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Design Approach of Solar Photovoltaic Hybrid Power Generating System

Pankaj Kr. Shrivastava

ABSTRACT

Solar Energy, the dominant and unfathomable non-conventional sources of energy has emerged as one of the major sources of energy. Over all these years solar energy has been transformed with R&D input from all stakeholders, so as to make it user friendly and low cost. In the Present research, SPV hybrid power generating system has been developed and designed for a college or office, which operate during day time. It has been observed that due to intermittent, irregular and fluctuating mains supply (220V AC), electronic private branch exchange (EPBX) and personal computers do not function continuously even during day time.

The only viable economical solution is to develop a hybrid power generating system to provide uninterrupted power supply to the above installed system. A non-conventional source can be utilized along with mains supply to operate EPBX for in house telephones and personal computers installed at various offices/rooms. SPV module converts Solar Energy (Sun Light) directly into DC electricity. The electrical energy (DC) so generated charges a battery bank through SPV charge controller with a charger cum inverter to generate 220V AC supply. The first part of the project includes basic design concept of Solar electricity, its advantages, Design philosophy, system integration details, basic block diagrams, technical specification and details of SPV Charge Control Unit, SPV modules and balance of system.

The second part of the study includes survey of design inputs, design Calculation, various options and cost estimate.

INTRODUCTION

It has been observed that due to intermittent, irregular and fluctuating mains supply (220V AC), our EPBX and personal computers do not function continuously even during day time i.c. college hours.

The only economical solution is to develop a hybrid power generating system to provide uninterrupted power supply to the above installed systems. A non-conventional source can be utilized along with mains supply to operate EPBX and personal computers installed in the examination rooms and offices. Here SPV module Converts Solar Energy (Sun Light) directly into DC electricity. The electrical energy so generated, charges a 12 Volt battery already installed with the charger cum inverter can be used for development purpose in the first phase.

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Advantage of solar electricity

- Energy independent.
- Maximum reliability.
- Minimum maintenance.
- Systems are easily expanded.
- Pollution free.
- Cost free.

History of PV cells

The principle of PV Cell was discovered in 1890. However, the application of the technology was in 1950 in the US, where these cells were used to power space ships. The oil crises of the mid – 1970 staggered research in PV technology for other applications, and the first PV industry vas established in the early 1980s in the US. In India, the first PV manufacturing Industry was started by the Bharat Heavy Electricals Ltd, in 1983, in the Central Electronics Ltd. Sahibabad.

DESIGN PHILOSOPHY

The design philosophy takes into account the following factors.

(a) Maximum power generation throughout the year.
(b) Proper charging of the battery for long Life operation.
(c) Number of sunless days (Days of autonomy).
(d) High efficiency automatic charge controller unit to provide low maintenance and low drainage of battery.
(e) Accommodate future growth.

Basic Design Concept

The size of PV module and battery will depend upon actual requirement of the load. Output voltage of one module is designed for charging 12-Volt battery bank. A number of parallel modules are used to increase the charging current of battery. SPV module behaves like a battery. The system has been designed to work satisfactorily under varying environmental conditions.

System integration details

Hybrid solar power generating system comprises of the following:

(a) Battery charger cum inverter.
(b) SPV module.
(c) Module mounting structure and hardware.
(d) SPV charge control unit.
(e) Battery Bank.
(f) Cables/Wiring set.

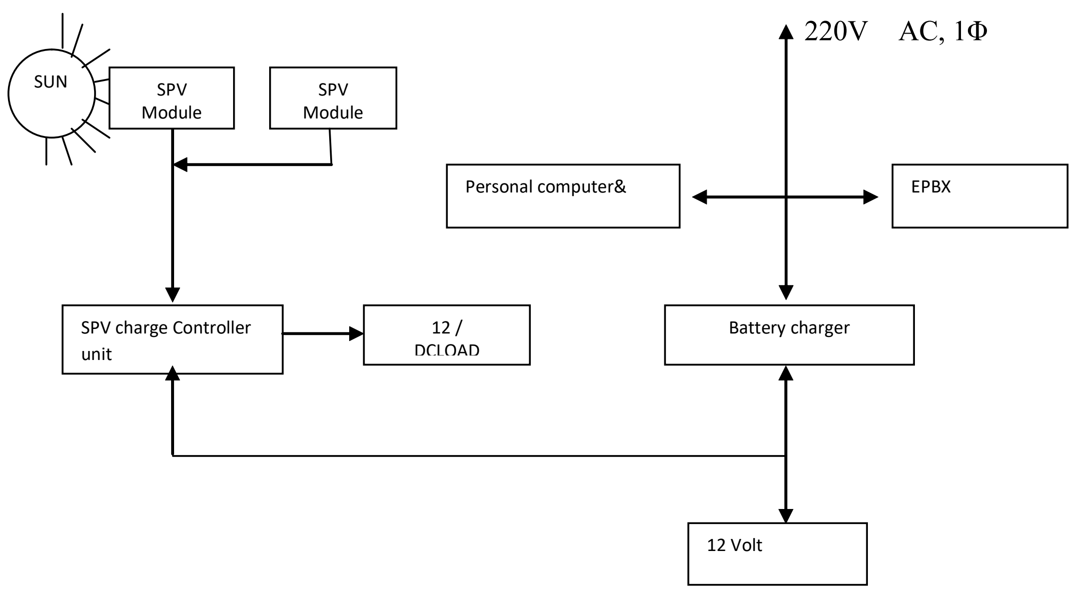

Fig.1: Basic block diagram of SPV hybrid Power Generating System

SOLAR PHOTOVOLTAIC MODULE

The heart of any SPV system is the solar cell, a semiconductor device, which when exposed to sunlight produces DC electricity. A number of such solar cells are interconnected in series combination and hermetically sealed with a toughened and highly transparent front glass cover to form a Solar photovoltaic Module, Modules are interconnected in parallel to increase the charging current of battery.

Module Mounting Structure

SPV modules are mounted on a specially designed galvanized angle iron support structure. The structure can be installed either on roof or on the ground at an angle of tilt with horizontal in accordance with the latitude of the place of installation.

SPV Charge Control Unit

Electrical energy generated by the Solar Photovoltaic Array is stored in the battery through the Electrical energy control unit. Over – charging and drainage of the battery bank beyond specified levels is detrimental to its life. The charge control unit, therefore, prevents over-charging by disconnecting the solar panel and drainage by disconnection the load. At present personal computers, printers and EPBX system are connected with the mains supply (220 V AC), so all the above AC loads are connected directly with the battery charger cum inverter unit. Thus drainage of battery is controlled by inverter unit and not by the SPV charge control unit. It also protects the SPV module from reverse flow of current from battery bank during no-sun condition.

Technical Specifications

1. Battery low cut-off level	11.5±0.2 V DC
2. Battery reconnection level	13.00.2 V DC
3. SPV panel disconnection level	14.50.2 V DC
4. SPV panel disconnection level	12.50.2 V DC

5. Indication

(a) Charging by SPV panel (Green LED)	(ONE)
(b) Battery over-charge (Yellow LED)	(HIGH)
(c) Battery low (Red LED)	(LOW)
(d) Battery reverse polarity (Red LED)	(REV)

6. Protections
   (a) Battery reverses polarity protection to the controller.
   (b)Reverse flow of current from the battery bank to the module.
   (c) Short circuit protection by use of suitable MCB at load end.

Provision for wall mounting as well as placing on table shall be provided.

Battery

The battery used shall have high AH charge-discharge efficiency. Low self-discharge rates and long life. The battery capacity shall be sufficient to meet the load requirement for required number of consecutive sunless days. The two topping up frequency of the battery shall be achieved through ceramic vent plugs fixed on each 2V cell of the 12V-battery bank. VRLA (Valve regulated lead acid maintenance free battery) can also be used for this system. The setting of the four potentiometers will be done as per specification of the battery.

Wiring set

Suitable wires, cables and lugs for connection SPV modules in parallel, SPV panel to the SPV charge controller, charge controller to battery and load shall be procured after verifying the voltage drop calculations.
Brief Technical Specification of SPV Module (12v/75 WP)

Open Circuit Voltage Voc	> 21V
Short Circuit Current Isc	4.96A
Maximum Current Imp	4.4 A (Nominal)
Nominal power output Pmax	75 W
Number of cells	36
Efficiency	> 12%

DESIGN INPUTS

Case study of a College & Administrative Department:

Total load requirement per day

S.N.	Unit (Location wise)	Number (Qty)	Wattage (W)	Usage (Hours/day)	Load (Watt-hour)
1.	Chairman's office				
	a. CFL (11 W)	4	44	3	132
	b. Computer (100 W)	1	100	2	200
	c. Printer (220W)	1	220	0.5	110
2.	EPBX (50W) Ideal Load	1	50	4	1200
3.	Principal's office				
	Computer (100W)	1	100	6	600
	Printer (220W)	1	220	2	440
4.	Examination Hall				
	Computer (100W)	1	100	6	600
	Printer (2)	1	220	4	880

Total = 5962 Watt. – Hour

Total load: 6000 Watt hour per day OR 6000/ 12: 500 AH per day.
Considering inverter's efficiency: 80% (Approx)
Total Amp. Hour (DC): 600 AH per day

DESIGN CALCULATIONS

Option –I (Design Calculation for SPV System Alone)

Choose module: TBP 1275 from M/S TATA BP Solar India Limited, Bangalore
Standard Test condition for irradiance = 1000 W/M^2
Maximum Power Pm = 75Wp
Maximum Current Imp = 4.41Amp.
Single module output in AH/day = Pack hour x Imp
= 5 x 4041
= 22.05 AH/day
Number of parallel modules =
Daily load in AH/Columbic efficiency x De-rating factor x One module output
= 600/0.8 x 0.9 x 22.05
= 600/15.876
= 37.79
Number of parallel modules = 38 Nos.

Battery Capacity Sizing

Battery Capacity = Discharge Current (A) x Discharge duration time (Hour).

The discharge duration time varies depending upon the discharge current; the battery capacity also greatly depends upon the discharge current; Normally batteries are rated at 10 hour rate, it means if battery capacity 1200 AH then we can draw 120 Amps current for 10 hours from the battery. But if we draw more current, the battery behaves as if its AH capacity has been reduced and if we draw less current, the battery behaves as if its AH capacity has been increased. However, the relationship is not linear.

Considering number of sunless day (days of autonomy) = 1 day

Battery capacity = Daily load x No. of sunless days/Max. depth of discharge (50%)
= 600 x 1/0.5
= 1200 AH
Battery capacity = 12 Volt, 1200 AH.

It is desirable to procure Exide low maintenance tubular Cells LMS type battery.
Model No. LMS 1200 at 10 Hr. rate of discharge.
Overall dimension = 338 x 680 mm.
Weight (a) Without acid = 85 Kg.
(b) With acid = 131 Kg.

We require six cells of 2 Volt each to get 12 Volt battery systems.

We can also install two sets of battery bank each of 12 Volt, 600 AH rating with separate SPV battery charger of 12 Volt, 100 Amp rating for each battery bank.

A make before break type switch can be installed with the batteries for switching over from one battery to another.

This will increase the reliability of the power supply system. Expansion and maintenance can be easily performed.

a. SPV charge regulator's rating (Amp)
= No. of modules in parallel x Isc x 1.3 (safety factor)
= 38 x 5.05 x 1.3
= 191.9 Amp.
= 12 Volt, 200 Amp.(Standard rating)
Assuming length of wire from SPV module to charge controller = 30 meters
(One way) OR 2 x 30 = 60 meters (Both way).
Maximum short circuit current Isc. Delivered by 38 modules = 38 x 5.05 A = 191.9 Amp.
Maximum current Imp, at peak power point
= 38 x 4.41 A = 167.6 Amp.

Voltage Drop Calculation

Resistance of 35 mm. sq. (267/.04) cable = 0.554 Ω per Km. at 20^0 C (Max)
Length of cable = 60 meter.
Considering four parallel paths of ten modules,
Voltage drop of one path V = IR
= 10 x 4.41 x 60 x 0.554/1000
= 1.46 Volt

Specification of Interconnecting Cable for Four Parallel Paths

Single core multistoried flexible PVC insulated copper conductor (unsheathed) cable of 35mm sq. (276/.0.4) or equivalent.
Red color: 120 meters (Approx.)
Black or Blue color: 120 meters (Approx.)
We require 4 similar parallel paths each of 9/10 modules for a bank of 36/40 modules.

Expected performance of system
Voltage at peak power point = 17.0 V.
Voltage drop in the cable = 1.46 V.
Voltage drop in the blocking diode = 1.0 V.

- Voltage available for charging 12 V battery bank 14.54 V.
- 600 AH/day load will be shared by 27 modules on working days and for charging battery on Sunday or weekly holiday.
- 242 AH/day generated by 11 modules will be utilized for charging battery.
- Battery will get fully charged within two days after a holiday.
- Considering the cost and sunshine area of Satna 30 SPV modules can be procured.

Option – II (Hybrid System)

Initial study:
(a) Considering mains power (220 V AC) interruption / fluctuation / failure for 4 hours (Max) daily during peak sun hours.
(b) Assuming battery is charged from the mains (220 V AC) Supply by the charger cum inverter during rest 20-hour period by 5 Amp. DC (Max) installed with
the system is equal to 5 x 20 = 100 Ah.
Reserve power in the battery = 100 AH per day.
Power requirement/consumption =600 AH per day.
Battery capacity installed = 180 AH / 12 V.
Two days are required for full charge of 180 AH battery.
Usable power from the battery (50%) = 180/2 = 90 AH.
Balance power required or (Drainage from the battery is 100% i.c. drastic decrees of the life of battery.

Number of modules required for 510 AH / 22.05 = 23.13 = 23 modules

(c) Specification of inter connecting cable single core multi-strand flexible PVC insulated copper conductor cable of 35mm. sq. (276/0.4) or equivalent along with suitable lugs.
Red color: 30 meters (Approx.).
Black or Blue color: 30 meters (Approx.).
(Voltage drop = 5* 4.41* 60* 0.554 / 1000 = 0.73 V).

COST ESTIMATE

SPV module 12 V / 75 Wp =Rs. 11500/- per module
SPV Charge control unit (12 V, 100A) =Rs. 25000/-
Mounting structure for one module =Rs. 150/-

Cables 2.5 mmsq. Single core
=Rs. 1000/- per 100 meters
16 mmsq. Single core
=Rs. 6000/- per 100 meters
25 mmsq. Single core
=Rs. 10000/-per100 meters
35 mmsq. Single core
=Rs. 12000/-per100 meters

Approximate Cost of Components for Option – II

SPV module 4 Nos.@ Rs. 11500/- = Rs. 46000/-
SPV charge control unit 12V, 25A = Rs. 8000/-
Mounting structure for 4 modules = Rs. 600/-
Balance or system (Wires, cable & lugs etc.)
= Rs. 4000/-
Total = Rs. 58600/- (approx)

Budget required= Rs. 60000/-

CONCLUSIONS

Assuming reserve power in the battery from mains supply (220 V Ac) = 100 AH per day. (Refer option II)

SPV power available from the Sun to charge the battery by one module = 4.41*5 AH = 22.05 AH per day.

