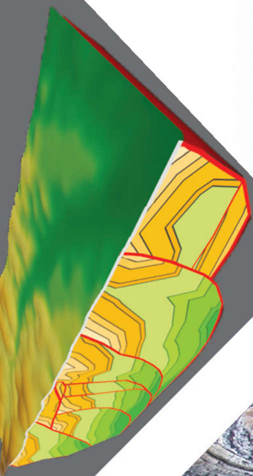

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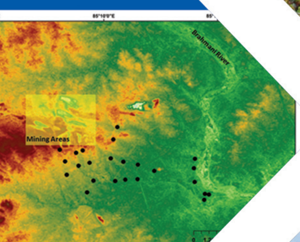
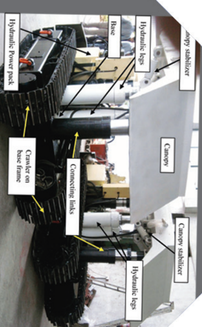
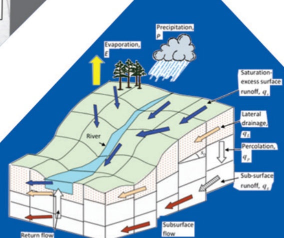
July-September 2019

A special issue on Mining Geology and Geotechnology



MGMI
News Journal
A Quarterly Publication





The Mining, Geological and
Metallurgical Institute of India

MGMI COUNCIL FOR 2018-19

CONTENTS

President's Message

Dear Members,

I hope, you are keeping well with your health and family.

You perhaps know that through this coloumn, I have conveyed to you all that the 8th Asian Mining Congress and International Mining Exhibition (IME, 2019) will be held during November, 6 – 9 at Kolkata. The preparation of the forthcoming 8th Asian Mining Congress is going on well and I hope, all the members of MGMI will take keen interest for success of the event in a big way.

All of you are aware that MGMI, the oldest Professional Institute in India is also the richest as far as the Geosciences knowledge bank of the country is concerned. The growth track of our country depends on the mineral sector. To affirm the energy security for the country, the role of MGMI is of paramount importance. Understanding the need of the hour, I wish to dedicate the services of MGMI for the National growth of our country. The country is now going through new challenges of economic growth with an ambitious target and complex business situation. Raw materials supply chain will be performing a crucial role in near future and the domain expertise of our Institution will be serving the planners of the Nation.

To meet the requirements of Mineral Sector of our country, and to fulfil the need and make it more vibrant as well as effective organization, the four Vice Presidents and their team will decide the services for the sector in their field.

I am honoured to have the opportunity of working for MGMI as President for the betterment of our country's growth path. I believe that honourable members of this distinguished institute will join hands together to make it a professional body of outstanding excellence contributing to the cause of development of Mining Engineering, Geological sciences and Metallurgical engineering, so essential for national economic development and growth.

I am happy to note that our News Journal in its recent issues has been highlighting important aspects of Mining, Metallurgical and Geological issues like future with Lithium and Graphite's future, water resource management, bulk material handling, emergence of e-maintenance. This issue with Associate editor is trying to encourage our esteemed members to participate in Geotechnical problem solving that our country needs.

With best wishes for the Autumn Festivities,

Anil Kumar Jha
President, MGMI

From the desk of Editor-in-Chief

Our sincere thanks go to Dr AK Singh, the Guest Editor of this Autumn issue, for his kind consent and working for bringing articles related to Geology and Geo-technology related to mining industry.

It is well known that mine planning and design is not like designing a machine or a power station. The basic inputs of geotechnical information based on which the mining operations and facilities are planned often found uncertain if adequate care is not taken during their acquisition. There are hardly any guidelines to establish quality of data and geotechnical models. The statistically established confidence level may be quite low if the accuracy of the data used for estimating are uncertain. Slope design, pillar design, support design are related to the reserve and resource occurrences and orientations. The dynamic changes in the stress levels as mining progresses under specific condition require careful studies. For such studies, the confidence level of data is important. Geotechnical data acquisition, archiving, analyzing and updating are indispensable in any mining venture. As a project moves from conceptual to operations through a series of studies and designing, the geotechnical data needs become more critical, thus data acquisition and analysis may become more skill demanding. Geotechnical characterization at the project planning stage should be refined by mine scale geotechnical data and a consistent updated database is necessary for developing an essential dynamic 3D model, which is capable of incorporating continuous changes under the mining operations. The geotechnical model required for mining include geological model, structural model, hydrogeological model and rock mass model. Reduction in uncertainties of the geotechnical models can reduce the risk of slope failure in mines or any other ground control related disasters.

At every stage of mining geotechnical information must be acquired and analysed. Therefore, at the mining level a separate cadre for Geotechnical Engineers with expertise of mining and Geo-mechanics must be created and deployed. This initiative of cadre creation is immediately called for avoiding future geo-mechanical hazards especially for deeper surface mining, where, mining of high stripping ratio mines, operating with space constraints, increased overburden handling and accessing difficult reserve under geological disturbances are witnessed. Economic consequences of slope failure, structural failure or geotechnical hazards of Indian mines are not estimated by the planners. Required research in this area is neither adequately taken up by the administration of scientific studies and R&D activities for mining and mineral development in India, nor had resulted any significant outcome.

We must change our strategy of geotechnical safety management. Regulatory compliance management through documentation alone will not prevent our geotechnical hazards. It is unrealistic to hope the complete elimination of safety and economic risk in mining, which however can be managed through engineering and procedural controls that are established through systematic data driven geotechnical analysis and engineering.

We should consider development of a Mining Geotechnical Data Repository within the mining companies along with the creation of geotechnical cadre for mining. Mere teaching rock mechanics in institutions or opening up new disciplines for post graduate degree will not serve the purpose of our industry or for the development of the Nation. If the industry does not come out with appropriate policy, the attempts of our institutions to develop skilled graduates will contribute only to brain drain and benefit the developed countries.

A myth regarding mining is that it is a hazardous profession, that may not be true as number of accidents and death are much less in mining compared to road transport or civil construction work. However, it is true that mining is dirty job as it affects the environment adversely if enough environment friendly measures are not initiated. For environmentally friendly mining, it is important that the mine planning and design takes lot of scientific investigation and research prior to mine planning and during monitoring of the execution of the planned design. The planners and operators need a consistent and interactive relationship through out the mining life cycle. Planning inputs for mine planning and design are often inadequate and number of assumptions are essential in every planning. A flexibility of certain extent is essential in every design so that as and when adequate information are established during the actual operations in the mine, the necessary modifications/alterations in planning and design can be incorporated.

Indian academic and Universities, R&D institutions have hardly participated in mine planning and design. Out of the 593 coal mines (as on 2016), not a single one has got participation of academic research in planning and design. The R&D activities of coal mining is also under the management of CMPDIL, and so far only few institutions have participated in carrying out research projects. The major scientific community is outside the mining research and scientific study related activities. As a result, most of our mining is lagging behind in inducting advanced technology through research. Technology introduction becomes vendor driven in many occasions. The training and development in Indian coal mining is also far from being world class. The vocational training centers in mines may also need systematic evaluation and upgradation. The staff training college kept under CMPDIL and the IICM also are trying but no significant changes through such training are visible. Academic institutions are offering training without any accountability. Most of the short term courses are of generalized lectures and the trainees leave without any doable new assignments in their hands other than being enlightened in the recent advances and with little motivation to do something new, which they often cannot take up due to lack of necessary environment in their workplace.

