes of a limestone deposit of a working mine situated in Maihar District has been analysed and following results as discuss.

Table: 1 Few Bore holes details of a working Lime-stone Mine located in Maihar District

BH No.	BH Depth (m)	Run (m)		CaO %	Run (m)		CaO %
		From	To		From	To	
1	35.50	8.30	13.30	45.91	14.30	14.80	47.79
2	30.00	3.00	11.50	48.08	14.50	18.00	45.37
3	30.00	3.00	30.00	44.67			
4	30.00	2.50	15.00	46.49	18.00	21.50	46.45
5	21.25	2.50	4.50	50.46	5.50	10.50	49.04
6	14.50	1.00	6.60	46.21	9.00	10.75	46.27
7	60.00	1.50	13.95	48.54	20.05	22.50	47.99
8	16.00	3.00	6.80	41.17	7.30	9.80	43.43
9	34.50	2.00	9.50	47.07	15.00	28.50	44.03
10	27.00	3.00	4.50	46.91	5.50	15.00	44.66

CONCLUSION

1. Stripping Ratio considering First band limestone = 146040/1359500 = 0.11 (**S/R 1 : 0.11**)
2. Stripping Ratio considering Inter-burden and Second Band Limestone = (146040 + 87112) / (1359500+382570) = 0.13 (**S/R 1 : 0.13**)
3. 14.44 % reserves will be increased if second band mining will be done considering 24.59% increased S/R.
4. Quality in terms of Cao will decrease from 44.58 to 42.44 but it is more the prescribed IBM threshold value.
5. Quality in terms of MgO will increase from 3.53 to 3.87 but it is less the prescribed IBM threshold value.