SPV power available from the Sun to charge the battery five modules = 5*22.05 = 110.25 AH/day.

Total power available from the battery any Sun = 100 + 110.25 AH/day

= 210.25AH/day

Power requirement to run three personal computers for three hours per day = 3*100*3 Watt-hour/day.
= 900 WH/day

Power required to run one printer for one hour = 1*220*1 WH/day.

= 220 WH/day.

Power requirement to run EPBX with 20 Imes for two hours = 1000WH/day.
Total power requirement / Consumption = 2120 Watt-hour/day.

=2120/12 = 176.6 AH/day.

Total power generated from SPV modules = 110.25 AH/day.

Power drawn from battery = 66.35 AH/day.

Percentage discharge from battery after one holidays = 33.2% (safe limit of discharge)

Installed charge cum inverter (650W) is continuously loaded to its full capacity.

Forced air-cooling may required during summer period to protect the switching transistors from over heating.

We can conclude that option two-three hours during day time without hampering the urgent work.

Budget required Rs. 60000/- (approx.)

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Sustainable Development Goals vis-à-vis Energy Dimension : Case Study of an Indian Manganese Mine

Pukhraj Nenival

INTRODUCTION

The mining industry has the opportunity and potential to positively contribute to all 17 of the SDGs ['*The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015', provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership'*]. The mining industry can impact positively and negatively across the SDGs. In recent decades, the industry has made significant advances in improving how companies manage their environmental and social impacts, protect the health of their workers, achieve energy efficiencies, respect and support human rights, provide opportunities for decent employment and foster economic development. Historically, however, mining in India has contributed to many of the challenges that the SDGs are trying to address – environmental degradation, displacement of populations from their ancestral homeland, worsening economic and social inequality (due to migration, skill gap among local population, poor education infra), armed conflicts, gender-based violence, tax evasion and corruption, and increased risk for many health problems (in inaccessible mining areas). Given the negative and positive impacts of mining combined with the industry's capability to mobilize human, physical, technological and financial resources, the Atlas demonstrates the role mining companies can play in contributing to all 17 of the SDGs. Study of SDGs and their status in mining sector has revealed that every product (say a processed Ore or ROM) when subjected to the assessment of environmental burden across its 'Life Cycle' help in the assessment of environmental impacts from the cradle to the grave (Bauman and Tillman, 2004). Thus it has been an established fact that 'Life Cycle Assessment' has been an useful tool for quantifying and interpreting the impacts. Despite its use in assessing mining products and processes has been limited. This situation is particularly true for non-coal as well as coal mining. In the recent years several studies have been reported about the application of the Life cycle assessment (LCA) in Mining globally. In case of India this continues to be a very new concept and the application has been limited. Khanda, et el (2018), studied in detail the environmental impacts of coal mining in Lakhanpur Opencast Project of Ib Valley Coalfield, Odisha using Life Cycle Assessment (LCA) model.

The scope and nature of mining activities create opportunities to leverage some goals in particular. While opportunities to positively contribute can be found across all of the goals, 'Energy Dimension' has an important role to maintain and achieve SDG goals.

LIFE CYCLE ASSESSMENT

Manganese is linked directly or indirectly to a lot of industrial processes which may be studied through LCA. Mn is important for steel making. These links make comprehensive life cycle inventory (LCI) information on Mn crucial for LCA in general. Often, life cycle inventory data on extraction processes for steel production is non-existent and this affects the completeness of LCIs for steel and other industrial processes.

In general mines do not reveal much of their data pertaining to processes and performance, as well as the limited life-cycle thinking in the mining industry this could be cited as the main reasons for the lag in LCA applications in mining.

LCA studies of Mn mining can help fill LCI data gaps, and perhaps generate data which could be helpful to the Mn mining industry as whole. LCA data can help in pin pointing processes from which the Mn mining industry can potentially benefitted of significant reductions in life cycle impacts of Mn. LCA can be used to complement other environmental systems analysis tools and aid in environmental sustainability reporting for any mining

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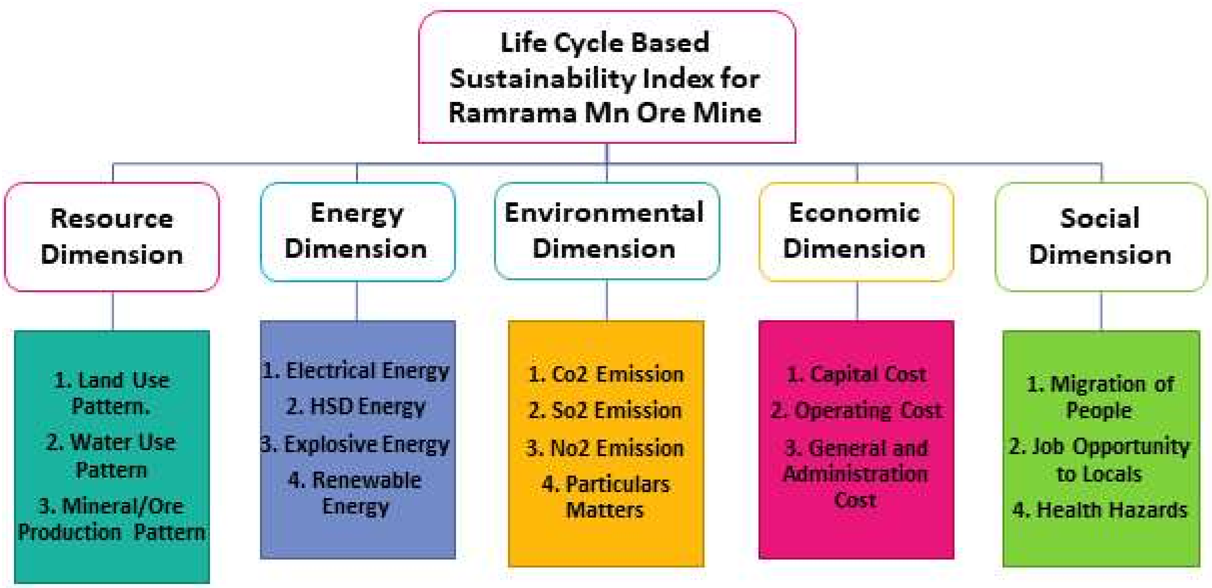
businesses. Alvarenga et al. 2019, reported about, an analysis of the benefits of a product-oriented perspective in an environmental sustainability strategy of the mining sector.

To simulate the life cycle inventory regarding the environmental aspects, the author has used the database from Indian Bureau of Mines (IBM), and State Directorate of Mines & Geology. Help was available from the International Reference Life Cycle Data System (ILCD) Handbook, based on ISO 14040 and 14044 (ISO 2006a, b), was considered to conduct the LCA. This handbook is a guidance document, providing recommendations on models and characterization factors to be used for impact assessment in applications such as LCA. This supports the analysis of emissions and resource consumption in a single integrated framework.

The following impact categories have been selected to assess the environmental impacts of Ram Rama Mn Mine which had commenced production as an opencast mine is being converted into an underground mine due to resource availability for opencast mining in addition to operational, safety and overall mining cost.

The concepts pertaining to life cycle Assessment, each industry has variation in sustainability indices and may vary across industry and organization, for the case of Ramrama Mn Ore Mine various sustainability indices has been identified and developed as per mining condition considering Techno- Socio parameters.



CASE STUDY

The various Sustainable Development Goals were studied in respect of this manganese mine located in a very ecologically fragile environment in the district of Balaghat. The present paper focused on the Life Cycle Based Sustainability Index for Ramrama Mn Ore Mine with special reference to Energy Dimensions. The description in this paper also cover the geographical location, geological set up of the mine.

RAMRAMA MN ORE MINE

This mine is situated in rural area of Balaghat district of Madhya Pradesh having lease area of 43.086 Hectare for the mining of manganese ore. Details of mine is as following-

TOPOGRAPHY

Topographically the lease area has a gentle rolling topography. The highest and lowest elevation are 342m and 336m, thus resulting difference in elevation is about 6m. the gradient of the area is towards the west, meeting in to Mahadeo nala, since the area has been worked more than six decades hence development like pits/huts/roads/ dumps management/office set up degraded the natural topography and their location has been shown on plan, majority of area is agricultural.

REGIONAL GEOLOGY

The Manganese deposits of M.P. are associated with early Proterozoic gneiess and schist belt of the Sausar Group. Sausar series encompassing phyllite, schist, gneisses, crystalline limestone/marble and calc-silicate/granulites and associated Manganese ore deposits of central India. Mansar phyllite and muscovite schist/gneiss having Manganese horizon at bottom, middle and top of the formation. Mineral of Sausar Group is- Hausmanite, Verdenburgite, Jacobsite, Braunite, Holandine and Bixbyte.

Stratigraphic Sequence of Sausar Group

Period	Formation	Lithounits
Recent		Alluvium
	Unconformity	
	Intrusive	Pegmatite and Vein Quartz
	Bichua Fm.	Dolomitic Marble calc-silicate rocks,
		Biotite-Muscovite Schist, Sillimanite
		Bearing Quartz-Biotite-Granuites.
	Chorbaoli Fm.	Garbet- Sturolite-Quartz-Muscovite Schist,
		Micaceous and Cherty Quartzite locally with
		garnet and magnetite.
Prterozoic	Mansar Fm.	Mn ore-I and Gondite-Muscovite Schist
		Mn Ore-II, Schist
		Mn Ore-III with Gondite
	Lohangi	Dolomite marbles with lenses of Mn ore
		calc- silicate rocks, calc-granulites, Quartz-
		Biotite Granulites and Gneisses
Archean	Tirodi	Disconnformity
	Biotite	Biotite Gneiss, Migmatite, Tonalite,
	Gneiss	Gneiss, Corderite Gneiss, Amphibolites.

LOCAL GEOLOGY

Entire area has been explored by 3 no of pit, whereas pit no 1&2 is running as Open cast and pit no 3 is running as Underground pit. By this exploitation we have found that upper surface is covered with alluvium. Hang-wall is belong to Chorbaoli formation (Quartzite, Quartz-Mica Schist) and Footwall is belong to Mansar formation (Muscovite-Biotie Schist and Quartz-Mica Schist). The lens of Mn ore is present in-between Chorbaoli and Mansar formation. Manganese mineral we found here is- Braunite, Rhodonite, Spessertie.

General strike of the ore body is N61^{0}W and average dip is 55^{0}N. At centra part N-S Dipping is also seen in U/G section. Pegmatite intrusion took place on footwall side which traversed Mn ore from Footwall to Hang-wall.

Entire area has been divided into three part-
1. Western Part
2. Central Part
3. Eastern Part

1. Western Part- From geological point of view, the western part has undergone polyphase folding and neo-tectonism. As a result, the maximum thickness of Mn ore beds varies between 1 m to 10m on the limbs of the fold.

2. Central Part- This area has been worked out for opencast development as Pit-2 and presently the ore body is exposed at the pit bottom mRL-300 (280m) and lateral length has been considered in 10-25 m lateral influence.

3. Eastern Part - The area has been worked out for O/c development as Pit-1 was worked from mRL-340 m to 295 m, further mineralization has been explore with old bore holes and outcome of exploration has been proved for non-mineralization up to UPD and UPL of the area.

MODE OF OCCURRENCE & CONTROL OF MINERALIZATION

Manganese mineralization associated with sausar group of rocks has been considered as metamorphosed syngenetic type owing to their intimate association with Quartz-Muscovite Schist of Mansar formation

Ramrama deposits occur as narrow repeated bands hosted within " Tirodi-Biotite Gneiss" again in close association with thin layers of Quartz-Mica Schist.

LITHOLOGY

Soil- Entire area covered with alluvium
Muscovite-Biotite Schist
Mn ore- Braunite, Rhodonte, Spessertite
Muscovite-Quartz Schist
Pegmatite

STRUCTURE

The Sausar series rocks are known to have undergone three phase of folding. Folding in Strike direction- Minor and repeated folding Folding in Dip direction- Tight folding forming Anticline and Syncline form of fold and overturned fold Shear direction- N50^{0}E, containing calcareous material. Plunge direction- E-W dip- 30-35^0

ENERGY DIMENSION

In Life Cycle Assessment (LCA) analysis (as stated at Figure 1), for the mining industry, the energy dimension plays a crucial role in assessing the environmental impact and sustainability of mining operations across their entire life cycle. LCA is a comprehensive methodology that evaluates the environmental burdens associated with a product, process, or activity, considering all stages from raw material extraction to end-of-life disposal. Electrical power plays a crucial role in manganese ore mining operations, contributing significantly to the efficiency, safety, and overall productivity of the mining process. Following below are several key aspects highlighting the importance and link with mining activities of electrical power in manganese ore mining:

MINING EQUIPMENT OPERATION

Excavation Machinery: Electrical power is essential for operating heavy machinery such as excavators, loaders, and drilling equipment used in the extraction of manganese ore. Electrically powered equipment can provide consistent and reliable performance in challenging mining environments.

MATERIAL HANDLING AND TRANSPORT

Conveyors and Crushers: Electrical power is used to operate conveyor systems and crushers, facilitating the efficient transportation of mined ore from the extraction point to processing facilities.

PROCESSING AND BENEFICIATION

Ore Processing Plants: Electrical power is required for running processing plants where manganese ore is treated and refined. Various unit operations, such as crushing, screening, grinding, and magnetic separation, rely on electrical energy for their operation.

LIGHTING AND VENTILATION

Underground Operations: In underground mining, electrical power is crucial for providing lighting and ventilation in tunnels and shafts. Proper illumination and ventilation are essential for the safety and well-being of workers. DGMS had also stipulated the 'Illumination

Standards' for Indian Metal Mines so as to ensure safe working place through Technical Circular -DGMS(Tech) (S&T) Circular No. 7 of 2016 Dated 8.04.2016.

COMMUNICATION SYSTEMS

Safety and Operations: Electrical power supports communication systems, including radios and signaling devices, enabling effective coordination among mining personnel and ensuring a timely response to emergencies.

AUTOMATION AND CONTROL SYSTEMS

Automated Processes: Electrical power is integral to the implementation of automation and control systems in mining operations. These systems help optimize processes, monitor equipment performance, and enhance overall efficiency.

DATA COLLECTION AND ANALYSIS

Monitoring Systems: Electrical power supports the operation of sensors and monitoring devices used for collecting data on equipment performance, environmental conditions, and ore quality. This data is valuable for making informed decisions and optimizing mining processes.

ENVIRONMENTAL MONITORING

Water Treatment and Pollution Control: Electrical power is essential for running water treatment facilities and pollution control measures, helping to mitigate the environmental impact of mining activities.