Under these scenarios we will have to prepare ourselves for greater challenges in addressing future geo-mechanical problems in the mines. Many dumps do not have necessary information for assessing their risks, many mines do not have adequate lands for making it safer, country does not have infrastructure to provide tailor made machines for site specific operations and the manufacturing sector in India are not growing particularly to provide necessary support for mining machinery. Indigenous monitoring instruments are not being developed. The core competency areas of the mining companies are outsourced through planning mines for outsourcing. The delay in mining project execution is never looked as planning deficiency, but as an operational problem. Mining financial performance is merely a presentation of prevailing data. Financial analysis by expert institutions are seldom carried out. Expertise enhancement of the planning executives through challenging tasks in association with world known experts are also limited. The few experts in planning are kept always overloaded.

The quality of life in an around mining is not attracting ambitious and dynamic youth to serve the Indian coal mining industry. As a result, there is a degeneration of expertise base that post nationalization mining industry started developing. It will be prudent to introduce fly-in and fly-out concept for expert executives to work in the remote mining areas. It may be pragmatic to take a stock of the central workshops and maintenance bases of the mines and areas, resilience level of the mines in case of disruption of service providers (within how many days a mine will be able to resume production level if at any time the outsourcing agencies try to interrupt operations). Every mine should check if it has properly developed job profiles of its employees. It should keep its job safety analysis reports published periodically. Every mine should have its site severity map. Every mine must have a supporting geomechanical or geotechnical experts to keep monthly update of its geotechnical risks. At mine level GIS based mine monitoring system must be established.

We are hopeful that our esteemed members will be contributing to reshaping the future of Indian mining industry. We look forward to your active participation in this news journal and we wish through your participation we can look forward to making this a monthly journal to address various issues. We are planning our next issue to be focusing on Mine Closure and Post Mining Liabilities. I request all of you to send us your experienced comments, letter to editor, case studies or technical papers for the special 2019 Winter Issue of MGMI News Journal.

With Autumn's Greetings

Dr Khanindra Pathak
Prof IIT, Kharagpur

"Mining asteroids will ultimately benefit humanity on and off the Earth in a multitude of ways."
Peter Diamandis

THE GUEST EDITOR'S COLUMN...............

It is my privilege to edit this special issue of MGMI News Journal on Geology and Geomechanics for the Mining and Mineral Industry. This special issue reflects the state-of-the-art and knowledge base of the research, development and demonstration (RD&D) phases in the Indian industry. The goal of this special issue was to bring to the fore some high-quality developments that could be adequately enhanced by industry-academia partnership, where we hope the MGMI can play a critical role.

When bringing out this special issue, our aim has been to keep in line with the advancements that are occurring in the global research landscape. Accordingly, the role of geoscience in adhering to the United Nations Sustainable Development Goals (SDGs) has been identified by leading voices in the following realms (Gill, J.C., Episodes, 2017, 40, 70-76) :

- Access to clean drinking water
- Food security and agro-geology
- Disaster risk reduction
- Energy supply and management
- Improved infrastructure and access to basic services
- Environmental and biodiversity management

For the supporting institutions of MGMI, identifying some of the critical challenges is necessary to set the tone for future research. As a result, we invited some distinguished experts to reflect on where they feel the field may be headed. In his perspective piece, Dr TN Singh, Former Director, Central Mining Research Institute, comments on the need to properly navigate the coal and non-coal mining spheres to encourage safer mining practices. In doing so, he concludes with a call for action for enhanced integration of geo and rock mechanics which will have reverberating impacts on sustainable mining as well as miners' safety.

In the next article, Dr U Saravana Kumar from the International Atomic Energy Agency (IAEA) and his colleagues talk about the issues of hydrogeology and groundwater management as arising due to mining activities. This closely intersects with the SDG on clean water and sanitation, and highlights why water-energy nexus issues need well though-out strategies at the local level. This also brings interesting challenges to the chemical and environmental engineering colleagues for water management practices in regions which have traditionally been highly water stressed. For instance, could new industrial ecology mechanisms be established by reuse of produced waters or mine waters for serving the society?

The third article by Dr Rajendra Singh from the CSIR-Central Institute of Mining and Fuel Research (CSIR-CIMFR) discuss some novel model techniques for safe and efficient mining practices and modeling techniques. Again, this paper demonstrates the role locally-targeted R&D practices could play in establishing sustainable solutions to the Indian mining industry. It is noteworthy that their group also published the underlying results in leading earth-science journals, which indicates an understanding by leaders in research to account for "think global, act local".

The fourth article by Prof UK Singh et al discusses their innovation for depillaring operation in coal mines. This work demonstrates a frontier in industry-academia interaction for a novel design which has been recently approved by the Directorate General of Mines Safety (DGMS). This initiative projects savings of Rs. 25,000 per slice by enhancing efficient use of manpower and resources.

Finally, the fifth article by Dr Archana Deodhar and her colleagues from the Bhabha Atomic Research Centre (BARC) again lays focus to the groundwater recharge and monitoring in mining-intensive regions. As with the earlier article, it is a positive step for MGMI publications to place a higher impetus on water management and also interface with leaders in the atomic energy agencies to broaden our perspective with respect to environmental management.

In all these interesting articles, the authors have tried to focus on geoscientific innovations and contributions that may help in delivering greater benefits to the society. In fact, a recent article points out to the relevance of the geosciences in attaining what may be the most critical challenge of our times – climate change mitigation (Stephenson, MH *et al, Petroleum Geoscience,* 2019, doi.org/10.1144/petgeo2019-084). This is important from the perspective of geologic sequestration of CO_2 deemed necessary for emissions reduction as well as initiating negative emission technologies for attaining the goals of the Paris Agreement. On another note, technologies such as compressed air energy storage are likely pivotal in sustainable electricity storage to make energy systems compatible with the Government of India's ambitious low-carbon growth strategies.

The publications of the MGMI have been designed as a mechanism to accelerate interactions with the Institute's 2200 strong membership. Therefore, it is our hope that the members will see these forums as a two-way communication medium, and help us think of novel RD&D pathways that we could focus on. The additions from BARC and IAEA colleagues depict two such illustrative pathways. It is noteworthy that the Geological Society of London organized a conference in January on the role of geosciences in decarbonization. Thus, this may very well may be avenue for discussion on such issues to have a more directed focus on global climate interactions.

I thank the authors for sparing their valuable time to contribute these thoughtful articles to this periodical. I am also grateful to the MGMI Council, Editor-in-Chief Prof. Khanindra Pathak and other editorial board members for this opportunity to edit this special issue.

Ajay Kumar Singh

Former Scientist and Head Methane Emission and Degasification CSIR-Central Institute of Mining and Fuel Research, Email : ajay.cimfr@gmail.com

KNOW YOUR ASSOCIATE EDITOR

Dr Ajay Kumar Singh was formerly a scientist at the CSIR-Central Institute of Mining and Fuel Research, Dhanbad, India. He headed the Methane Emission and Degasification Division at CSIR-CIMFR for a period of almost two decades, during which he initiated a number of new research areas within the department. Dr. Singh has led 100+ projects as Project Leader/Coordinator on diverse areas such as estimation of fugitive methane estimation from coal mines in India, coalbed methane potentiality studies, underground coal gasification and carbon sequestration. These grants have been funded by the UNDP, US EPA, various ministries of Government of India, and almost all major coal/petroleum companies in India. He is a Lead Author for three reports of the Intergovernmental Panel on Climate Change (IPCC). Ajay has also led the chapters for fugitive methane emission in four communications of the Government of India to the UNFCCC, as well as in the Indian Network on Climate Change Assessment. The emission factors developed with his expertise for underground coal mining have featured in the IPCC Emission Factor Database. He has guided and is currently guiding several doctoral and masters students. He obtained his PhD degree from IIT Kanpur in 1991. His book on Coalbed Methane in India : Opportunities, Issues and Challenges for Recovery and Utilization, has been recently published by Springer.