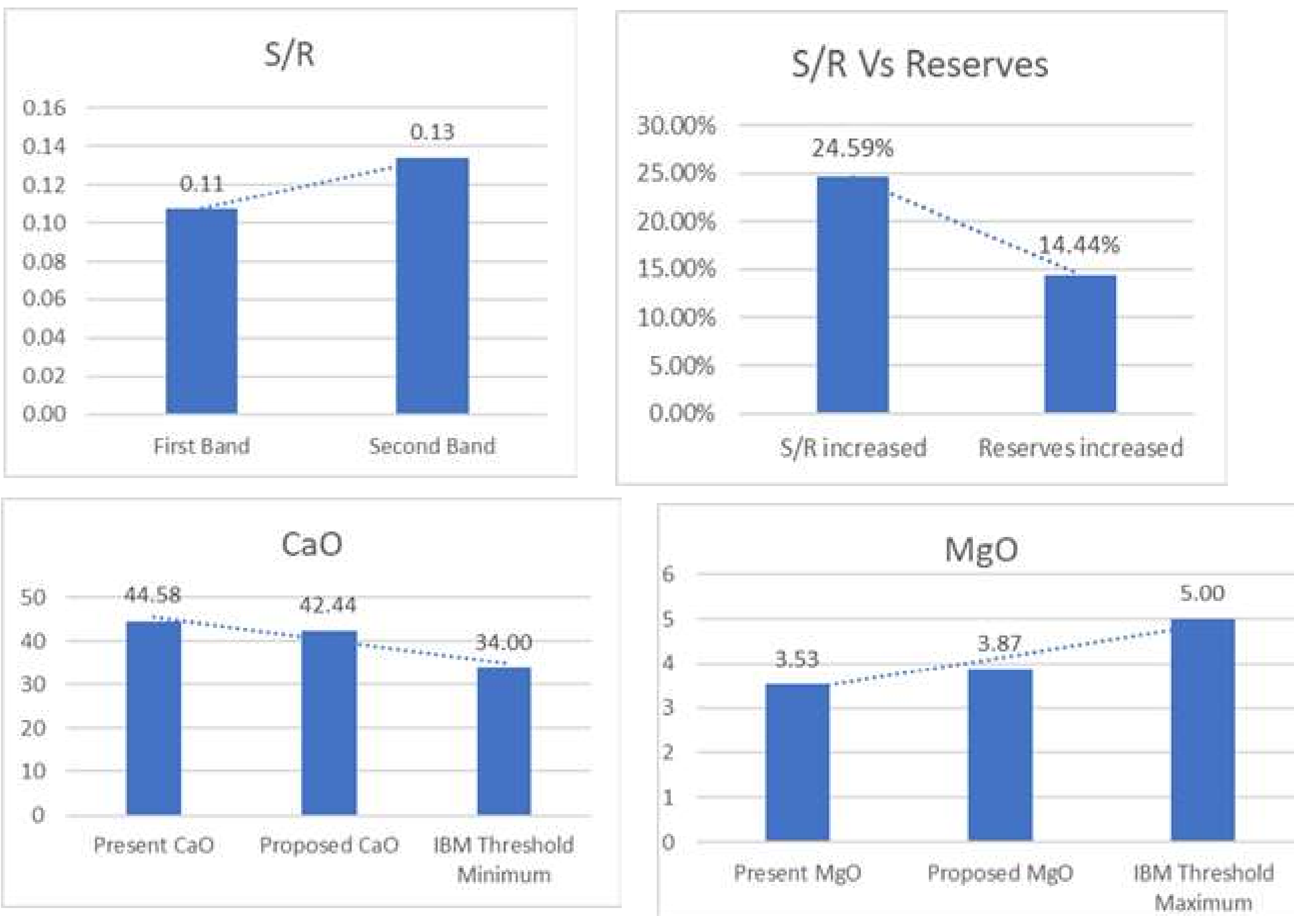

Figure: 2 : Showing the Striping ratio Vs Reserve, CaO, MgO

percentage in different bore holes.

1. Life of the mine will also be increased by 14 – 15 %
2. Mineral conservation helps ensure the long-term availability of essential minerals by promoting their responsible and sustainable extraction.
3. Responsible mineral conservation practices will contribute to the long-term economic sustainability of communities that depends on the mining activities.
4. Mineral conservation is essential for environmental protection, economic sustainability and the responsible use of Earth's resources.
5. It will be possibly by proper mine planning, mining method uses, processing facility and scheduling.
6. Exploration efforts may continue during the operation of the mine.
7. Blending of high grade and low-grade limestone in right proportions can be an effective strategy to optimize the quality and cost effectiveness of the

resulting product. This can be done through laboratory testing and analysis to find the right balance.

8. The utilization of second band limestone can be economically viable when properly managed and processed.

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Sedimentological and Economical Studies of Bhander Limestone Deposit in and Around Amanganj Area, Panna District, Madhya Pradesh, India

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ABSTRACT

The limestone deposit of Amanganj area belongs to Bhander Group of Vindhyan Supergroup. Sagma Shale divides the upper and lower units of the Nagod limestone. Together with the Sagma Shale, a mixture of shale, siltstone, and sandstone, the Nagod Limestone Formation is composed of grey, light grey, light pink, brown, and yellow, ash grey, and greenish grey limestone laminated to very thin bedded limestone. The limestone displays a variety of sedimentary features, including algal stromatolitic formations, clay galls, intra-formational breccia, and desiccation fissures. With a depositional basin akin to an epeiric sea, the rocks of the Nagod Limestone formation exhibit signs of deposition in a shallow marine environment. The majority of the grey-colored limestone in the sample appears to be cement grade based on the CaO level. Low magnesian limestone makes up the dark grey limestone unit of the Nagod Limestone Formation. The limestone in the base unit is light buff in colour and rather sandy, with sporadic columnar algal formations towards the top. This is mostly micritic with dolomite substitute. This unit's upper surface is identified by a strip of flat pebble conglomerate that ranges in thickness from 15 to 30 cm. A band of calcareous shale that is greyish follows this. The limestone that follows this shale band is pale and dark grey in colour, with numerous mud fissures and algal stromatolites of different shapes developing. This limestone unit occasionally develops sparry calcite and is likewise micritic. The limestone in the higher unit is well bedded and dark grey. It appears that the basal unit bird's eye structures and mud cracks, together with appreciable amount of terrigenous admixture, represents a deposit of supratidal flats. The upper dark grey limestone with development of pyrite and organic matter suggest deposition in deeper subtidal environment with occasional development of euxinic conditions, favouring for formation of pyrite and organic matter. According to the analysis's findings, the cement-grade limestone.

Keywords: Mineralogy, Geochemistry, Bhander Limestone, Stromatolite, Amanganj Area, Panna.