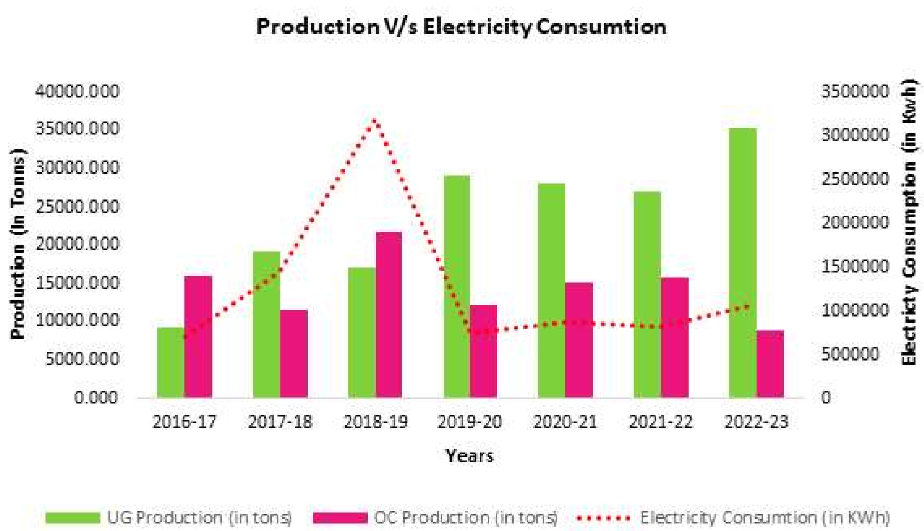
COLONY/CAMP FACILITIES

Worker Accommodations: Electrical power is required for providing electricity to worker accommodations, including lighting, heating, and other amenities, contributing to a safe and comfortable living environment for mining personnel.

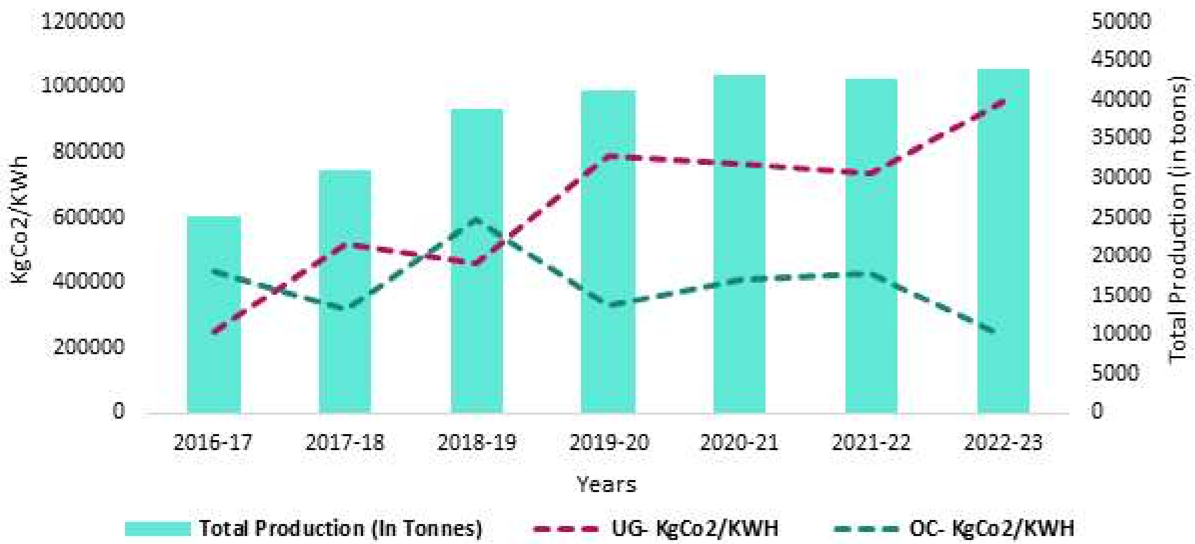
MAINTENANCE AND REPAIRS

Workshop Tools: Electrical power is essential for running tools and equipment in maintenance workshops, where routine servicing, repairs, and equipment upgrades are conducted to ensure the reliability of mining machinery.

The reliability and availability of electrical power are critical for sustaining continuous mining operations. Mines often rely on a combination of grid power, generators, and backup systems to ensure a stable power supply. Given the energy-intensive nature of mining operations, optimizing energy use and exploring sustainable power sources, such as renewable energy, are increasingly important considerations for the mining industry to enhance efficiency and reduce environmental impact. Overall Electricity consumption for the production from UG and Opencast Mining for the Ramrama Mn ore mine is compared, which shows that power consumption for production is decreasing, as the production from UG is constantly increasing.



As per the Central Electricity Authority of India annual report, recorded Kilogram Co_2 per KWH electricity consumption is 0.82. for the Ramrama Mn ore Mine, $KgCo_2$/kWh for the UG and Opencast Mining compared with total Production is represented in the figure.



In Case of UG, trend of C02 emission is increasing due to higher production rate and higher electricity consumption for the activity such as ventilation, artificial illumination for day and night working, to reduce the Co2 emission, solar power generation of 4145 KWH Per/ day is installed. They have settled cords in the ground which are helping bi-facial modules generate maximum energy. At present the average billing is 6655 KWH Per/ day as per the Net Metering Regulation Act 2015. At last we would happily like to announce that by opting green energy we have successfully reduced the consumption of electricity from electricity board with the achieved generation of 4145 KWH Per/ day. Also reducing almost 3800 KG of CO2 from the atmosphere, which is equal to planting 2500 trees.

HIGH-SPEED DIESEL (HSD) ENERGY

High-Speed Diesel (HSD) power, commonly used in the form of diesel fuel, plays a significant role in manganese ore mining operations. Due to the complex ventilation network in the underground mines, presence of gases, availability of adequate quantities of Oxygen, etc, DGMS had brought out a set of norms as a part of its DGMS(S&T)(Tech.) No. 01 dated 13.08.2018. In the following discussions several aspects highlighting the importance of HSD power in manganese ore mining has been presented.

MOBILITY AND FLEXIBILITY

Diesel-powered equipment, including haul trucks, excavators, and drilling rigs, provides the mobility and flexibility needed in mining operations. This is crucial for accessing different areas of the mining site, especially in open-pit mining scenarios.

OFF-GRID OPERATIONS

In many mining locations, especially remote areas, access to the electrical grid may be limited. Diesel generators can provide off-grid power, allowing mining operations to take place in locations where establishing a connection to the grid is impractical.

VERSATILITY IN EQUIPMENT

Diesel engines are widely used in a variety of mining equipment due to their versatility and robustness. They can operate efficiently in different conditions, including high altitudes and extreme temperatures.

ENERGY FOR DRILLING AND BLASTING

Diesel-powered equipment is often used for drilling and blasting activities in mining. This includes blast hole drills and explosives transport vehicles, which rely on diesel engines for power.

BACKUP POWER

Diesel generators can serve as a backup power source in case of electrical grid failures. This is particularly important to ensure the continuity of critical operations and avoid downtime.

EXPLORATION AND SURVEYING

Mobile equipment used for exploration and surveying, such as drilling rigs and geophysical survey vehicles, often run on diesel power. This enables these operations to be conducted efficiently in diverse and remote terrains.

EMERGENCY POWER SUPPLY

In emergency situations, diesel generators can provide a reliable source of power for essential services such as lighting, communication systems, and safety equipment.

EQUIPMENT RELIABILITY

Diesel engines are known for their durability and reliability, making them suitable for the harsh operating conditions encountered in mining activities. This contributes to the overall reliability of mining equipment.

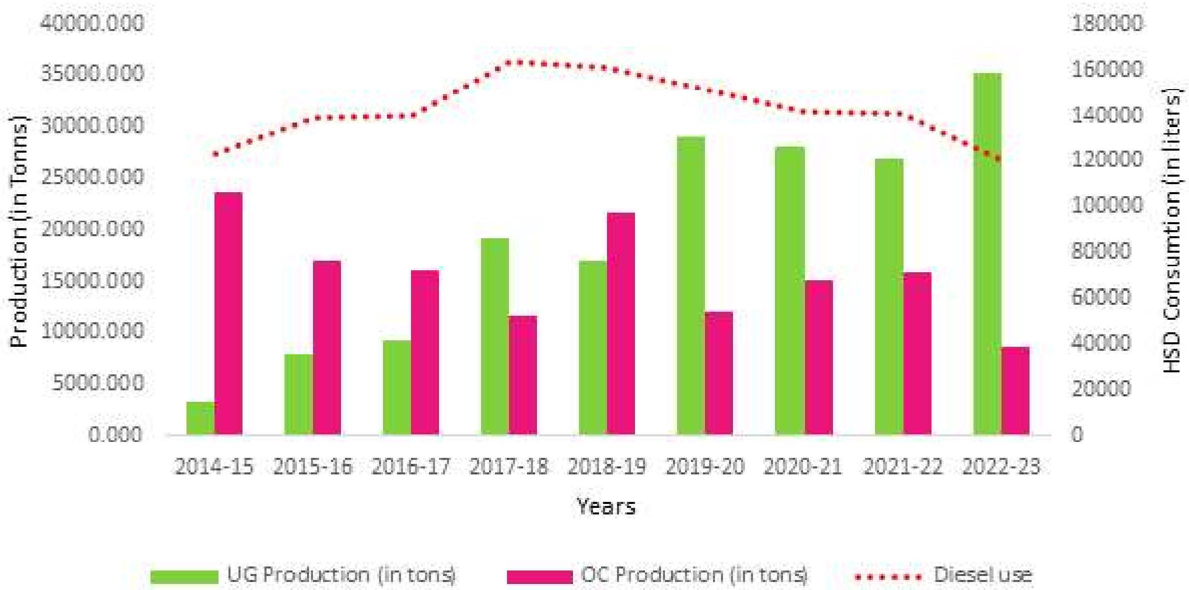
FUEL STORAGE AND TRANSPORT

Diesel fuel is relatively easy to store and transport, making it a practical choice for mining operations where bulk storage and frequent refueling are necessary.

MINING VEHICLES (HEMM-HEAVY EARTH MOVING MINING MACHINERIES)

Many Heavy Earth Moving Mining Machineries, including haul trucks and loaders, are powered by high HP diesel engines. These vehicles are essential for the transportation of ore and overburden within the mining site.

While diesel power provides essential benefits in terms of mobility, flexibility, and reliability, it's important to acknowledge the environmental impact associated with diesel combustion, such as greenhouse gas emissions and air pollution. As global efforts to reduce carbon emissions intensify, mining operations are increasingly exploring alternative energy sources and technologies to minimize their environmental footprint.



In case of Ramrama Mn ore mine, transition from opencast method of mining to underground mining method resulted in dependency on HSD based equipment's for excavation, transportation, now the HSD consumption decreasing as a result of drastically decrease in production from Opencast mining, since the Underground equipment's are working on prime source of electricity, for the emergency purpose the DG set are in power backup which are important for UG mining in terms of reliability and flexibility of mining operation.

EXPLOSIVE ENERGY

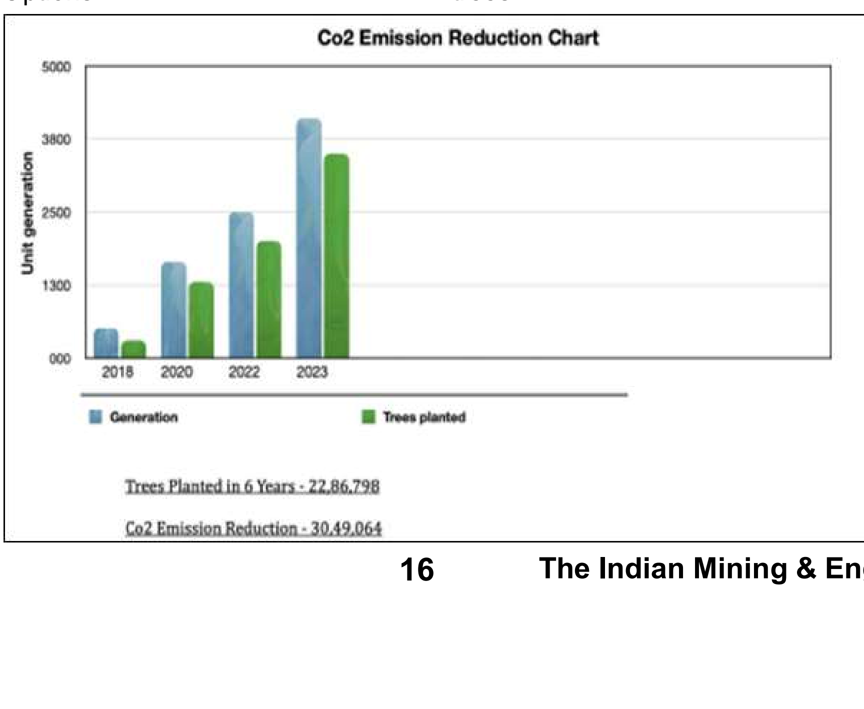
An explosive is a chemical material that is capable of extremely rapid combustion resulting in an explosion or detonation. Selection of explosives, methods of initiation, design of blasting rounds for different operations (development and stoping) contribute to the energy use in any mining operation. Apart from fragment size, the post blast emissions from the blasting are some of the critical areas for increase in energy consumption. Evacuation of toxic fumes, resultant time taken to stoppage of work are some of the factors which contribute to idling of equipment, manpower as well as maintaining all systems operated by electricity in active operation mode

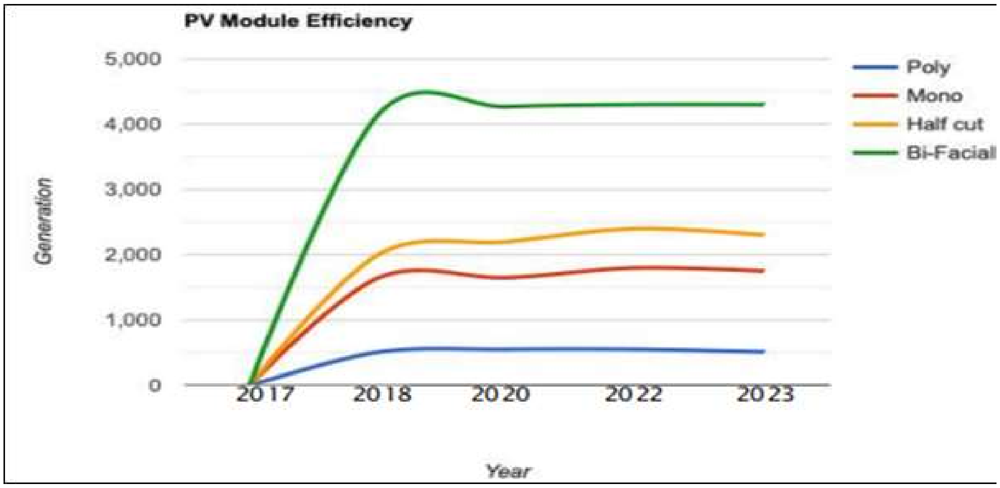
SOLAR ENERGY

Solar energy in a location in the Mines lease area can be a smart decision for various reasons. Solar energy has become increasingly popular and cost-effective due to advancements in technology and environmental concerns. Here are some reasons to opt for solar energy in Mines:

- Environmentally Friendly
- Abundant Sunlight
- Long Lifespan
- Reduced Energy Bills
- Government Incentives
- Energy Independence
- Low Maintenance
- Energy Storage Options
- Social Responsibility
- Energy Storage Options

Due to heavy electricity consumption and 40% duty on KWH electricity consumed, understanding our social responsibility, APTS Ramrama Mines opted for a solar plant. We started our solar journey in the year 2018, In the beginning, the chosen plant capacity was 170 KW, in which total generation was 507 KWH units Per/day. The type of solar module was polycrystalline. Our actual consumption was 10800 KWH Per/ day and billing was 10293 KWH Per/ day as per the Net Metering Regulation Act 2015. In the year 2020 the capacity was increased by 330 KW with the advancement of technology, panel used was monocrystalline which is more efficient than polycrystalline. The performed generation was 1220 KWH Per/ day. The total achieved generation was 1645 KWH Per/ day . The reasons behind the plant extension were reduced bills, the eco- friendly environment also increased consumption. Recently in the year 2023 the add-on of 405 KW has been done. This can also be considered as the third phase which represents the latest technology known as monoperc half-cut bi-facial photovoltaic modules, successfully producing 2500 KWH Per/ day . Total recent generation is 4145 KWH Per/ day. They have settled cords in the ground which are helping bi-facial modules generate maximum energy. At present the average billing is 6655 KWH Per/ day as per the Net Metering Regulation Act 2015. At last we would happily like to announce that by opting green energy we have successfully reduced the consumption of electricity from electricity board with the achieved generation of 4145 KWH Per/ day. Also reducing almost 3800 KG of CO2 from the atmosphere, which is equal to planting 2500 trees.