PHOTO GALLERY

Shri Anil Kumar Jha, President MGMI & Chairman, Coal India Ltd, interacting with the reporters

PRESS CONFERENCE
AUGUST 23, 2019
at The Oberoi Grand,
Kolkata

Shri Rajiw Lochan, Honorary Secretary, MGMI welcoming Dignitaries, Guests & Reporters

Mr Andrew Ford, Australian Consulate - General Kolkata interview with the Reporters

Shri PK Sinha, CMD, NCL, facing interview with the Reporters

View of the Dignitaries, Guest and Reporters listening and noting

PHOTO GALLERY

61st Holland Memorial Lecture
September 24, 2019
at hotel Le Meridien, New Delhi

Lighting of the lamp for 61st Holland Memorial Lecture

Shri Amitabh Kant, IAS, CEO, NITI Aayog delivering the 61st Holland Memorial Lecture

Shri NC Jha, Past President, MGMI along with Shri Rajiw Lochan, Hony Secretary, MGMI, Shri PR Mandal, Chairman, MGMI Delhi Chapter, Shri U Kumar, Past President, MGMI presenting memento to Shri Amitabh Kant

Address by Shri U Kumar, Past President, MGMI

Shri NN Gautam, Special Secretary (Events), MGMI Delhi Chapter addressing the audience

Adieu to our another Doyen of Indian Mining, Mineral and Geology Fraternity...........

Samir Kumar Ghosh *(26th March 1938-17th July 2019)*

Samir Kumar Ghosh, a Life Member (5293-LM, 1988-89) and existing HonoraryTreasurer of MGMI passed away on 17th July 2019 at about 4.00 a.m., at AMRI Hospital, Dhakuria, Kolkata.

Samir Kumar Ghosh was born on 26th March 1938. Graduated in Science (Metallurgy) from Calcutta University in 1957. Initially, he worked for M/s Indian Aluminum Company Ltd., for five and half years. He worked 31 years for Hindustan Copper Ltd., Ghatshila in various capacities in Rolling Mills, Smelter, Flash Smelter and in Pollution Control Projects. He rose to the rank of Manager (Metallurgy) in HCL. After retirement he worked for around 4 years as Technical Consultant for a Pvt. Company, executing the modernization of Hot Strip Mill of Bokaro Steel Plant. He was trained for flash Smelter abroad by HCL/ICC. He was Council Member of MGMI from 1996-99. He was an active member of the Institute in all occasions held by the Institute including the biennial Asian Mining Congress and Exhibition. He was successfully organizing MGMI President's Cup Golf Tournament since 1995 as Co-convener. He was a Life Member of The Indian Golfing Union.

He was the Honorary Secretary of Indian Institute of Metals, Kolkata Chapter for the last 4 years.

Late Ghosh had a very amiable personality. He was very much approachable by one and all. He is remembered for his smiling personality. He will be deeply missed by his family, friends and all members of MGMI.

With heartfelt grief the MGMI Members wishes his soul to rest in peace in his heavenly abode. May Almighty give strength to his surviving family members and to bear the loss.

He has left behind his wife, a son and a daughter.

May he be in eternal peace in his heavenly abode……

CHAPTER ACTIVITIES

Delhi Chapter

MGMI Delhi Chapter organized 7th Round Table Conference, jointly with IEF & ISMAA DC on 24th September 2019. The Conference was inaugurated by Shri Pralhad Joshi, Honourable Minister for Coal, Mines and Parliamentary Affairs who was the Chief Guest of the conference. Shri SC Garg, Secretary Power, Secretary Coal (represented by Advisor, Projects, MOC) were Guests of Honour. Shri Anil Kumar Jha, President, MGMI and Chairman, Coal India Ltd. was to attend the events but he could not able to attend due to some unforeseen situation on the day. Shri Rakesh Kumar, CMD, Neyveli Lignite Corporation Ltd also attended the event. Shri Kirith Parikh, former Member Planning Commission was the Chief Guest at the Valedictory Session of the Conference.

At the evening Shri Amitabh Kant, CEO, NITI Aayog delivered a very informative and illuminating, 61st Sir Holland Memorial Lecture.

The Conference was attended by well over 150 distinguished guests, delegates, members and the members of the Media.

APPEAL
TO ALL THE CHAPTERS OF MGMI

Number of MGMI Chapters had a glorious past! Many of them had witnessed the birth and growth of mining around their areas. However, we are not getting their reports of activities to let our members to read and learn.

Our President Mr Anil Kumar Jha always encourages MGMI to compile a mining history of our country. We look forward to taking actions for it. For this purpose I request every Chapter of MGMI to send us names of five persons who can contribute to a discussion group to formulate a project proposal and workplan to compile a MGMI Publication : Contemporary HISTORY OF MINING IN INDIA.

Please forward your suggestions to the email id : office@mgmiindia.in

ANNOUNCEMENT
Special Issue of MGMI News Journal

The next issue of the News Journal ***(Vol 45, No. 2, October-December-2019)*** *will highlight issues related to Mine Closure and Post Mining Liabilities. All the esteemed members are requested to contribute technical notes/letters to the editor or from down the memory lane issues related to mine closure managgement and regulatory controls. Companies willing to advertise their achievements in mine closure initiatives through this issue are requested to contat MGMI HQ at office@mgmiindia.in.*

NEW MEMBERS

(As approved in Council Meeting on 27. 07. 2019)

AS LIFE MEMBER

10817-LM, Dr Arup Kumar Mandal, PhD (Metallurgy), BE (Met), Asstt. Professor (Gr.1), NIT Durgapur, Department of Metallurgical and Materials Engineering, Durgapur – 713209 (West Bengal), Ph : 9434788110(O), 9532023931(R), E-mail : arup.mandal@mme.nitdgp.ac.in,arup9180@yahoo.co.in

10818 - LM, Shri Narendra Prasad Pramanik, B.Tech (Hons) Min. Adv Dip in MGT, General Manager (P&D) SAIL, Raw Material Division, Block – 4, Flat – 403, Ganga Jamuna Enclave, Botanda, Sundarpada, Bhubaneswar – 754002, Ph : 9437078160, 9620876694 E-mail : nppramanik2011@gmail.com

10819-LM, Shri Satish Jha, BE (Min) M.Tech (IEM), General Manager (Corporate Planning), Northern Coalfields Limited, D/14, Amlohri Colliery, P.O. Amlohri, Dist. Singrauli, Madhya Pradesh – 486887, Ph : 07805-266674 (O) 9009200504, Mobile : 9406711702 E-mail : satish67jha@gmail.com

AS ASSOCIATE

10820-A, Shri Madhur Goenka, B.Tech. (Mech), Design Engineer, Nanda Millar Co., Sri Niket Building, Flat No. D,11 Ashoka Road, Alipore, Kolkata 700 072, madhur@nandagroup.com

We welcome our new members and request to bring new activities to our Chapters and Headquarters. MGMI News Journal will love to publish thoughtful articles from its members in any mining related issues, e.g.

1. Indian mining policies and its effects on mining growth
2. Indigenous tools and equipment developed in Indian mining applications
3. Actions for reducing post mining liabilities
4. Valuation of mining projects and performance analysis through economic indices
5. Mining for enhancing quality of life in and around mines

New Mining Infrastructure

To meet the country's target of 1-billion tonne of coal production by 2015-26, SECL is planning to provide 26% of this. The biggest challange will be to have bulk material handling and transporting infrastructure availability to the mining industry.

On October 12, 2019 the opening of the Kharsia to Karichapar railway line will boost the mining infrastructure of SECL for evacuation of its coal production from Mand-Raigarh and Korba coalfields. This will facilitate supply of coal to the thermal power stations of Gujrat and Maharastra to power the industrial belts to boost Indian economy.

Chattisgarh East Railway Ltd (CERL) developed by SECL(64%), the Govt of Chattisgarh (10%) and IRCON International Limited (26%) is developing 136 km East Rail Corridor at an estimated investment of Rs 3055 crore to connect Kharsia- Korichapar.-Dharmjaygarh-Korba.