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Groundwater Management of Umaria Region, Madhya Pradesh, India

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ABSTRACT

Ground water is important sources of drinking water for many communities, especially in rural areas. However, the quality of this water can be impacted by various factors such as natural geological processes, human activities and environment pollution, The entire Umariya distinct is falling under Son sub basin area of the Ganga basin the main river of the district is the son which flows from south -west to north- east direction and forming district boundary between Shahdol and Umariya district. The Son or Survarna means the gold is one of the biggest tributary of the rivers Ganga, and it is considered as sacred river. The river Son originates from Son kund from Amarkantak plateau, located in Anuppur district of Madhya Pradesh. Rivers Johila and Chhoti Mahanadi are main tributaries of Son river in Umariya district is underlain by Gondwanas sandstone, Archaeans granite- gneisses,-clays, Lametas and Deccan trap basalts, with the objective of elucidating the complex dynamics of groundwater systems for the purpose of sustainable resource management. Characterizing the hydrostratigraphy, evaluating the quality of the groundwater, and identifying the variables affecting the recharge and outflow patterns of groundwater in the river sub basin are the main goals of this study. Using advanced geospatial tools and hydrogeological modelling software, we were able to accurately simulate the flow of groundwater. The result was the creation of a detailed conceptual model, revealing the exact spatial distribution of aquifer characteristics and their Connection to the nearby river network. This study offers crucial insights to the sustainable management of water resources in the Umaria policy makers and water resource managers can make conscientious choices regarding groundwater extraction, preventing contamination, and executing successful conservation strategies. Comprehensive approaches to water resource management, taking into account the interplay between surface water and groundwater.

Keywords: Hydrogeological, Ground water

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Assessment and Management of Groundwater Resources of Beohari Area, Shahdol District Madhya Pradesh, India

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ABSTRACT

The paper analysis the assessment and management of groundwater resources of Beohari area Shahdol distrcict Madhya Pradesh India. In the study area having compact sandstone dug well should be preferred instead of borewell. In the paper asses the groundwater resources and suggest various artificial recharge structure percolation pond etc. Chapman, O. (1992) Based on geological and hydrogeological data the roal of NGO's and awareness programmes regarding the conversation of water have been discussed. Sufficient ddata of each village is required regarding the identification of sites suitable for dugwell and bore wells.

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Rock Crushing in Large-Scale Rock Slope Failures

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ABSTRACT

Rock crushing up to grain-size composition optimal for further processing and extraction of the valuable component from the ore is one of the main technological processes of mining industry. Do we know something similar in nature? In my talk I would like to describe fast and efficient crushing of the enormous amount of hard rocks taking place during formation and motion of rock avalanches. Such phenomenon can be characterized as an extremely rapid, massive, cataclastic laminar flow of fragmented rock converted from a large rockslide.

Rock avalanches occur in high mountainous regions almost all over the World. They originate, usually, when volume of the initial rockslide exceeds 1 million of cubic meters, and, what should be pointed out, regardless of types of rocks involved. Rock avalanches are known in weak Neogene conglomerates and in hard Mesozoic, Paleozoic and Precambrian sedimentary, metamorphic and igneous rocks. The resultant rock avalanche deposits are characterized by the very specific dual internal structure – with coarse, often relatively thin carapace, sometimes with meters-size blocks, blanketing the entire rock avalanche body, and voluminous so called "body facies" composed of intensively fragmented rock debris ranging in size from few decimeters up to micron-size and even up to nano-size particles. Sometimes the basal facies can be observed too. Moreover, there are some evidence that harder the initial rock is, more intensive fragmentation takes place.

Another interesting peculiarity of rock avalanches is their motion as a laminar-like flow, without turbulent mixing of debris. It is clearly visible in those case studies, which source zones are composed of rock of different types (and color). Sometimes even loose talus accumulations or fluvial gravels being involved into rock avalanche motion, form separate "layers" or "lenses" in the deposits. One of the important effects of this phenomenon is that coarse carapace forms not due to upward floating of larger blocks from the entire moving debris, but due to much weaker crushing of the uppermost rock unit, often without any visible transition zone between blocky carapace and fragmented body facies. It recalls crushed ice over spring water flow.

Such characteristic features are typical of rock avalanched regardless of their runout and of their transition and deposition zones confinement conditions. Taking in mind that formation of rock avalanches that move with a speed of 100-400 km/hour, even of the longest of them, last from several tens of seconds and up to several minutes, the efficiency of rock comminution that takes place during their emplacement should be considered as extremely high. Absence of debris mixing allows assumption that fragmentation within the body facies occurs not due to repeated collision of separately moving clasts, as, for example, in rock falls, but due to intensive "pressure waves" combined with shearing, that cause formation of transient force chains where stress exceeds rock's strength.

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