Year	Unit	Generation	Utilisation
2017-18	KWH	87500	(Connected with grid, full utilization)
2018-19	KWH	175000	(Connected with grid, full utilization)
2019-20	KWH	170333	(Connected with grid, full utilization)
2020-21	KWH	276290	(Connected with grid, full utilization)
2021-22	KWH	510950	(Connected with grid, full utilization)
2022-23	KWH	797089	(Connected with grid, full utilization)

Considering energy dimensions (Electricity, HSD, Explosive & Solar Power) for the Ramrama Mn ore Mine, to reduce the GHG emission and to enhance sustainability, transition from opencast to underground mining method reflects the constants efforts of reducing the Carbon footprints for the future, since kgCO2/kWh is being reduced with using solar power generation and its connection to grid. KgCO2/Liters of HSD burning is decreasing constantly due to constantly reduction in opencast mining operation, Explosive utilization also optimized for reducing impact on environment and ecology.

CONCLUSION

With the help of Life Cycle Assessment, each industry has variation in sustainability indices and may vary across industry and organizations. In case of Ramrama Mn Ore Mine various sustainability indices has been identified and developed as per mining conditions considering Techno-Economic parameters. The most important indices like Resource Dimension had not only helped in optimization of the valuable resources and energy needs of the mines for ensuring sustainable mining operations. In the today's mining scenario where land is a very difficult resource, it contributes immensely to the growth of the sector vis-a-vis its acquisition and utilization has an impact on overall cost of mining also for sustainable mining.

ACKNOWLEDGEMENT

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Acidophile Community Populating Acid Mine Drainage (AMD) Site at Coal Mine Area of Singrouli, Madhya Pradesh

Dr. Kamlesh Choure* Dr. Deepak Mishra* Ms. Sandhya Pandey*

ABSTRACT

Microorganisms growing in highly acidic environments (pH values below 3) are found in all three domains of life: Archaea, Bacteria and Eucarya. Such organisms thrive in acidic sulfur springs and in association with mining activities where microbial oxidation of pyrite and other reduced sulfur compounds lead to the formation of sulfuric acid. Acidophilic prokaryotes are also involved in the industrial leaching of copper and other metals from ores.

Surface water pollution by acidic, metalliferous drainage (commonly known as acid mine drainage or simply AMD) from abandoned mine sites is a widespread problem in former mining areas of the India and many other countries world-wide. Given that mine water pollution can persist over periods of many centuries, the need for low-cost, long-term techniques for treating polluted mine waters is now more pressing than ever .The most promising low-cost treatment methods developed to date are the "passive treatment techniques" which principally involve the construction of wetland ecosystems with characteristics favouring water quality improvement. Bioremediation of acidic mine waters by sulphate reduction in novel, compost-based, field-scale bioreactors.

In our preliminary studies, we have focused on the characterization of indigenous microorganisms in the study systems using a combination of isolation/identification and biomolecular approaches. Mineral rich acidic environments are of especial interest to the microbiologists because, in general, the acidic condition of the habitat is the result of microbial metabolism and not a condition imposed by the systems as in case of other extreme environments.

Major objective of this research was isolation of acidophilic microorganisms that are capable of oxidizing sulfur and iron usually produce sulfuric acid resulting into the formation of Acid Rock Drainage (ARD) or Acid Mine Drainage (AMD) systems. The present study was undertaken to explore the microbial diversity of acidophilic bacteria in one such AMD samples of coal mine area of Singrouli, Madhya Pradesh. Mixed populations of acidophilic microorganisms were obtained from AMD water samples. Several colonies of mesophilic sulphur oxidizing bacteria and acidophilic chemolithoaurotrophic bacteria were isolated from sampling sites that were capable of growing in ferrous iron as well as elemental sulfur and various reduced sulfur compounds.

INTRODUCTION

Microorganisms growing in highly acidic environments (pH values below 3) are found in all three domains of life: Archaea, Bacteria and Eucarya. Such organisms thrive in acidic sulfur springs and in association with mining activities where microbial oxidation of pyrite and other reduced sulfur compounds lead to the formation of sulfuric acid. Acidophilic prokaryotes are also involved in the industrial leaching of copper and other metals from ores[1]. Some acidophiles grow at high temperatures. Physiologically, the acidophiles are very diverse: there are aerobic and facultative anaerobic chemolithotrophs and different types of heterotrophic prokaryotes, photoautotrophic eukaryotes, predatory protozoa and others. Acidophilic microorganisms maintain their intracellular pH close to neutrality and their cytoplasmic membrane may support proton gradients up to five orders of magnitude; their membrane potential is often reversed

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in comparison with neutrophiles and alkaliphiles, with an intracellular positive charge[2].

Surface water pollution by acidic, metalliferous drainage (commonly known as acid mine drainage or simply AMD) from abandoned mine sites is a widespread problem in former mining areas of the India and many other countries world-wide[3]. Given that mine water pollution can persist over periods of many centuries, the need for low-cost, long-term techniques for treating polluted mine waters is now more pressing than ever.

The most promising low-cost treatment methods developed to date are the "passive treatment techniques" which principally involve the construction of wetland ecosystems with characteristics favouring water quality improvement[4]. Bioremediation of acidic mine waters by sulphate reduction in novel, compost-based, field-scale bioreactors. The use of aerobic reed-beds to treat alkaline mine waters contaminated only with Fe is now well-established and is reasonably well understood in scientific terms[5]. For the more acidic mine waters, which typically contain a wider range of contaminant metals, compost-based passive treatment systems are prescribed. These are intended to promote alkalinity generation and metal sulphide precipitation by means of microbial sulphate- and / or iron-reduction processes. Recent monitoring of such "compost wetlands" both by our own group and others has shown that these microbial reduction-based passive systems do quite effectively lower the concentrations of iron and aluminium in mine waters, whilst increasing their alkalinity and pH[6].

Upon exposure to oxygen (O_2) and water (H_2O), metal sulfides undergo oxidation to produce metal-rich acidic effluent. If the pH is low enough to overcome the natural buffering capacity of the surrounding rocks ('calcium carbonate equivalent' or 'acid neutralising capacity'), the surrounding area may become acidic, as well as contaminated with high levels of heavy metals[7]. Though acidophiles have an important place in the iron and sulfur biogeochemical cycles, strongly acidic environments are overwhelmingly anthropogenic in cause, primarily created at the cessation of mining operations where sulfide minerals, such as pyrite (iron disulfide or FeS_2), are present[8].

Acid mine drainage may occur in the mine itself, the spoil heap (particularly colliery spoils from coal mining), or through some other activity that exposes metal sulfides at a high concentration, such as at major construction sites. Basic summary of the processes that occur:

$$2FeS_2 + 2H_2O + 7O_2 = 2Fe^{2+} + 4SO_4^{2-} + 4H^+(aq)$$

Pyrite + water + oxygen = ferrous iron + sulfate + acid

The oxidation of metal sulfide (by oxygen) is slow without colonization by acidophiles, particularly *Acidithiobacillus ferrooxidans*(synonym *Thiobacillus ferrooxidans*)[8]. These bacteria can accelerate pyritic oxidation by 10^6 times

We undertook fundamental research into the biogeochemical processes that occur in reduction-based passive treatment systems receiving acidic, metal-rich waters. However, very important questions remain about the nature and long-term efficacy of the biogeochemical processes occurring within such systems. Key questions include the following: (1) which process(es) control(s) the raising of pH?; (2) what are the key "sink" processes for pollutant metals?; and (3) what role does the depletion of organic carbon sources play in the dynamics and life-span of a compost wetland system? The uncertainties represented by questions such as these appear to be acting as a disincentive to the wider uptake of reduction-based passive treatment systems.

We have focused on the characterization of indigenous microorganisms in the study systems using a combination of isolation/identification and biomolecular approaches[9]. Mineral rich acidic environments are of especial interest to the microbiologists because, in general, the acidic condition of the habitat is the result of microbial metabolism and not a condition imposed by the systems as in case of other extreme environments[10].

Major objective of this research was isolation of acidophilic microorganisms that are capable of oxidizing sulfur and iron usually produce sulfuric acid resulting into the formation of Acid Rock Drainage (ARD) or Acid Mine Drainage (AMD) systems.

MATERIALS AND METHODS

The present study was undertaken to explore the microbial diversity of acidophilic bacteria in one such AMD samples of coal mine area of Singrouli, Madhya Pradesh, India

Mixed populations of acidophilic microorganisms were obtained from AMD water samples.
The following solid media were prepared:

1. Inorganic media
2. Enriched medium
3. 10 mM ferrous sulfate–0.02% (wt/vol) yeast extract–basal salts liquid medium

Medium pH was adjusted initially to pH 2.0. All of the bacteria were grown at 30°C for 7 days[11].

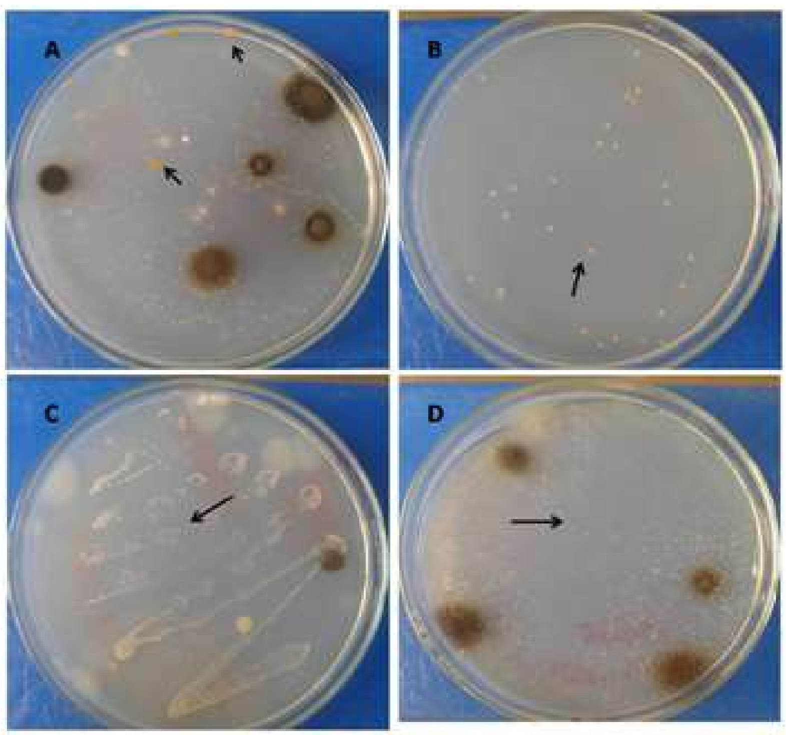
RESULTS AND DISCUSSION

Several colonies of mesophilic sulphur oxidizing bacteria and acidophilic chemolithoaurotrophic bacteria were isolated from sampling sites that were capable of growing in ferrous iron as well as elemental sulfur and various reduced sulfur compounds (photoplate 1).

To alleviate the problem of acidic nature of water of AMD following research may be conducted for better ecosafe solution: *a)* Isolation of microorganisms from AMD and microcosm studies, *b)* Physiological characterization and 16SrRNA sequence analysis of chemolithoautotrophic isolates to reveal that the strains are Acidophiles, *c)* To check the outflow of acidic liquids and other pollutants from mines is often catalysed by acid-loving microorganisms; these are the acidophiles in acid mine drainage, *d)* To control of these acidophiles by exploiting new class of microorganisms i.e. sulphate reducing bacteria and Iron-III reducing bacteria, *e)* Harnessing the acidophiles for industrial biotechnology for industrially important enzymes, and *f)* To use the acidophilic organisms in mining is a new technique for extracting trace metals (Fe, Cd, Al.Cu, Hg, Ar etc.) through bioleaching.

Photoplate 1

Colonies of mesophilic sulphur oxidizing bacteria and acidophilic chemolithoaurotrophic bacteria (arrow)



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Role of Alumina Nano Mineral Particle on PVA Based Nanocomposite Polymer Electrolyte Fiber Mats for Energy Devices

Dr. Neelesh Rai

ABSTRACT

An attempt has been made in the present work to prepare and characterize ammonium thiocyanate (NH_4SCN) salt and Alumina (Al_2O_3) Nanomineral doped polyvinyl alcohol (PVA) based nanofiber mats. Fiber mats of PVA:NH_4SCN:Al_2O_3 composite electrolytes are prepared by electrospinning process and characterized. XRD results show improvement in amorphous nature of electrolyte fiber mat with addition of Al_2O_3 as a nanofiller material. Electrochemical measurements reveal improvement in electrochemical window of these mats upon dispersal of Al_2O_3 filler particles. Temperature dependence of bulk electrical conductivity follows a combination of Arrhenius and VTF behavior. Jonscher Power Law has been used to test/confirm A.C. conductivity measurement of fiber mats.

Keywords: Nanomineral particles, Electrolyte nanofibers, Polymer nanocomposite electrolyte nanofiber mats, Ionic conduction.

INTRODUCTION

Polymer electrolytes have become material of great importance for use in different electrochemical devices due to their unique characteristics such as easy mouldabality, good electrode-electrolyte contact and light weight [1-2]. Within this frame-work, polymer gel electrolytes have received considerable attention due to ionic conductivity values approaching to that of liquid electrolyte [3]. Generally, when most of the studied gel electrolytes are retained for a long period, exudation of liquid from gel lump occurs which may cause instability in device performance.