The sttating of this new infrastructure will boost coal production of SECL.

UPCOMING EVENTS

Structural and Geo-Confluence
November 8, 2019
St. Charles, Missouri China Coal & Mining Expo 2019
30 October 2019 - 02 November 2019 China's number one event of the coal and mining industry. At New China International Exhibition Center No. 88 Yuxiang Road, Tianzhu, Shunyi District, Beijing, 101302, China

04-06 November 2019, "Petroleum Engineering Conference 2019" Venue : Dubai, United Arab Emirates. For further detailed contact : hptts:// petroleumengineering.euroscicon.com / 40Bloomsbury Way Lower Ground Foor. London. United Kingdom, Phone : +44-2033182512. Email : petroleum@ engineeringeuropscicon.com

Mining & Minerals Expo 2019
https://www.iec-expo.com.ua/en/mieen-2019.html
05 November 2019 - 07 November 2019
International Exhibition Centre, Kyiv, Ukraine

06-09 November 2019, 8th IMME – 2019. "International Mining, Equipment Minerals & Metals Exhibition". For future detailed contact : miningexpo@tafcon.com

MetCoke World Summit 2019
https://www.metcokemarkets.com/metcoke-summit
05 November 2019 - 07 November 2019

ALTA 2020 Nickel-Cobalt-Copper, Uranium-REE, Gold-PM, In Situ Recovery, Lithium Conference & Exhibition

02-03 December 2019, "2nd International Conference on Oil and Gas 2019". Venue Dubai, United Arab Emirates. For further detailed Contact : Allied Academies, Sarah Clarke, Programme Manager, 85 Great Portiand St. Marylebone, London United Kingdom. Phone : 02037691753. Email : petroleum2k18@gmail.com Web : http://oil-gas. alliedacademies.com

Geo-Congress 2020

February 25-28, 2020
Minneapolis, MN

Organized by Geo-Institute of the American Society of Civil Engineers

https://www.geocongress.org/
registrations@asce.org

Coal 2020,
Coal Operators' Conference,
12-14 February 2020 at the University of Wollongong, Australia.
Email : naj@uow.edu.au
Eurocoke Summit 2020

20-22 April 2020, Amsterdam, The Netherlands
Slope Stability 2020
Slope Stability Conference

12-13 March 2020, "Mining Tech Africa 2020". Venue : Johannesburg, South Africa. For further detailed Contact Spire Events Pte. Ltd. Mining Tech Africa 2020. Mahesh Babu, 24 Peck Seah Street #02-09 Nehsons Building, Singapore. Phone : +65 6717 8500 Fax : +65 5716 6015 Email : Mahesh.babu@spire-events.com Web : https://www.spireevents.com/ conferences

April 27, 2020 - April 30, 2020
Cape Town, South Africa
Email : bwills@min-eng.com
Web : http://www.min-eng.com/

Australian Centre for Geomechanics
The University of Western Australia
Civil and Mechanical Engineering Buildingay
12, 2020 - May 14, 2020

info-acg@uwa.edu.au

May 23, 2020 - May 30, 2020
Perth, Australia
Five international conferences in one week : ALTA 2020

ALTA 2020 is a world-class annual metallurgical conference, celebrating 25 years, and a leading platform for innovation. The emphasis of the program is practical rather than academic, and the themes running through the conference are the various aspects of technology and project development.

Program Topics :

- Nickel-Cobalt-Copper (25-27 May) including Hydromet Processing of Ni-Co-Cu Sulphides
- Uranium-REE (28 May) including Application of Membranes
- Gold-PM (28 May) including Cyanide Alleviation & Alternative Lixiviants
- In Situ Recovery (ISR) (29 May) including Application of ISR to Copper
- Lithium Processing (29 May) including Innovations in Lithium Processing

6th International Symposium on Sustainable Minerals (Sustainable Minerals 2020)

June 10, 2020 - June 11, 2020
Falmouth, United Kingdom
Email : bwills@min-eng.com
Web : http://www.min-eng.com/

Mining Tech Africa 2020
March 12, 2020 - March 13, 2020
Johannesburg, South Africa
Email : mahesh.babu@spire-events.com
Web : https://www.spire-events.com/conferences

10 - 11 June 2020. "6th International Symposium on Sustainable Minerals (Sustainable Minerals 2020)". Venue : Falmouth, United Kingdom. For further detailed Contact : MEI Barry Wills; Dr. 1 Freeman Collins Drive Trescobeas Road. Falmouth, United Kingdom, Phone : +44(0)7768 234 121 Email : bwills@min-eng.com Web : http://www.min-eng.com

GEOMETALLURGY 2020

July 02, 2020 - July 03, 2020
Lima, Peru

Sol de Oro Hotel

II International Congress focused on hydrometallurgical & electrometallurgical processes.

Lima, July 2-3, 2020
Venue : Sol de Oro Hotel, Calle San Martín 305, Miraflores
2th International Comminution Symposium (Comminution 2020)

ISFOG2020

International symposium for Offshore Geotechnics
August 16-19, 2020
Austin, Texas

Organized Offshore Geotechnics by the Geo-Institute of the American Society of Civil Engineers and the Deep Foundations Institute https://www.isfog2020.org/

SMART 20

Department of Mining Engineering IIT Kharagpur is going to organize an International Conference in November 2020 : Safe Mining and Advance Resource Techanology-20 (SMART 20) to bring the experts of advance technologies from mining sector and give an opportunity to the academic, researchers, industries to talk about state of art advance and smart technologies. It would not only help the government in Indian mining sector but also will contribute to global mining to embrace Industry 4.0 movement. For details contact Prof. Rakesh Kumar at rkumar@mining.iitkgp.ac.in

NEWS UPDATE

The Railway and Mining interdependency……

Coal transport facilities of Indian Railway is now under modernization

Global credit ratings agency Moody's Investors Service's utilities team has suggested a potential 7%-per-annunm average contraction in US coal demand over the next decade could translate into US$5 billion of lost revenues for railroads - or 5.5% of 2018 industry revenues.

Today's railway company don't burn coal but their lifeline is coal transport. Indian Railways, Asia's largest railway network charges about 31% extra to transport coal to power plants over the other items it carries. This helps it make up for the losses incurred in providing cheaper passenger services.

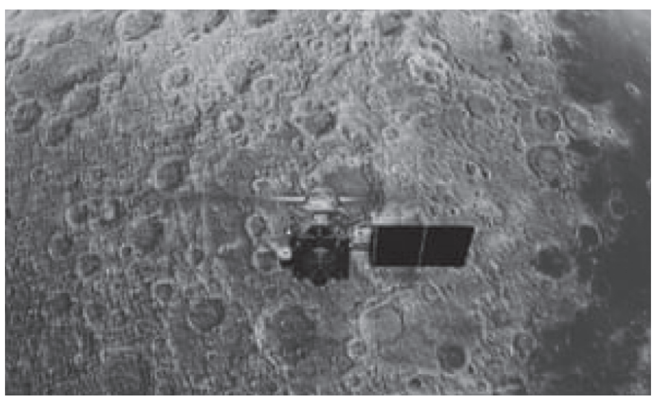
Coal accounts for some 44% of Indian Railways' freight revenue, in 2017-18, this revenue stood at over Rs 9,471 crore ($1.37 billion), more than double the Rs 4,297 crore Indian Railways earned from passenger operations. With a track length of 115,000 kilometres, Indian Railways is Asia's largest and the world's second-largest rail network depends on coal!

LUNAR WATERO

On September 25, 2009 NASA revealed Chandrayaan-I had traced water molecules on the moon's surface. It also 'thanked' ISRO for making the discovery possible. And today, an international race is building to measure and potentially exploit water resources found on the Moon's surface, says geological and mining consultant Watts, Griffis and India was McOuat of Toronto. The first to prove lunar water and currently looking forward to more probing through Chandrayan-2. Though the lander Vikram of Chandrayan-2 faced trouble during the last descending of less than 2 km, on September 8, a big jump in space knowledge sector has been achieved by ISRO's proud attempts. It has now been able to get the location of Vikram on the moon's surface. World will be receiving more knowledge input from Chandrayan-2 orbiter in the coming days.

MGMI Journal profusely adores the scientists of ISRO toiling behind the prestigious Lunar Mission of India.

The Indian Space Research Organisation (ISRO), with the help of the Chandrayaan 2 orbiter, has found out the exact location of the lander Vikram, that had lost contact with the space agency just moments before its scheduled soft landing on Saturday. On September 7, the soft-landing of Chandrayaan-2, that ISRO was hoping to achieve, was not successful as the space agency lost contact with the landing module just moments before it was scheduled to land.



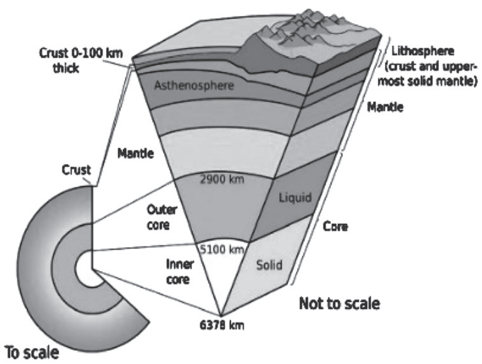
Vikram before its descent to the moon's surface

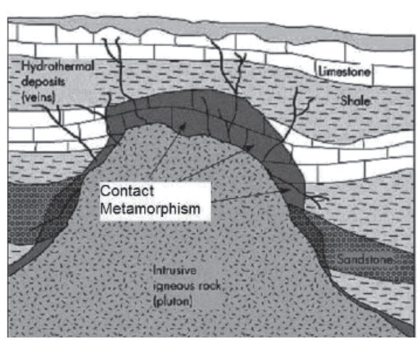
Perspective Piece

GEOLOGY, GEOMECHANICS AND MINING

Dr TN Singh[1]

Mining is an activity for exploitation of minerals preserved by the mother earth under soil on the surface to depth under hard rock formation. Despite all hardship, the earth has preserved most of them under hard rock till today for the human being. Information about near surface deposits have come often by chance as nuggets signing on the surface or during soil digging by the farmers or laborers engaged in civil work. The record of such workings for gold, gems and lead zinc and iron etc are since ancient ages. The information about the deep seated igneous, metamorphic or sedimentary deposits have been discovered by those geoscientists busy in gathering knowledge about the earth, defining their quality, quantity and depth cover.





EARTH SECTION MINERAL - SEDIMENTARY METAMOPHIC

Systematic exploitation of most of these minerals started with renaissance and with increase in demand, mining as a profession developed in Europe and America. Copper Age culture is traced in Saptsindhu region supported by the traces of copper mining near Chanhu Dero and Bijnaut which are located along the alignment of dry Sarswati. Copper vessels were regularly in use during the third millennium BC. but entered in the field of coal mining in 17th cent., starting from digging of coal exposed on the surface. Entry to deep levels in search of better-quality coal started in Raniganj coalfield and that trend came within Jharia coalfield even though the best quality coal was available on the surface. To promote coal mining a "Coal Committee" was constituted in 1836 that realized the need of an agency to gather detailed information about the resources of the land. Geological Survey of India came into existence in 1851, that delineated Gondwana coal basin and coal mining started in different basins. Gold mining starting from sand panning to surface digging over 2000 year ago entered underground to touch the igneous veins over 125 years ago in Karnataka in Kolar that became one of the deepest coal mining field in the world. In fact, this is the field where the first rock mechanics laboratory was started by John Taylor and Sons to predict rock burst occurring in the mines because of stress concentration and geological discontinuity over 70 years ago. It was primarily a geophysical -seismic wave study with sensors underground and on surface. Coal mining on the other hand has long history of 250 years but remained in primitive form in the hands of different small companies.

COAL MINING IN INDIA

Being underground is encroachment in stable domain of earth, inviting hostility of the pressure of the over

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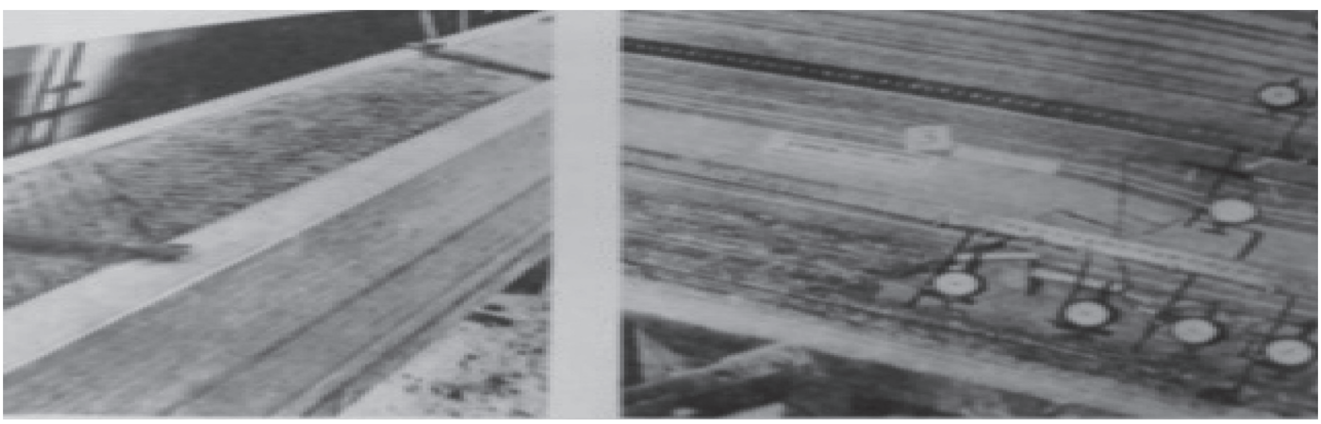
lying rock mass. Early coal mining in India was on the lines of Britain, forming bords of safe width and leaving pillars strong enough to support the load coming over and additional coming with the creation of voids around. The miners faced the problem of roof falling because of the natural weakness-fissures, cracks, shear planes and had to support by props where and when required. With the pressing demand of coal during World Wars, this norm was ignored; galleries were widened, and pillars were exploited often in random manner. The impact of such mining was manifested in terms of pillar loading/crushing of pillars, falling of roof rock pieces along the shear cracks or natural cleavage and mass failure of roof rock mass after bending/sagging beyond limit or along the shear planes. Sand stowing was started to support exposed roof and minimize surface subsidence, protect disturbance of the infrastructures and particularly maximize the recovery of quality coal from thick coal seams since 1936. In addition to wooden props, chocks to support operational area roof, this was the only additional technique adopted for strata control.

Coal mining was an art till that stage when the physical property like cleavage, cleats or open cracks and fissures were observed and used for cutting ease of coal by picks. Pillar crushing, roof fall, bumps became common with "slaughter mining" and was taken as professional hazard. A meter-long timber stick the in hands of the overmen was the only sensor used to knock the roof, hear the sound response and put wooden props with lead cap on the top ensure safety of the miners. The murmuring sound of the pillars heard by the experienced professionals was the sign of major fall, air blast there with and need to withdraw miners from the mine.