In recent times, dispersion of a third component in pristine polymer electrolytes has been effectively tried to overcome the problem of liquid oozing to a great extent [4]. The third component may be either a high molecular weight polymer leading to formation of blend based electrolyte [5] or inorganic inert nanofillers [6, 7] leading to formation of nanocomposite polymer electrolytes. Among the different polymer electrolyte systems reported in literature, Agrawal and co-workers have extensively studied PVA based gel electrolyte systems owing to good gel forming properties of PVA [3, 8]. However, these electrolytes have been found to suffer from mechanical degradation and solvent exudation when kept in air for elongated periods.

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Looking into of such problems, an attempt has been made in the present work to improve the performance of PVA based electrolyte through dispersal of Al_2O_3 nano mineral particles and subsequent formation of their nano fiber mats. This nano filler has been extensively studied as active third component in composite polymer electrolyte [8] and easily available and so chosen in present investigation. This approach is expected to drastically impede crystallization process in polymer based nanocomposite electrolyte besides trapping the electrolyte. This in turn is likely to improve ionic conductivity and as well as electrochemical stability for long-term use in devices. The nanofiber mats of electrolytes have been prepared in a two-stage process, namely, preparation of gel solution followed by its electrospinning. The electrolyte fiber mats have been further characterized using XRD, Cyclic voltametry and electrical conductivity measurements.

MATERIALS AND METHODS

In this study, PVA (average molecular weight 124,000–186,000 Aldrich make), ammonium thiocyanate (NH_4SCN), AR grade sd. fine chem. make and aprotic solvent dimethyl sulphoxide (DMSO) Merk limited, Mumbai make were chosen for synthesis of nanocomposite polymer electrolyte nanofibers (NCPENFs). Al_2O_3 used in the study was obtained from Alfa Aesar, CAS Number: 1344-28-1 possessing average particle size 40-50nm. In the first step, PVA was dispersed in 1 M salt solution of NH_4SCN in DMSO in different stoichiometric ratios to form pristine electrolyte (PE) by the well-known solution cast technique [3]. Nanocomposite polymer electrolytes were prepared by adding as received Al_2O_3 in pristine electrolyte solution in different weight fractions followed by thorough mixing for nearly 8 hours at 46°C temperature on a magnetic stirrer. The so obtained viscous solutions were subsequently used to electrospin them in form of nanofibers in the second step. The experimental setup has been described in an earlier paper [9].

X-ray diffraction (XRD) patterns of fibers were recorded on an X-ray Diffractometer (RIGAKU, JAPAN make, model MINIFLEX-II) at room temperature for the Bragg angle (θ) varying from 2° to 90° (λ=1.5418Å).

Cyclic Voltammetry analysis was carried out in air atmosphere at room temperature using an Electrochemical Analyzer (CH Instruments, USA model no. CHI608D) in the voltage sweep range ±3V keeping the scan rate at $0.1 Vs^{-1}$.

Complex-impedance spectra were recorded in the frequency range 40Hz–100 KHz at different temperatures ranging in between 30°C and 100°C with help of a computer controlled LCR meter (Hioki Japan, make model 3520). The fiber mats were sandwiched between two platinum electrodes in an especially designed sample holder for impedance measurements described earlier [9].

Dielectric parameters were extracted with the help of impedance data using the relations:

$$\varepsilon^* = \varepsilon' - j\,\varepsilon'' \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Where $\varepsilon' = \dfrac{-Z''}{\omega C_o\,(Z'^2 + Z''^2)}$ and

$$\varepsilon'' = \frac{-Z'}{\omega C_o\,(Z'^2 + Z''^2)}$$

Here, the angular frequency (ω=2πf), Z' is the real part and Z'' the imaginary part of impedance.

RESULTS & DISCUSSION

XRD studies

The XRD patterns of polymer electrolyte fiber mats of pristine PVA electrolyte without and with Al_2O_3 nano mineral particles are shown in Figure 1 (a-g). The XRD profile of Al_2O_3 (Fig. 1a) shows a well-defined micro-crystalline peak around 2θ = 46° & 67° along with other peaks (2θ = 31°, 33° & 39°) reflecting orthorhombic structure.

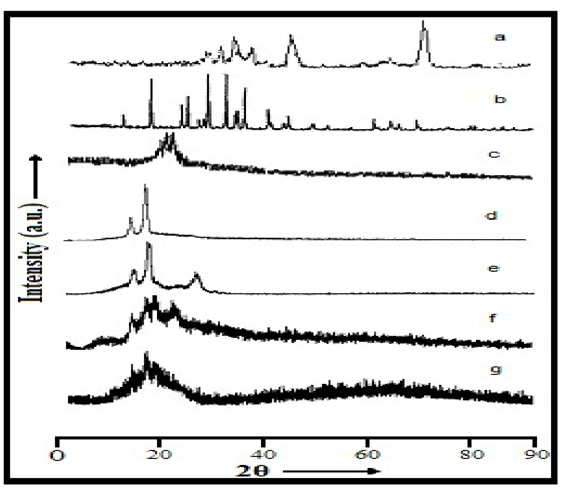

Fig. 1. X-ray diffractograms of (a) pure Al_2O_3 nano mineral (b) pure NH_4SCN, (c) PVA:DMSO fibers and DMSO:PVA:NH_4SCN nanocomposite polymer electrolyte fibers mat with (d) 0 wt.%, (e) 2 wt%, (f) 4 wt% & (g) 6 wt% Al_2O_3 nanofiller.

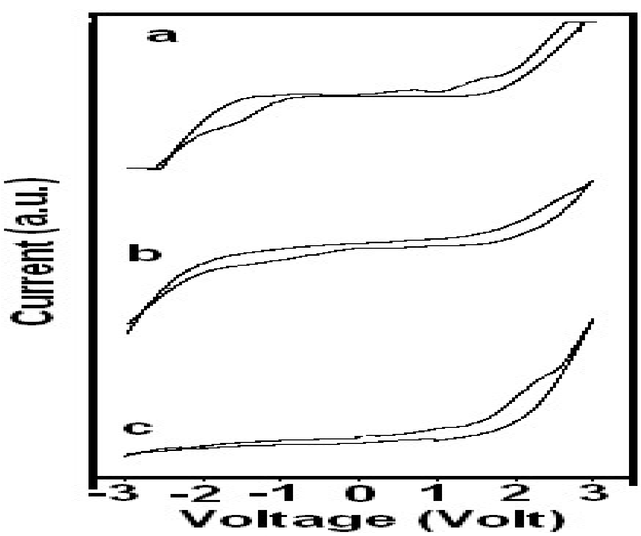

Fig. 2. Cyclic Voltammograms of: (a) DMSO:PVA:NH_4SCN nanofibers and its composite containing (b) 4 wt% and (c) 6 wt% Al_2O_3 filler content.

Diffractogram for DMSO casted PVA fiber mat (Fig. 1c) exhibits a moderately broad peak around 20.7°, which shifts to lower 2θ value in fiber mat of polymer electrolyte (Fig. 1d). Recently, this shifting of PVA related peak has been correlated to interaction of pristine components leading to formation of polymer electrolyte [3]. Further, the peaks related to PVA become sharper on drawing fibers of electrolyte owing to fast evaporation of solvent in the process of electrospinning. When Al_2O_3 is added, the prominent PVA related peak once again broadens up with increase in intensity. Addition of Al_2O_3 prevents polymer chain reorganization, which causes significant disorder in the polymer chains. This is likely to promote interaction among components leading to enhancement in amorphous behavior of electrolyte fiber mat. Further, no peak related to Al_2O_3 (Fig. 1e) could be tracked in XRD profile. This feature ascertains improvement in system morphology with complete absorption of Al_2O_3 particles in PVA matrix [9]. Further, a drop in XRD intensity of PVA has been noticed upon Al_2O_3 loadings in XRD profile of polymer nanocomposite electrolyte nanofibers. This again possibly results from interaction among constituents (polymer and salt) in the presence of filler. SEM studies have also shown the interaction of Al_2O_3 with salt and polymer PVA in an earlier work [9]. All these results clearly indicate improvement in system morphology (enhancement in amorphous nature of fibers) upon addition Al_2O_3.

CV STUDIES

Figure 2 compares the cyclic voltagrams of pristine PVA electrolyte nanofibers without and with Al_2O_3 nanofiller. It is apparent from this figure that the electrochemical stability is moderately good without any filler which ranges from -1.5V to +1.2V. On addition of nano filler, stability is seen to improve significantly (-2V to +1.4V). A stable potential window is of great practical importance for applications in batteries and super capacitors [11]. An interesting observation is the appearance of a single prominent oxidation/reduction peak for all pristine and composite electrolyte fibers, which is on account of NH_4^+ ion (±1.6V) that contributes to ionic conduction. These studies indicate improvement in electrochemical stability of nanocomposite electrolyte fibers in the presence of Al_2O_3 nano mineral particles. Optimum electrochemical window was observed to be from -2V to +1.5V for composite fibers containing 4 wt% Al_2O_3 filler.

CONDUCTIVITY STUDIES

Temperature dependence of electrical conductivity of pristine and composite electrolyte fiber mats is shown in figure 3. Ionic conductivity of PNCEF mats is seen to augment with rise of temperature and the behavior can be rationalized by recognizing free volume model [12]. According to the free volume model, when the temperature increases, the vibration energy of a chain segment is sufficient to push against the hydrostatic pressure imposed by its neighbours and create a small amount of space surrounding its own volume in which vibration motion can occur.

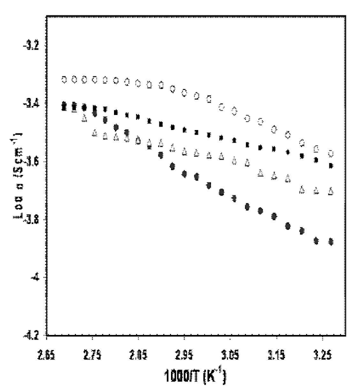

Fig. 3. Temperature dependence conductivity of nanocomposite polymer electrolyte fibers mat with (●) 0 wt.%, (△) 2 wt.%, (○) 4 wt.%, (■) 6 wt.% Al_2O_3 contents.

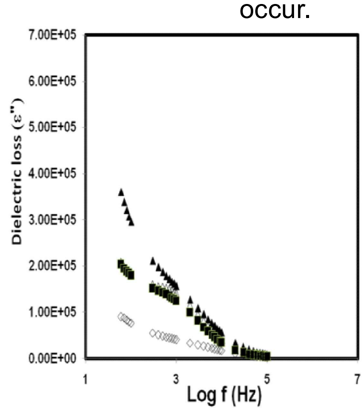

Fig. 4. Variation of dielectric loss (ε'') with frequency for composite polymer electrolyte fibers mat with (▲) 0 wt.%, (■) 2 wt.%, (△) 4 wt.%, (□) 6 wt.% Al_2O_3 contents.

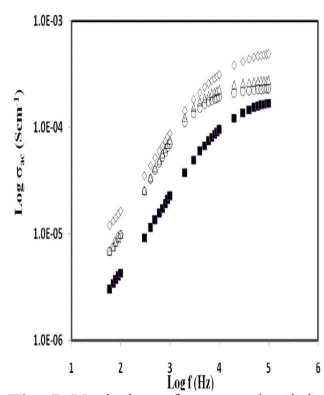

Fig. 5. Variation of a.c. conductivity with frequency for composite polymer electrolyte fibers mat containing (■) 0 wt.%, (○) 2 wt.%, (□) 4 wt.%, (△) 6 wt.% Al_2O_3 mineral particles.

This in turn positively affects the mobility of ion and polymer segments, resulting in rise of bulk conductivity. The amount of increase in conductivity thus depends upon the free volume around the polymer chain. Arrhenius and empirical Vogel-Tammam-Fulcher (VTF) relation have been successfully used to describe temperature dependence of ionic conductivity of polymeric system [13]. In the present experiment, low temperature behaviour is well described by Arrhenius relation while VTF relationship is seen to satisfy the high temperature (>55°C) behavior. Optimum rise in conductivity is observed for fibers loaded with 4 wt% Al_2O_3 and large changes take place in low temperature regime. Further, marginal drop in σ is apparent for samples containing 6 wt% Al_2O_3 possibly due to filler/salt segregation leading to change in morphology of system.

DIELECTRIC LOSS STUDIES

Ion association in a heterogeneous system like composite polymer electrolyte is directly related to the presence of dipoles due to solvent dipoles/ion pairs [6]. Dielectric relaxation and frequency dependent conductivity both being sensitive to motion of charged specie of dipolar polymer provide wealth of information on ion transport property of nanocomposite electrolyte under dynamical conditions. Figure 4 shows the variation of dielectric loss as a function of frequency for different loadings of Al_2O_3 in pristine electrolyte nanofibers. For all the curves in Figure 4 – a strong frequency dispersion in ε" was recorded in low frequency regime followed by a nearly frequency independent behavior in high frequency region – a feature described by most of the polymer electrolytes [7]. This feature is attributed to electrical relaxation or inability of fast rotation of dipoles, which creates a lag between frequency of oscillating dipoles and applied electric field. The ionic and orientational source of polarizability decreases with increase of frequency and finally disappears due to inertia of mobile ions to finally result in a constant value. Interestingly, low frequency dispersion in dielectric loss is seen to suppress down significantly with increase of Al_2O_3 loadings in pristine electrolyte fibers. This feature is in contrast to PEO:SiO_2:NH_4SCN composite system where it augments with rise of filler content [6]. Careful examination of Figure 4 shows appearance of a broadened peak symptomising the presence of scaling dipoles correlated to á relaxation of pristine electrolyte fiber. Broadening is possibly due to the presence of filler particles hindering the dipoles to ortent themselves freely in the direction of applied field. The relaxation peak for pristine electrolyte fiber is seen around 1.4 KHz frequency, which shifts to lower frequency with increases of filler content. This relaxation peak corresponds to á relaxation of composite electrolyte fiber.

A.C. CONDUCTIVITY

Fig. 5 shows the variation of A.C. conductivity of nanocomposite electrolyte fibers with frequency for different compositions of fiber mats. The values of A.C. conductivity were obtained with the help of dielectric permittivity (ε') and loss tangent (tanδ) data using the relation

$$\sigma_{ac} = \varepsilon' \varepsilon_o \omega \tan\delta \qquad \text{(ii)}$$

Where ε_o is the vacuum permittivity and ω the angular frequency. It is apparent from Fig. 5 that A.C. conductivity increases with frequency in the low frequency regime followed by a nearly frequency independent behavior. The increasing conductivity behavior is connected to the electrode-electrolyte phenomena i.e. it results from electrode polarization effects [6], while saturation like behavior results from the failure of hopping of ions from one site to another with increasing frequency. The over all A.C. conductivity can be best described by Jonscher's power law relation:

$$\sigma_{ac}(\omega) = \sigma_{dc} + A\omega^{p} \qquad \text{(iii)}$$

Where σ_{dc} is bulk d.c. conductivity, A the pre-exponential factor, p the fraction exponent and ù the angular frequency. This kind of behavior has been reported for wide range of nanocomposite polymer electrolytes [14]. In the present case, the exponent factor was found to be ~0.50 for pristine electrolyte and it increases to 0.59 for 4wt % Al_2O_3 loading. The observed frequency dispersion for different composite fibers can be rationalized with the help of jump relaxation model [6] since the dynamical effect of polymer host caused by segmental renewal rates, is less significant below microwave frequencies. According to this model, an ion can hop from a site to neighboring vacant site successfully to contribute to conductivity. At high frequencies the probability for ion to hop back increases due to short time periods. This forward-backward hopping at high frequencies together with relaxation of dynamic cage potential seems to be responsible for high frequency plateau.