The characterization of the rocks started only after the formation of GSI (1851), when geologists as routine study started collecting information with physical study of rocks and minerals with tools like hammer, magnetic compass and chisel. For the mining, they were helpful in delineating faults, defining the reserve quality and quantity and this continued for next hundred years. Bore holes were drilled and cores were recovered to get the coal horizons, correlate them with seams, define their quality and reserve position and recommend the scope of economic exploitation. Once it was done, the rigs were shifted elsewhere and except the coal horizon, other cores were dumped for nothing. The mining professionals' interest was limited to coal seams and the study of formation beyond was of no concern to them. It was only after the over exploitation of the pillars during World War I that followed subsidence on the surface and affected common people. Surface subsidence study was initiated by the MGMI in 1914 and a report was submitted in 1928, giving negative angle of draw.

ROCK MECHANICS AND STRATA CONTROL

Rock mechanics as a stream was started in India in 1965 at the then Central Mining Research Station (Now Central Institute of Mining and Fuel Research),



Equivalent material Model Simulating Coal Measure Formation

Dhanbad with testing of the mechanical properties-compressive, tensile and shear strength of the coal and rock samples of 5cm cube size. The samples for the purpose were cut to the size, that required strong part of the coal seams free of cracks and fissures and so the compressive strength was invariably very high and the pillar size for depth recommended as per coal mines regulation was too large. After testing different size samples, 30cm cube sample the strength was found equivalent to the pillar size and that helped in design of pillars and stooks in mines.

For mass production of coal, wide voids - with depillaring and long wall or wide stall were created, and danger increased from the roof side. Strata movement study in mines was started at the same time at CMRS (now CIMFR) with the measurement of load on supports, pillar compression, roof convergence and surface subsidence. The roof bolting techniques were tried to support the roof on the basis of pull test, but the roof formation study was limited to the study of cracks and fissure only. Based on field observation, several empirical indices were developed for the stability and caving of roof. Equivalent Material Mine Modelling, a new technique was developed during this period and modelling was started in 1964 to simulate inaccessible strata formation. This required mass property of overlying beds that differed from the sample property.

EQUIVALENT MATERIAL MODEL SIMULATING COAL MEASURE FORMATION

It required geo-mechanical property of all the overlying beds in addition to conventional core recovery and RQD that was available from the exploration bore holes drilled primarily to prove coal beds. Equivalent Material simulation of strata formation in physical model required mass property of formation, practically inaccessible because of the depth cover. It was possible only with the cooperation of the geologists who could help in getting some geomechanics parameters. In fact need of getting mass property from small sample testing was realized by many and Leonard Muller who promoted the International Society of Rock Mechanics (ISRM) said “We do not know the rock mass strength and that is why we need an International Society”. ISRM founded in 1962 is yet to decide the standard system for this purpose. In what way, a sample differs from mass and formation in totality is the geological discontinuity, formation characteristic, cohesion of the bedding planes and filling within vis-à-vis Petro fabrics. The researchers addressed to this subject in their own way, (Q system of Barton,1972, for tunnel design; Rock Mass Rating RMR system of Bieniawaski (1976), considering the structural region of the rock mass. Barton used RQD, frequency of joint sets, nature of joint surface filling along the RMR of weak planes to cover the mass structure, while Bieniawaski used uniaxial compressive strength and the nature of geological discontinuity for shallow depth design.

SYNERGY OF GEO AND ROCK MECHANICS FOR MODELLING

The modelling requires the geo-mechanical and mechanical properties to simulate each layer with joints, fissures and bedding planes but for the purpose, nothing except cores drawn during the drilling for exploration was available. The cores stored in the boxes were studied for the percentage of core recovery and Rock Quality Designation (RQD) : the modified recovery of sound formation core more than 10cm length. The difference between core recovery and RQD shows the strength of binder characteristic - argillaceous, calcareous and ferruginous and erosion characteristic of the binder under water pressure. Whereas the coal seams were accessible for testing of large size sample in situ, this was not possible for the strata above. Mechanical strength of the rock sample was obtained by testing in the laboratory but for arriving at mass property, details of weak horizons, frequency of bedding planes, fillings in the joints, weak layers in between, weathering character of the formation were the indirect means to arrive at the mass property. Some of this information were lost during drilling, storage of the cores, their transport and hence required spot study and consultation with the drilling crew.

For the purpose a few drilling sites of Maharashtra and Assam were visited in person and interaction with the drilling crew and geologists, the study of gumming's coming out of drill hole with water at every level and study of RQD before the cores became dry was necessary. Experience of over a month stay with the geologists of Dahegaon (Nagpur) drilling camp of National Coal Development Corporation, Ranchi was very educative in this respect.

Sedimentary formation over the coal bed occurred in stages, over millions of years in cyclic manner. The matrices with each cycle were dumped in the valleys over vegetable mass and as per the sorting process, coarse particles settled at first followed by fine grain and in the last stage micaceous flakes/fine clay particles, forming weak horizon. The matrices cemented by calcareous or ferruginous matter with time formed competent beds; that developed joints and fissures under the influence of geological activities. The weak planes were opened by drilling jerk and washed with water or disturbed during the handling of the cores. This information was possible only during the process of drilling from the penetration rate or gumming's coming out from the drill holes with water. Like information was possible from the outcropping beds as well because of the effect of weathering agencies which promoted bed separation even in otherwise competent formation. In effect this factor promoted exfoliation of the beds and a competent bed parted along the weak planes and when accounted for in simulation with weakening coefficient of samples because of the geological discontinuity and nature of formation.

INTEGRATION OF GEO AND ROCK MECHANICS IN MINING

Roof support and safe caving are the main problems of a long wall working or depillaring. The bending strength of a beam forming roof in wide opening varies with its thickness; square and therefore if the same roof formation is divided in two sections by a micaceousflake as intrusion, it will drastically decrease, leading to early failure even if the tensile strength of both the sections was the same. For more realistic figures of RQD, weak horizons and bending strength, use of double tube core barrel was recommended to the Exploration wing of CMPDI, Ranchi while modelling the Jhanjhara coal measure formation. The core was to be coated by paraffin wax immediately after recovery to protect separation along the weak planes under the influence of atmosphere.

Russian experts engaged in the study of caving bump prone Dishergarh seam caving in Chinakuri mine used two holes drilling across the immediate roof formation; normal to seam and inclined by a fixed drilling rig. The core in the normal drilling process was subjected to drilling thrust all around at a time, creating situation to part while in case of inclined hole, it was subjected to same thrust over longer section and thereby saving it from separation for study in the laboratory. By such study, it was possible to investigate the nature of weak planes and possibility of weakening them by water infusion if the matrices show the tendency of moisture softening and thus ensure exfoliation of thick formation to several thin beds caving easily. This is a unique example of integrating geomechanics to rock mechanics in mining. With time, in rock mechanics, these initiatives were online to help in caving of coal seams under hard, thick immediate roof and show effective application of drilling and role of a geologist in mining of coal under difficult situations in days to come. CIMFR, Dhanbad, has developed a number of Rock Mass Rating systems for roof support planning and design, strata characterization and rock mass failure criterion for coal measure formation, subsidence prediction, pillar design for different mode of mining alternatives and formulation for roof support. The result has been very encouraging with exploitation of thick coal seam standing on pillars at NCPH Mine by Cable Bolting, mining of thick contiguous seam standing on pillars with underpinning without timber support and NEW (Non Effective Width) mining under infrastructures. The challenges are however serious standing in the way of mining deep seated coal seams by long wall under difficult roof. National Institute of Rock Mechanics, Kolar Gold Field, established in 1988 is providing services in entire spectrum in study, monitoring and consultancy. Other institutes like, ISM (IIT), Dhanbad, IIT BHU, Varanasi, IIT Kharagpur, IIT Bombay and IIT Roorkee have made commendable contributions in the field of rock mechanics in their own way. The need is only involving GSI, MECL and CMPDI having long experience in drilling and exploration and other exploration agencies with geo-mechanics and come out of empirical norms and thumb rules for defining mass property and computation.