CONCLUSIONS

XRD patterns exhibit broadening of diffraction patterns of composite electrolyte fibers on addition of Al_2O_3 nano mineral fillers suggesting improved amorphousness. Maximum absorption of nano mineral is found to be 4 wt%. Addition of Al_2O_3 nano filler provides electrochemical current stability to PVA electrolyte nanofibers and as well as broad electrochemical window. Temperature dependent study of conductivity response is described by combination of Arrhenius and VTF behavior. Presence of α relaxation has been evidenced in dielectric loss measurements. Jonscher power law best describes the A.C. conductivity response.

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Noise Survey and Noise Modelling of Open Cast Coal Mining Machineries - A Case Study in Indian Coal Mines

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ABSTRACT

Obtaining a suitable work environment for the labourer's is fundamental for attaining higher processing and benefit in both surface and underground mines. Noisy working conditions have negative consequences for the labourer's resolve and badly affect their wellbeing and execution. To survey the status of noise (noisy) levels in mines, various reports on noise reviews are required to be directed utilizing suitable statutory rules so that viable control measures might be taken in mines. Keeping this in view, this paper was embraced to do noise review in few open cast non coal and coal mines of Odisha. In this paper only one survey pertaining to one coal mine situated in the state of Odisha is reported.

INTRODUCTION

Noise is generated by almost all opencast mining operations from different fixed, mobile, and impulsive sources, thereby becoming an integral part of the mining environment. It is defined as sound without agreeable musical quality or as unwanted sound. In opencast mines, noise is a common environmental factor as generated by the heavy earthmoving machineries. The equipment and environment conditions continuously change as the mining activity progresses. Depending on their placement, the overall mining noise emanating from the mining equipment varies in quality and level. In opencast mines most of the mining machineries produce noise levels in the range of 90-115 dBA, exposure to which over long time can result in noise induced hearing loss and other non-auditory health effects in the miners. Hearing loss can impair the quality of life through a reduction in the ability to communicate with each other. Overall, it affects the general health of the human beings in accordance with the World Health Organization's (WHO) definition of human health. Hearing loss (HL) can be defined as "the decibel difference between a patient's thresholds of audibility and that for a person having normal hearing at a given frequency". In mining industry, hearing loss or hearing damage is considered as a serious health problem, as reported by various health organizations like the U.S. Environmental Protection Agency (USEPA), the National Institute for Occupational Safety and Health (NIOSH) and the WHO. In 1976, a study carried out by the National Institute for Occupational Safety and Health, for coal mining concluded that the coal miners had health conditions worse than the national mean and the hearing damage to coal miners were serious. The impacts of noise in opencast mines depend upon the sound power level (SPL) of the noise generators, prevailing geo-mining conditions, and the meteorological parameters of the mines. The noise levels need to be studied as an integrated effect of the above parameters. In mining conditions, the equipment conditions, and the environmental conditions continuously change as the mining activity progresses. Depending on their placement the overall mining noise emanating from the mines varies in quality and level.

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METHODOLOGY

Thus, for environmental noise prediction models, the noise level at any receiver point needs to be the resultant sound pressure level (SPL) of all the noise sources. The need for accurately predicting the level of noise emitted in opencast mines is well established. Some of the noise forecasting models used extensively in Europe are those of the German Draft Standard VDI-2714 Outdoor Sound Propagation, Conservation of Clean Air and Water in Europe (CONCAWE) and Environmental Noise Model (ENM) of Australia. These models are generally used to predict noise in petrochemical complexes and mines. These standards or algorithms were proposed in between 1970-1985. Out of these standards, some are not suitable to predict noise accurately as these standards do not take into consideration the attenuations factors such as ground effect, vegetation, barriers, industrial areas etc. To overcome this problem, International Standard Organization (ISO) proposed an empirical noise prediction model in 1996. The algorithm used in these models relied for a greater part on the interpolation of experimental data which is a valid and useful technique, but their applications are limited to sites which are more or less similar to those for which the experimental data were assimilated. In the empirical models, nearly all influences are taken into account even when they cannot be separately recognized. This is the main advantage of these models. However, the accuracy of these models depends on the accuracy of the measurements, similarities between the conditions where the noise attenuation is analyzed and the conditions where the measurements are carried out, and the statistical method that is used to make the empirical model. The deterministic models are based on the principles of physics of sound and therefore, can be applied in different conditions without affecting the accuracy. But their implementation usually requires a great database of meteorological characteristics such as atmospheric pressure, atmospheric temperature, humidity, wind and so on, which is nearly difficult to obtain. Hence, the implementation of the noise prediction models is usually restricted to the special area where the meteorological data can be available. All the noise prediction models treat noise as a function of distance, SPL, different forms of attenuations such as geometrical absorptions, barrier effects, ground topography, etc. Generally, these parameters are measured in the mines and best fitting models are applied to predict noise. Mathematical models are generally complex and cannot be implemented in real time systems. Additionally, they fail to predict the future parameters from current and past measurements. It has been seen that noise prediction is a non-stationary process and soft-computing techniques like Fuzzy systems (Mamdani Fuzzy Inference System, Takagi-Sugeno-Kang Fuzzy Inference System), Adaptive neural network-based fuzzy inference systems (ANFIS), Neural networks, Multi-layer Perceptron (MLP), Radial Basis Functions (RBF), Functional Link Artificial Neural Network (FLAN), Neural Fuzzy, PPN) etc. have been tested for non-stationary time-series.

NOISE MEASURING INSTRUMENTS

The most common instruments used for measuring noise are the sound level meter (SLM), the integrating sound level meter (ISLM), and the noise dosimeter. It is important that we should understand the calibration, operation and reading the instrument when in use. Table-1 provides some instrument selection guidelines.

Sound Level Meter (SLM)

A Sound level meter is the simplest instrument available to determine noise levels. The meter usually contains the following basic elements (Figure 1):

(1) A microphone to sense the sound-wave pressure and convert pressure fluctuations into an electrical voltage,
(2) An input amplifier to raise the electrical signal to a usable level,
(3) A weighting network to modify the frequency characteristics of the instruments,
(4) An output amplifier,
(5) A rectifier to determine the rms value, and
(6) An indicating instrument to display the measured sound level.

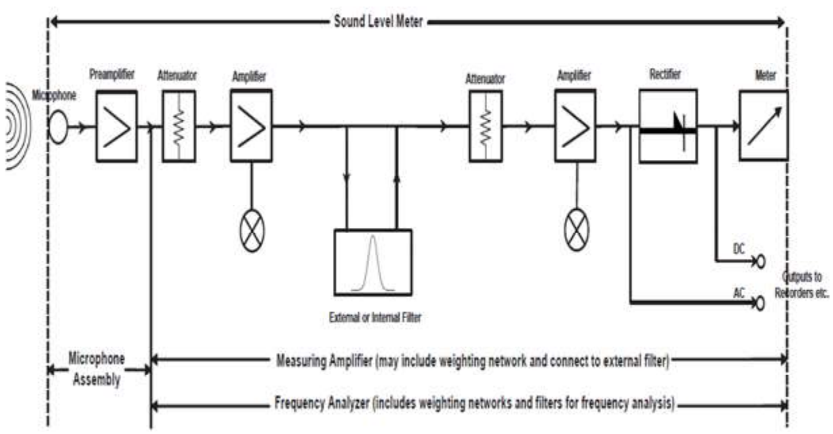

Figure 1: Circuit diagram of Sound Level Meter

The response of the meter and the characteristics of the indicating instrument depend significantly upon whether the instrument is of type 1, 2, or 3. The SLM must be calibrated before and after each use. With most SLMs, the readings can be taken on either SLOW or FAST response. The response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Workplace noise level measurements should be taken on SLOW response. Impulse characteristics and peak-hold features are sometimes provided as special features. To take measurements, the SLM should be held at arm's length at the ear height for those exposed to the noise. With most SLMs it does not matter exactly how the microphone is pointed at the noise source. The response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Workplace noise level measurements should be taken on SLOW response. A Type 2 SLM is sufficiently accurate for industrial field evaluations. The more accurate and much more expensive Type 1 SLMs are primarily used in engineering, laboratory, and research work. Any SLM that is less accurate than a Type 2 should not be used for workplace noise measurement. An A-weighting filter is generally built into all SLMs and can be switched ON or OFF. Some Type 2 SLMs provide measurements only in dB (A), meaning that the A-weighting filter is ON permanently. A standard SLM takes only instantaneous noise measurements (Figure 2). This is sufficient in workplaces with continuous noise levels. But in workplaces with impulse, intermittent or variable noise levels, the SLM makes it difficult to determine a person's average exposure to noise over a work shift. One solution in such workplaces is a noise dosimeter.

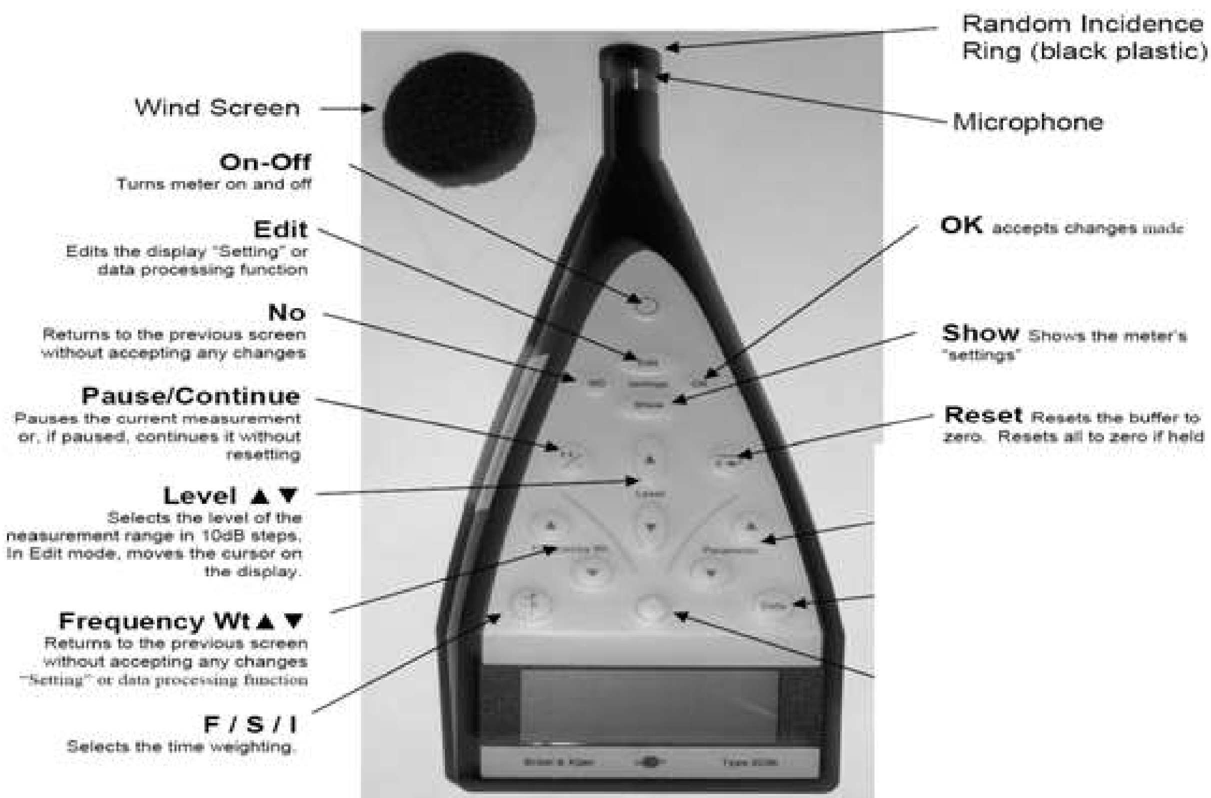

Figure 2: Sound Level Meter. B & K (2236-C Type)

Table 1: Guidelines for Instrument Selection

Type of Measurement	Appropriate Instruments (in order of preference)	Result	Comments
Personal noise Exposure	1) Dosimeter	Dose or equivalent sound level	Most accurate for personal noise exposures
	2) ISLM*	dB(A)	If the worker is mobile, it may be difficult to determine a personal exposure, unless work can be easily divided into defined activities.
	3) SLM**	dB(A)	If noise levels vary considerably, it is difficult to determine average exposure. Only useful when work can be easily divided into defined activities and noise levels are relatively stable all the time.
Noise levels generated by a particular source	1) SLM**	dB(A)	Measurement should be taken 1 to 3 metres from source (not directly at the source).
	2) ISLM**	Equivalent sound level dB(A)	Particularly useful if noise is highly variable; it can measure equivalent sound level over a short period of time (1 minute).
Noise survey	1)SLM	dB(A)	To produce noise map of an area; take measurements on a grid pattern.
	2) ISLM	Equivalent sound level dB (A)	For highly variable noise.
Impulse noise	1) Impulse SLM	Peak pressure dB(A)	To measure the peak of each impulse.
* SLM stands for Sound Level Meter ** ISLM stands for Integrating Sound Level Meter			

NOISE SURVEY

Many machines do not operate constantly or at a constant noise level. Exposure to noise varies due to mobility of workers, mobility of noise sources, variations in noise levels or a combination of these factors. Noise measurements should include maximum and minimum, SPLs produced in dB (A) in any survey & all noise levels less than 80 db (A) may be ignored. If the survey indicates that worker is exposed to noise >115db (A) then he should be provided with hearing protection.

A noise survey takes noise measurements throughout an entire mines or section to identify noisy areas. Noise surveys provide very useful information which enables us to identify:

- ❖ Areas where employees are likely to be exposed to harmful levels of noise and personal dosimetry may be needed,
- ❖ Machines and equipment which produce harmful levels of noise,
- ❖ ☐Employees who might be exposed to unacceptable noise levels, and
- ❖ ☐Noise control options to reduce noise exposure.

Noise survey is conducted in areas where noise exposure is likely to be hazardous. Noise level refers to the level of sound. A noise survey involves measuring noise level at selected locations throughout an entire mines or sections to identify noisy areas. This is usually done with a sound level meter (SLM). A reasonably accurate sketch showing the locations of workers and noisy machines is drawn. Noise level measurements are taken at a suitable number of positions around the area and are marked on the sketch. The more measurements are taken, the more accurate the survey. A noise map can be produced by drawing lines on the sketch between points of equal sound level. Noise survey maps, like that in Figure 3 provide very useful information by clearly identifying areas where there are noise hazards. The SLM must be calibrated before and after each use.