Technical Note

ISOTOPE HYDROLOGY AND GEOCHEMICAL STUDY TO ASSESS THE GROUNDWATER ORIGIN AND THEIR QUALITY IN TALCHER COAL MINING AREA, ODISHA, INDIA

U Saravana Kumar[1], Md Arzoo Ansari[2], Archana Deodhar

INTRODUCTION

Mining of economical minerals resources are being done in different parts of the world including USA, Australia, India, China, South America, South Africa and Europe. The mining operations generate huge amount of solid waste due to over burden dumping and liquid waste from the washing plants. The uncontrolled discharge of these mining wastes interacts with the hydrological systems (groundwater and surface water) of the region and degrades their quality. It has been observed that open cast mines have greater impact on the hydrological system than the underground mines (Liang et al., 2017). It has been seen that water resources degradation in mining regions are mainly caused by two processes which occur simultaneously, the first is the acid mine drainage and second is the release of toxic element by the dissolution of solid waste in acidic environment (Mohanty et al., 2018). The water resources degradation in the coal mining areas has been observed in many places in India and abroad (Cravotta and Brady, 2015; Mohanty et al., 2018; Prathap and Chakraborty, 2019).

Environmental isotopes and chemical tracers are being used for more than five decades as valuable tools for investigating groundwater contamination, recharge processes and flow mechanisms in hydrologic systems. In particular, O ($\delta^{18}O$) and H ($\delta^{2}H$) isotopes are ideal conservative tracers of water sources because they are part of the water molecule itself and can provide preliminary indications where it came from and what happened to it on its way (Nobel and Ansari, 2019). Variations in the isotopic composition of different waters, their isotopic "fingerprints", are used to assess the vulnerability of groundwater to pollution from the surface by determining its movement and recharge source. This improves the prediction of reactive contaminant transport in the subsurface.

The investigated area is having numerous open cast and underground coal mines that are in operational conditions and in abandoned too. Additionally, many industries such as thermal power plant, was hery, workshop are also in operation in nearby the mining region. Furthermore, the groundwater in this coal mining region is being extensively used for the domestic and agriculture purposes.

In view of the above, an isotope hydrological and geochemical investigation has been pursued in the coal mining area in Talcher, Odisha to evaluate the quality of the water resources and to find out the recharge source to the groundwater.

BACKGROUND OF THE STUDY AREA

Location and Climate

The study area is located in Talcher town in the Angul district of Odisha (Figure1). The area is mainly drained by the Brahmani river and is characterized by an uneven topography, some scattered hillocks, forest blocks and rocky outcrops. The altitude ranges from 58 m to 139 m amsl and the slope is towards the SE-direction. The area experiences tropical climate with mild winter and hot summer. The average annual rainfall is approximately 1250 mm (June to September). The mining activities are mainly concentrated in upstream part in the NW region of the study area.

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Geology and Hydrogeology

The area is largely covered by sedimentary rocks of Karharbari and Barakar formations belonging to the Gondawana super group. The coals bearing Karharbari and Barakar formations lie over the Talcher formation and have very thick sandstone and shale sequence. The Karharbari sandstones are characteristically pale brownish yellow colour, medium to coarse grained and contains superior quality coal seams along with the clasts of Talcher shale. The Barakar formation, which overlies the Karharbari, is characterized by a thick and conspicuous conglomerate horizon at its base. The basal conglomerate unit is overlain by a thick sequence (more than 500 meters) of medium to coarse grained grayish feldspathic sandstone, grey to dark grey shale, carbonaceous shale, thick coal seams mostly inter bedded with shale. The generalized geological succession is shown in Table 1.

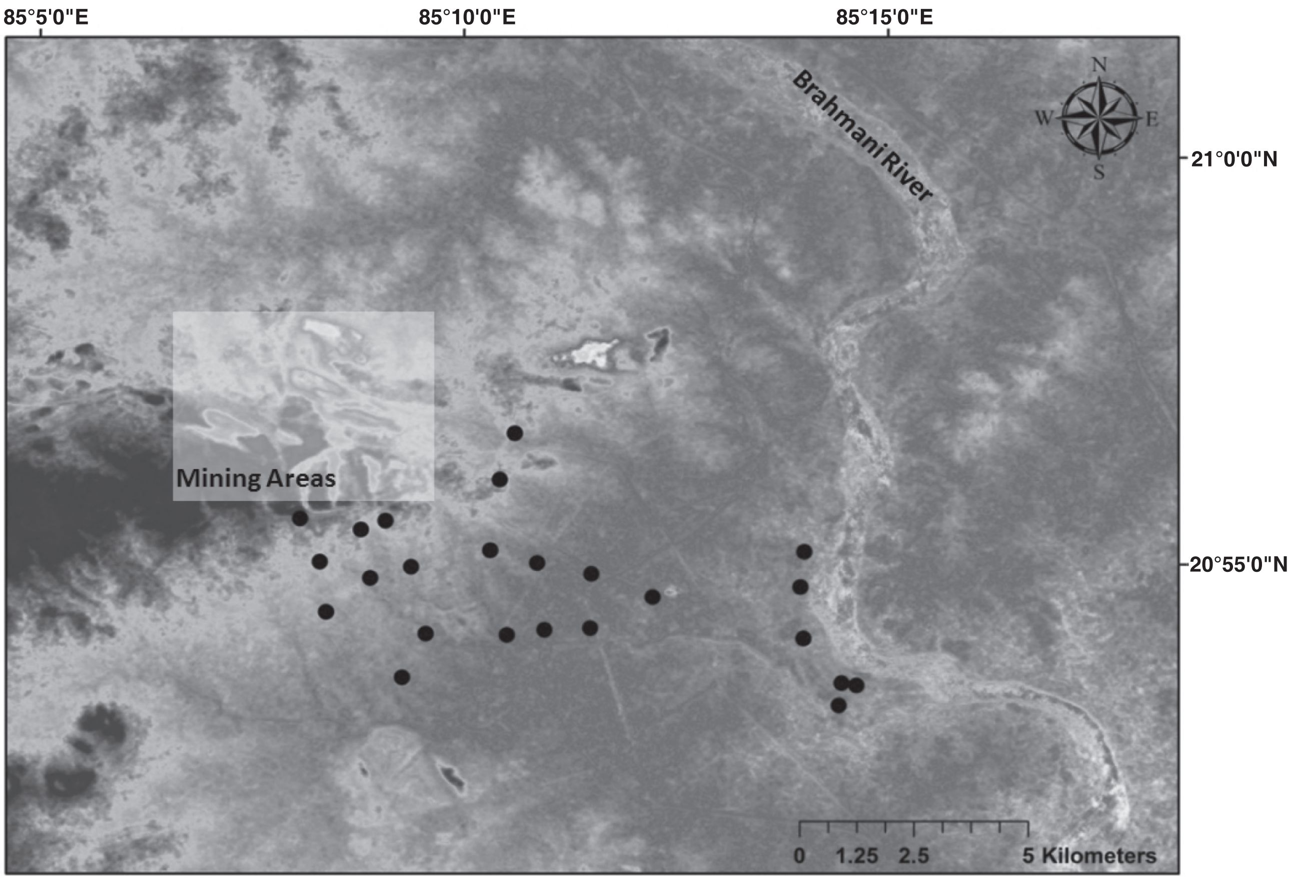

Figure 1 :
Location Map of the Study Area Showing Mines
and Groundwater Sampling Points

Table. 1 Generalized Geological Succession of the Study Area

Age	Formation	Lithology
Recent		Alluvium and Laterite
Upper Permian to Traissic	Kamathi	Fine to medium grained sandstone, carbonaceous shale, coal bands, with greenish, pink clays and pebbly sandstones at top.
Lower Permian	Barakar	Medium to coarse grained sandstone, shales, coal seam with oligomictic conglomerate at base
	Karharbari	Medium to coarse grained sandstone, shales, coal seams.
	Talcher	Diamictite, fine to medium grained greenish sandstones, shales, ryhthmite, turbidite etc.
~~Unconformity~~~~~~		
Precambrian		Granite, gneisses, amphobolites, migmatites, etc.