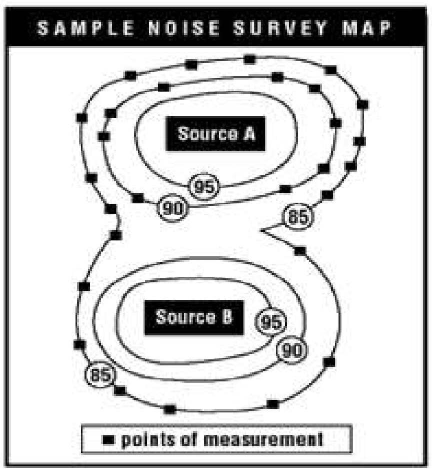

Figure 3: Sample noise survey map

NOISE STANDARDS/ GUIDELINES
Ambient Noise Standards

Noise (ambient standards) published in the Gazette No. 643 dt-26.12.89, succeeded by The Noise pollution (Regulation and Control) rules, 2000 (Gazette of India, vide SO123 (E), dated 14.2.2000 and subsequent amended vide SO 1046(E) dated, 22.11.2000) is given in Table 2.

Table 2: The Noise pollution (Regulation and Control) rules, 2000

Area Code	Category of Area	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 reckoned in between 6.00 am to 9.00p.m, Note 2: Night time reckoned in between 9.00p.m to 6.00am, Note 3: Silence zone is defined as areas up to 100 meter around such premises as Hospitals, Educational institutes, and Courts. The Silence zones are to be declared by the competent authority, Note 4: Mixed categories of areas should be declared as “one of the four above mentioned categories” by the Competent Authority and the corresponding standards shall be applied.

Work Place Noise Standards

DGMS Circular No.18 (Tech), 1975 A warning limit of 85-dB (A) may be set as the level below which very little risk to an unprotected ear of hearing impairment exists for an eight-hour exposure.

- ❖ The danger limit value shall be 90-dB (A) above which the danger of hearing impairment and deafness may result from an unprotected ear.
- ❖ A worker should not be allowed to enter, without appropriate ear protection, an area in which the noise level is 115-dB (A) or more.
- ❖ Personal protective equipment shall be worn, if there are single isolated outbursts of noise, which can go above 130-dB (A) “Impulse”, or 120-dB (A) “Fast”. ¨ No worker shall be allowed to enter an area where noise level exceeds 140-dB (A).

CASE STUDIES
Noise survey in Samaleshwari open cast project (OCP)

Original project of Samaleswari OCP was planned for 3 Mty capacities, which was sanctioned in August 1992. Subsequently, due to increase of coal demand from Ib-Valley Coalfield, the project was expanded to 4 Mty (Ph-I) and then 5 Mty (PH-II). Phase-III expansion to 7 Mty was approved in April 2007 annexing additional area. Phase-IV expansion of the project is proposed for incremental production of 5 Mty (Total of 12 Mty) to meet the increased demand of coal from the coalfield. It is proposed that about 0.61 km^2 area in the north of the approved OCP boundary and there by the barrier between Howrah-Mumbai railways line.

LOCATION MAP

Samaleswari OCP is located to the west of Hingir Rampur colliery in Jharsuguda district in the state of Odisha (Figure 4). It is situated between latitudes **210°47’- 210°49’** North and longitudes **830°53’- 830°55’**east as per survey of India toposheet.

Figure 4: Samaleswari OCP in Odisha map

Samaleswari OCP is well connected by road. A concrete road of about 2.5 km connects this mine to Brajrajnagar railway station situated in the west. It is approachable from Sambalpur via Jharsuguda by road. Sambalpur is located at a distance of about 70 km. Jharsuguda is the district head quarter and is situated about 20km away from Brajrajnagar.

FIELD VISIT & DATA COLLECTION

The field experiments were carried out at mechanized unit of Samaleswari Open Cast Project. The main noise sources at the projects were as follows: Surface miners, shovels, dumpers and dozers. The sound pressure levels of noise sources were taken at different distances of interval 1m from the source. In order to understand the noise effects on the workers' locations, management buildings and the areas in the vicinity of the mining and industrial plants, measuring of noise levels were carried out in Samaleswari OCP. The distances between the sources and the receivers at all locations were changed during the fieldwork. The noise level was measured at a height of 1.6 m from ground level, 1 m from walls and 2 m from crossing to avoid the earth reflection of the sound waves. An average of fifteen values of noise level of each source was taken. While, the sound pressure level was measured at different distances from the noise sources.

INSTRUMENTATIONS

The instrument used was a standard CEL -283 integrating impulse sound Level meter (U.K). It measured noise levels produced both near the source and the operator's level covering a range of 40 -120 dB (A) and had a selectable A/ Flat frequency characteristics. Fast slow time constants and impulsive response. Workplace noise level measurements were taken on SLOW response. The A-network was used in the present work, which approximates the human response.

RESULTS AND DISCUSSION

Results of predicted sound pressure levels of machineries at Samaleswari OCP are presented in the given Tables (3, 4, and 5) and Figures (5, 6, and 7). The maximum sound pressure level was found at rope shovel of 102 dB (A) & Dumpers of 103dB (A). During the field study it was observed that the workers engaged in loading and unloading operations were not equipped with ear plugs and ear muffs which can lead to hearing loss. So implementation of hearing protectors aid should be provided to the mine workers when exposed to harmful level of noise. Also, it can be seen that, the sound pressure levels were greater than that acceptable level (90 dBA).The measured noise level at the management building and the workshop area in Samaleswari OCP prove that the workers are suffering from high noise levels more than the acceptable levels.

Table 3: Simulation study of shovel noise

Distance from Source	Measured field data(dB)	K1	10 log $4\pi r^2$	K2	K3	K4	VDI (dB)	Avg % error
1	102.5	6.365	10.98	0.0065	0.0787	4.084	91.9458	
2	102	6.865	17.01	0.013	0.3	4.476	85.296	
3	98.5	10.365	20.55	0.019	0.629	4.15	81.747	
4	98	10.865	23.031	0.025	1.019	3.763	79.257	
5	97.5	11.365	24.96	0.032	1.428	3.356	77.319	
6	97.5	11.365	26.55	0.038	1.827	2.96	75.72	
7	96.5	12.365	27.89	0.045	2.197	2.592	74.371	
8	95	13.865	29.05	0.051	2.529	2.262	73.203	
9	93	15.865	30.07	0.058	2.822	1.971	72.174	
10	92.5	16.365	30.98	0.064	3.076	1.72	71.255	19%
11	91.5	17.365	31.81	0.071	3.297	1.501	70.416	
12	91.5	17.365	32.57	0.0774	3.486	1.315	69.6466	
13	91	17.865	33.26	0.0838	3.65	1.153	68.9482	
14	90.5	18.365	33.91	0.0908	3.79	1.015	68.2892	
15	89	19.865	34.51	0.0966	3.91	0.898	67.6804	
16	88.5	20.365	35.07	0.102	4.01	0.801	67.112	
17	88	20.865	35.59	0.109	4.11	0.703	66.583	

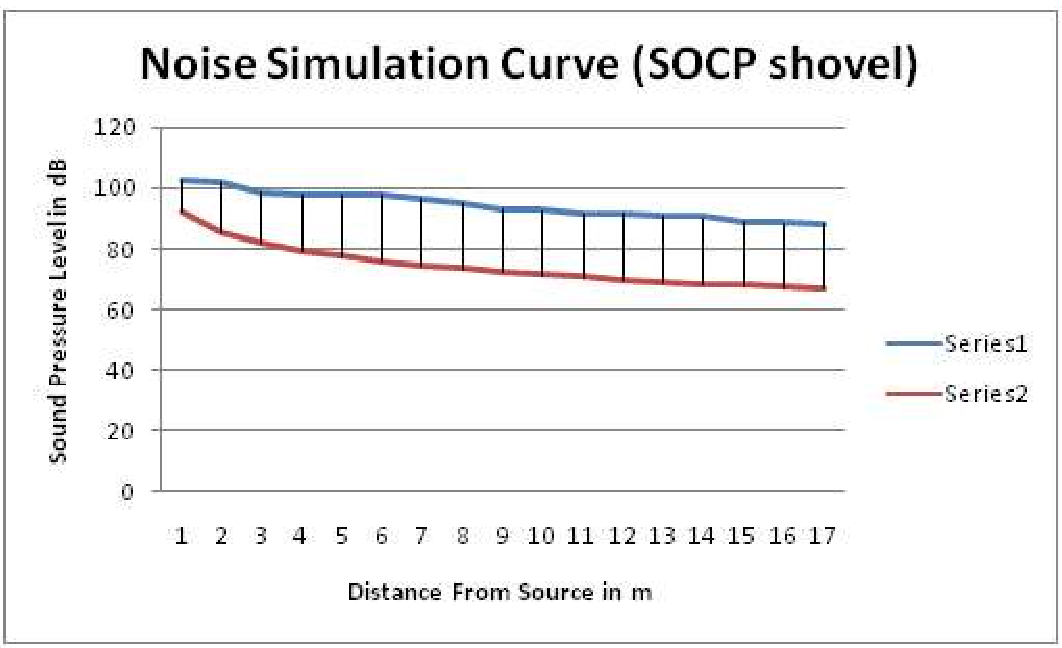

Figure 5: Noise simulation curve

Series 1= Measured data vs distance from the source

Series 2= Predicted data vs distance from the source

Table No 4: Simulation study of dozer noise

Distance from Source(m)	Measured field data	K1	10 log $4\pi r^2$	K2	K3	K4	VDI	Avg % error
1	100.5	6.955	10.98	0.0065	0.0787	4.084	90.5358	
2	100	7.455	17.01	0.013	0.3	4.476	83.886	
3	98	9.455	20.55	0.019	0.629	4.15	80.337	
4	97.5	9.955	23.031	0.025	1.019	3.763	77.847	
5	97	10.455	24.96	0.032	1.428	3.356	75.909	
6	95	12.455	26.55	0.038	1.827	2.96	74.31	
7	95	12.455	27.89	0.045	2.197	2.592	72.961	
8	93.5	13.955	29.05	0.051	2.529	2.262	71.793	20%
9	93.5	13.955	30.07	0.058	2.822	1.971	70.764	
10	92	15.455	30.98	0.064	3.076	1.72	69.845	
11	91.5	15.955	31.81	0.071	3.297	1.501	69.006	
12	89.5	17.955	32.57	0.0774	3.486	1.315	68.2366	
13	88.5	18.955	33.26	0.0838	3.65	1.153	67.5382	
14	88	19.455	33.91	0.0908	3.79	1.015	66.8792	
15	87.1	20.355	34.51	0.0966	3.91	0.898	66.2704	
16	87	20.455	35.07	0.102	4.01	0.801	65.702	
17	86.6	20.855	35.59	0.109	4.11	0.703	65.173	

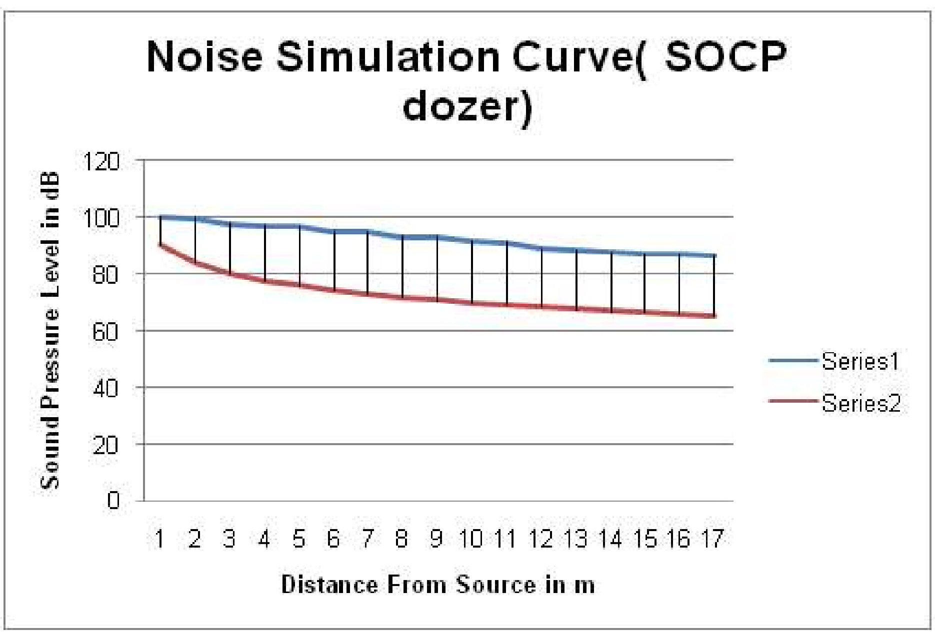

Figure 6: Noise simulation curve (SOCP dozer)
Series 1= Measured data vs. distance from the source
Series 2= Predicted data vs. distance from the source

Table 5: Simulation study of dumper noise

Distance from Source	Measured field data(dB)	K1	10 log 4πr2	K2	K3	K4	VDI(dB)	Avg % errors
1	102.4	5.78	10.98	0.0065	0.0787	4.084	91.2608	
2	101.2	6.98	17.01	0.013	0.3	4.476	84.611	
3	99.3	8.88	20.55	0.019	0.629	4.15	81.062	
4	98.4	9.78	23.031	0.025	1.019	3.763	78.572	
5	97.5	10.68	24.96	0.032	1.428	3.356	76.634	
6	95	13.18	26.55	0.038	1.827	2.96	75.035	
7	94.2	13.98	27.89	0.045	2.197	2.592	73.686	
8	93	15.18	29.05	0.051	2.529	2.262	72.518	20%
9	92.61	15.57	30.07	0.058	2.822	1.971	71.489	
10	90.9	17.28	30.98	0.064	3.076	1.72	70.57	
11	89.9	18.28	31.81	0.071	3.297	1.501	69.731	
12	88.5	19.68	32.57	0.0774	3.486	1.315	68.9616	
13	88.12	20.06	33.26	0.0838	3.65	1.153	68.2632	
14	87.4	20.78	33.91	0.0908	3.79	1.015	67.6042	
15	86.5	21.68	34.51	0.0966	3.91	0.898	66.9954	

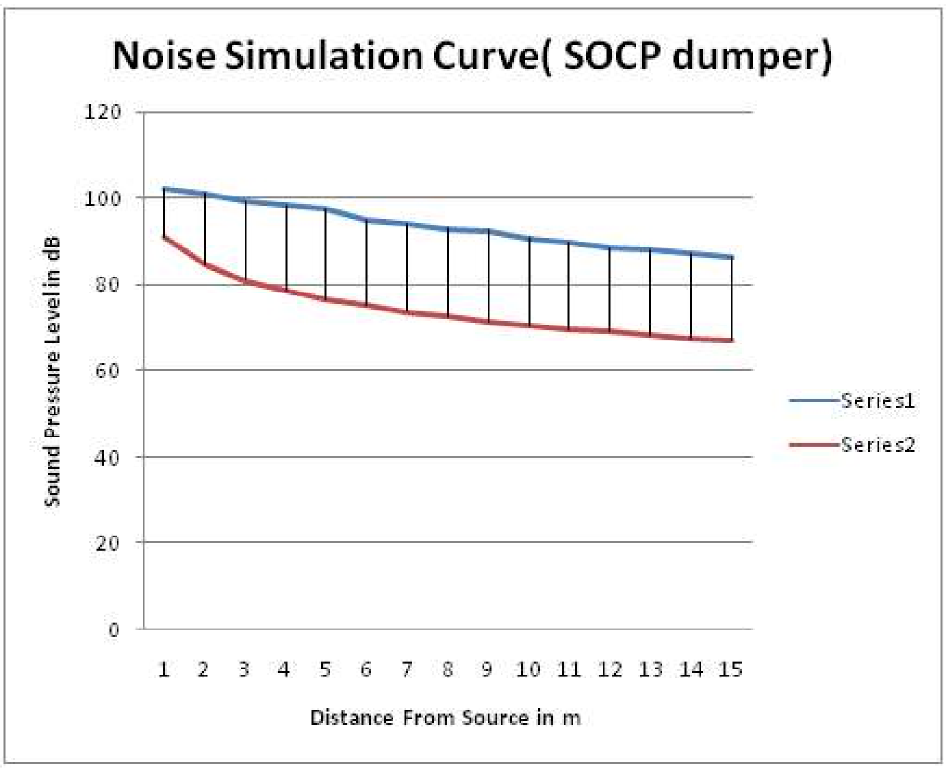

Figure 7: Noise simulation curve (SOCP dumper)
Series 1= Measured data vs. distance from the source
Series 2= Predicted data vs. distance from the source

CONCLUSION

Provision of suitable work environment for the workers is essential for achieving higher production and productivity in both opencast and underground mines. Noisy working condition has negative effects on the worker's morale and adversely affects their safety, health and performance. In order to assess the status of noise levels in mines, systematic illumination and noise surveys are needed to be conducted using appropriate statutory guidelines so that effective control measures can be taken up in mines. The results obtained indicated that the sound pressure levels of various machineries used in open cast coal mines of MCL were higher than the acceptable limits (>90dB (A)). Most of the mine workers were exposed to SPL (sound pressure level) beyond TLV (90dBA) due to machinery noise. Therefore, control measures should be adopted in mines for machinery as well as hearing protection aids should be supplied to the workers in order to protect the mine workers from NIHL (Noise induced hearing loss) & to keep the environment safe.

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Experiment with Hydroponic Vetiver for Management of Refinery Waste Water

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INTRODUCTION

Vetiver grass, scientifically known as *Chrisopogonzizanoides* has been found to have high potential for treatment of waste water. This has been used for treating waste water from various applications. Vetiver is being used for environmental management in many countries after Mr Paul Truong of Australia carried out some pioneering work (Truong, P.N. and Baker, D., 1997, 1998;Truong P. N., 1999). Vetiver grass has been used for environmental management in Indian mining industry for the first time in the iron ore mining sector (Pathak, K. 2012, Pathak et al. 2012). However, there is no enough literature of its use in managing effluents of petroleum refinery. A refinery has number of locations releasing waste water of different contaminants. Besides other the waste water has oil contamination as well as other elements along with N, P, K which supports algal bloom and therefore effluents from refinery released as it may cause environmental problems in the neighborhood. In management of petroleum refinery waste water two aspects are important. The oil in the water need to be contained and the TDS, TSS and conductivity should be reduced as much as possible. The oil films or even oil shin in the released water may create a public concern and therefore any refinery must plan for adequate treatment of the waste water.

To this end Bongaigaon refinery has been so far managing well with an eco-pond that retains the waste water and eliminates the volatile and aromatic contaminants by aeration and settling time management. However, occasional release of oil with water and dissolved and suspended particles are not totally eliminated.

The present paper reveals the results of a study carried out jointly by Mining Engineering Department, IIT Kharagpur and Environment and Safety Divison of BGR, IOCL to investigate the possibility of using hydroponic vetiver as oil trap and as an agent for consuming N,P,K along with testing the survival of the grass under the varying concentrations of different contaminants.

EXPERIMENTS AND DATA ACQUISITION

The approach of the study carried out is shown in Figure 1. The experiments were carried out in two phases during 2013-14. During the first phase of the study, vetiver grass was procured and a nursery was established near the eco-pond of BGR. Different types of low cost raft were designed and hydroponic vetiver was established (Figure 2). The survival and growth of the vetiver system was monitored and encouraged by the observed results, number of vetiver rafts were increased to create a vetiver barrier in the eco-pond. Oil was found to be trapped by the vetiver. The vetiver roots were found to be competing with the adverse conditions and the roots grew faster under more oil in water situations.

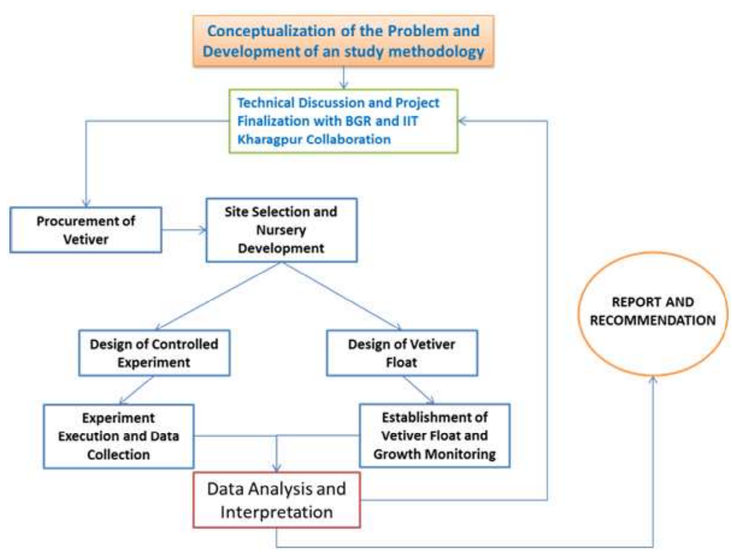

Figure 1: Approach of the Investigative study

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Figure 2: Vetiver nursery development and design of floats

Controlled experiments were also designed to observe the growth of vetiver under different salt concentrations. Figure 3 shows the experimental tanks in which the controlled experiments were carried out.

Figure 3: Experimental Tanks for study of hydroponic vetiver

In the 2nd phase of investigations, controlled experiments were designed and systematic sampling was carried out to study the behavior of vetiver under prevailing conditions. The uptake capacity of vetiver for N, P, K was studied by measuring periodically the concentrations of these elements in the sample water taken from tanks where vetiver grass was planted on raft. The water samples were also tested for other elements.

The roots and shoots of the vetiver grown in refinery waste water were tested for determining the heavy metal contents in them. The relative percentage of heavy metals in roots and shoots were determined. The same were compared with the soil grown vetiver.

OBSERVATIONS AND RESULTS

The study reveals that the vetiver floats can be used for trapping oil in the refinery waste water. The plants perhaps do not uptake oil, however oil get trapped around the network of roots. With more oil in water the roots grow faster and effectively retain the oil. The oil trapped roots may be harvested and the vetiver will further grow and serve. Figure 4 shows the survival of vetiver in the waste water and works as oil trap.

Figure 4: Survival of vetiver in refinery waste water and its function as oil trap

The dissolved solids get reduced and the heavy metals are fixed into the roots of vetiver. However, for quantification of this and evaluation of the performance further research with systematic sampling and testing of samples and analyzing the results with meteorological data will be necessary.

The oil accumulated in front of vetiver floats should be cleaned by adequate method. IIT Kharagpur has developed a oil cleaning broom which could be effectively deployed to sweep the oil and dissolving the same into a solvent developed for this purpose.

The waste water in the pond is mixture of waste water from different units of the refinery. How the waste water of different units affect the hydroponic vetiver was studied by planting vetiver in experimental tanks and the results showing the growth responses of roots and shoots are shown in Figure 5 and Figure 6 respectively.

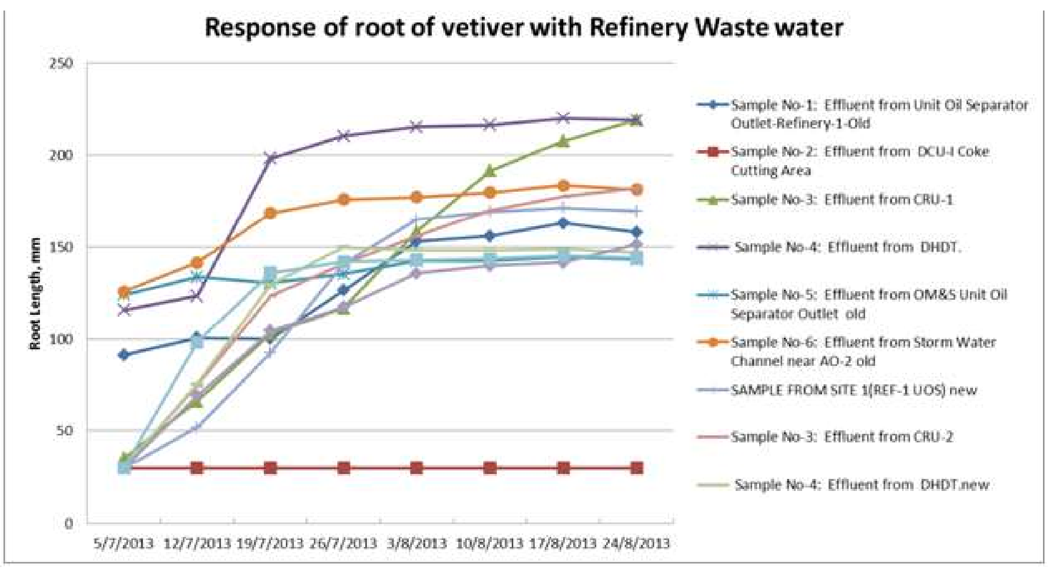

Figure 5: Weekly growth response of vetiver root with refinery waste water

It was observed that the increase in root length of vetiver is much faster compared to increase in shoot length in effluent water of refinery. The roots trapped the oil in water and it did not affect its survival. It was observed that when there was higher concentration of oil in water, the root length increased faster. However, more experiments will be necessary to quantify and to prove this behavior.

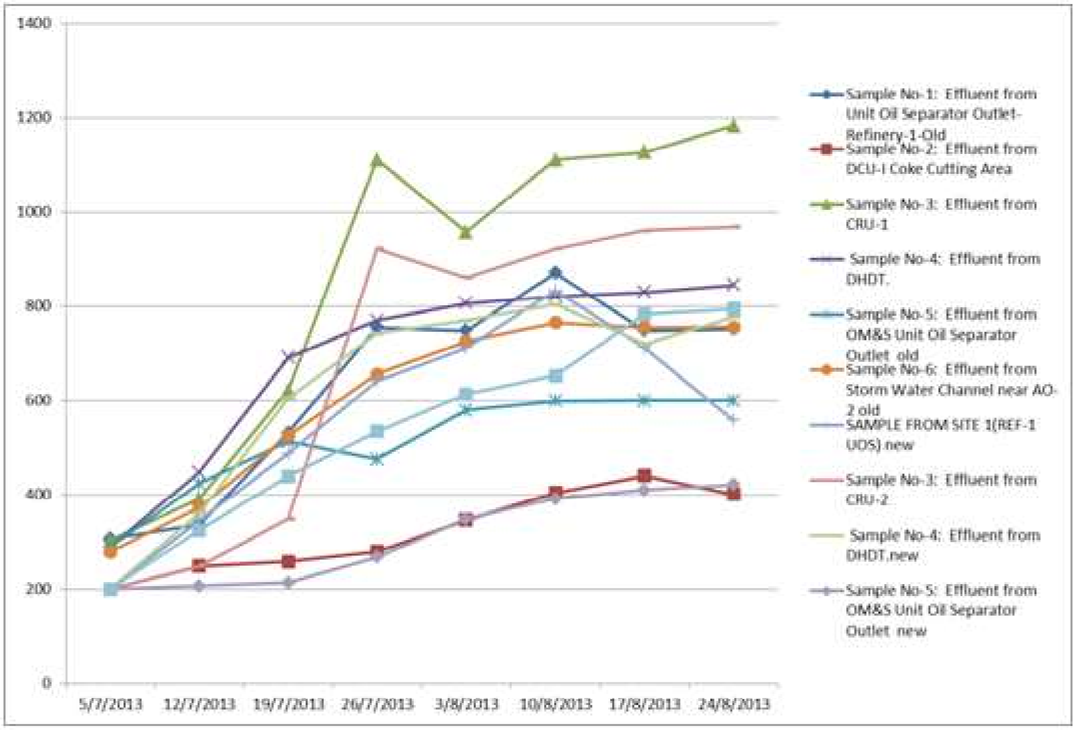

Figure 6: Response of vetiver shoot to refinery waste water

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were derived from the study:

1. Vetiver grass responds well to the mixed effluents of refinery waste water.

2. The effluent from DCU-4 coke cutting area does not support growth of vetiver roots.

3. The shoot growth was minimal in the effluents from coke cutting area as well as OM&S unit oil separator outlet.

4. Vetiver float can be used in the waste water drains. However, when the flow rates are high, the oil contaminants spoil the stems and the vetiver growth is affected.

5. The increase in root length of vetiver is much faster compared to increase in shoot length in effluent water of refinery. The percentage increase in root length was 61.98% after 7 days while that for shoot length was 41.36%.After a duration of 35 days the % increase in root and shoot was 81.57% and 76.58% respectively.

6. The root showed vigorous growth of the first 14 days with increase from 61.98% to 69.02% and 69.02% to 77.55%.However later on the growth rate slowed down with % increase of 81.18% and 81.57% within duration of 28 days to 35 days respectively.

7. the growth rate for shoot was vigorous for first 14 days with increase from 41.36% to 62.05%.However later on the growth almost became steady with % increase of 72.25%, 75.54%, 76.59% within a duration of 21, 28, 35 days respectively.

8. Second phase of experiments proved that the average root lengths gradually increase upto 35 days, after which there is a slight decrease in their lengths, following which it again increases. The time when the average decrease is observed, there are more number of new small roots have come up, which brings down the average length.

9. Both the root and shoot lengths increase with time with a faster rate at the beginning and then slow down with more new roots and shoots growing. The total mass has not been measured which could be an

increasing function with time. The possible cause of reduced growth rate after initial fast growth period may be uptake of nutrients from the effluent water as well as accumulation of metals in the roots. Further detailed investigations will be necessary to confirm this.

10. It was observed that the same root has not grown equally in each week. Average length did not grow but more new roots appeared in some weeks, the average length even became shorter than the previous week at times. In general it was confirmed that different roots grow differently, i.e. root growths are not uniform, and there is competition amongst them.

It is recommended that vetiver should be planted at least five rows in Pond 1 and 3 rows in Pond 2 of BGR and the trapped oil should be swept by developing appropriate means. Detailed bacteriological study and identification of organic pollutants in the waste water was not within the scope of the present work. It is recommended that such study should be initiated and reclamation of waste water should be implemented.

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