The groundwater reservoir in the area is semi consolidated Gondwana formations comprising mainly of sandstone and shale and consolidated crystalline rock of Precambrian age. The weathered and fractured sandstone constitute good aquifer. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the fracture zone. The depth of water level varies from 0.6 to 15 m bgl.

METHODOLOGY

Water samples were collected from the tube wells, rain, ponds and river for in-situphysico-chemical parameter (Electrical conductivity, pH, and temperature), chemical (major and minor ions) and isotope (δ^2H,$\delta^{18}O$) analysis (Fig. 1). Theδ^2H and $\delta^{18}O$ were measured using Isotope Ratio Mass Spectrometer (Isoprime-100) and reported as δ values in permil (‰);

$$\delta^2\mathrm{H}\ (\text{or}\ \delta^{18}\mathrm{O}) = \left(\frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}}\right).10^3 \qquad (1)$$

(Precision : $\delta^2H = \pm0.5$‰; $\delta^{18}O = \pm0.2$‰ at 1σ).

Analysis of major cations and anions were carried out using Dionex-DX-500 Ion chromatography as per the standard methods (APHA, 2005) with a detection limit of 0.01 mg/L. The precision and accuracy of the analysis is ±5%. Aquachem 3.7 was used for the estimation of ion balance, dissolved minerals and other hydrochemical parameters. Furthermore, principal component analysis (PCA) along with Pearson's correlation analysis was used to explore large hydrochemical data sets.

RESULTS AND DISCUSSION

Hydrochemistry and Water Quality Evaluation

The variations of in-situ physico-chemical parameters (electrical conductivity, temperature, pH) in groundwater and surface water are shown in box plots (Figure 2). The pH of the groundwater ranged from 6.4 to 7.8 with an average value of 6.9, whereas in surface water, it ranges from 7.4 to 8.6 (mines quarry water : 7.9). The pH of groundwater is acidic to alkaline whereas surface water is neutral to alkaline in nature and they are falling within WHO (2011) optimum limits (6.5 and 8.5). The electrical conductivity (EC) for groundwater ranged from 183to 2160μS/cm with an average value of 1124μS/cm whereas in surface water (River, Pond, Quarry), it ranges from 94 to 1470μs/cm that also lies within the permissible limit of 1500μS/cm (WHO, 2011).

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentration in groundwater ranged from 20.9 to 122 mg/l (mean : 72 mg/l) and 4.7 to 60 mg/l (mean : 28.8 mg/l) respectively, whereas, in surface water, Ca^{2+} and Mg^{2+} varies from 11.6 to 61.1 mg/l and 3.3 to 15.8 mg/l respectively (Figure 3). Both theses ions are found within the allowable limits as per WHO (2011) (maximum allowable limit for Ca^{2+} and Mg^{2+} are 75 mg/l and 30 mg/l respectively). It has been observed that

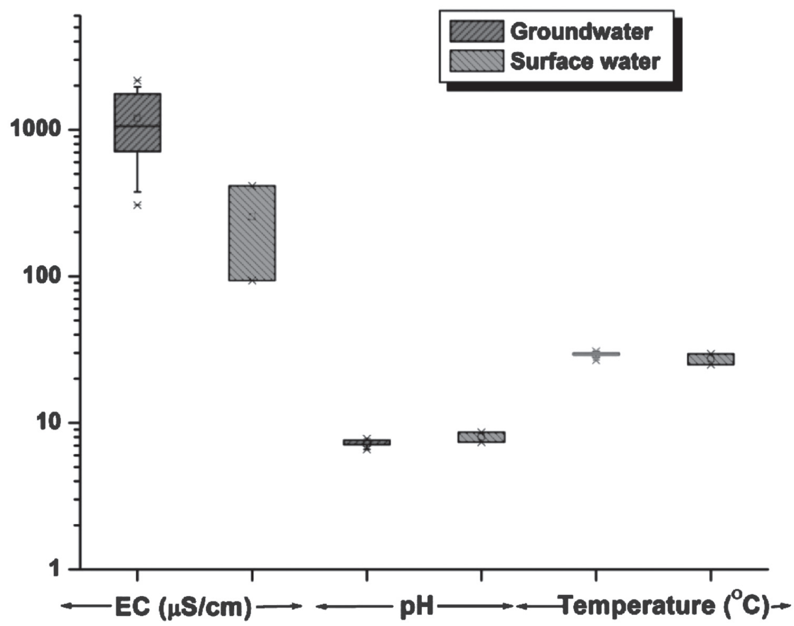

Fig. 2. Box and Whisker Plot Showing the Variation of Physico-chemical Parameter in Groundwater and Surface Water.

higher concentration of Ca^{2+} and Mg^{2+} were found in the discharge area. Na^+ and K^+ concentration in ground water varied from 16.4 to 616 mg/l (mean : 113.9 mg/l) and 0.64 to 15.3 mg/l (mean : 4.6 mg/l) respectively, where as in surface water, Na^+ and K^+ varies from 5.4 to 34.1 mg/l (mean : 19.7 mg/l) and 2 to 3.9 mg/l (mean : 2.9 mg/l) respectively. One groundwater sample is having above permissible limit (200mg/l) of Na^+ as per the WHO (2011). The mean concentration of fluoride in groundwater is 1.16 mg/l, which ranges from 0.1 to 4.4 mg/l. About 31% of the groundwater samples are having above permissible limit (1.5 mg/l) of fluoride as per WHO (2011).

Fluoride usually comes in groundwater because of the dissolution of fluoride containing minerals such as fluoraptite, hornblende, biotite, fluorspar etc. Nitrate concentration in groundwater varies from 0.5 to 67.6 mg/l with mean value of 17.4 mg/l. Only one sample is having above the allowable limit (50mg/l) of nitrate as per the WHO (2011). Chloride concentration in groundwater varied from 7.1 to 685 mg/l with an average of 128 mg/l (Figure 3). A few groundwater samples (2 Nos.) are having above maximum permissible limit (250 mg/l) of chloride. The sulphate content in groundwater varied from 2.8 to 174 mg/l with mean value of 59.8 mg/l and they are found to be within the permissible limit as per the WHO (2011). The mean value of bicarbonate (HCO_3^-) in groundwater is 377 mg/l and ranged from 134 to 632 mg/l. Calcite and dolomite dissolution as well as atmospheric CO2 usually contribute the bicarbonate in groundwater (Ansari et al., 2015).

Environmental Isotope Composition of Groundwater and their Sources

Rainwater is the principle components of hydrological cycle and deuterium (δ^2H) and oxygen ($\delta^{18}O$) composition of rainwater are the basis for identifying the sources of groundwater recharge. The δ^2H of rainwater ranged from -83.8‰ to -17.1‰ while $\delta^{18}O$ ranged from -11.4‰ to -3.2‰. The δ^2H and $\delta^{18}O$ composition of groundwater ranged from -37.9‰ to -18.3‰ and -5.1‰ to -2.3‰ respectively whereas surface water (river and stream) varied from -37.4‰ to -17.6‰ for δ^2H, and -5.6‰ to -2.0‰ for $\delta^{18}O$. The isotopic analysis shows a discontinuous trend with some of the groundwater samples are showing enrichment indicates evaporation prior to recharge to the groundwater system. The Local Meteoric Water Line (LMWL) for the study area has been developed using δ^2H and $\delta^{18}O$ of rainwater and is presented along with the Global Meteoric Water Line (GMWL) developed by Craig (1961) (Figure 5). It has been observed that most of the groundwater samples are falling along the LMWL indicates they are getting recharge from the rainwater. However, contribution of stream in groundwater recharge has been seen only in few samples.

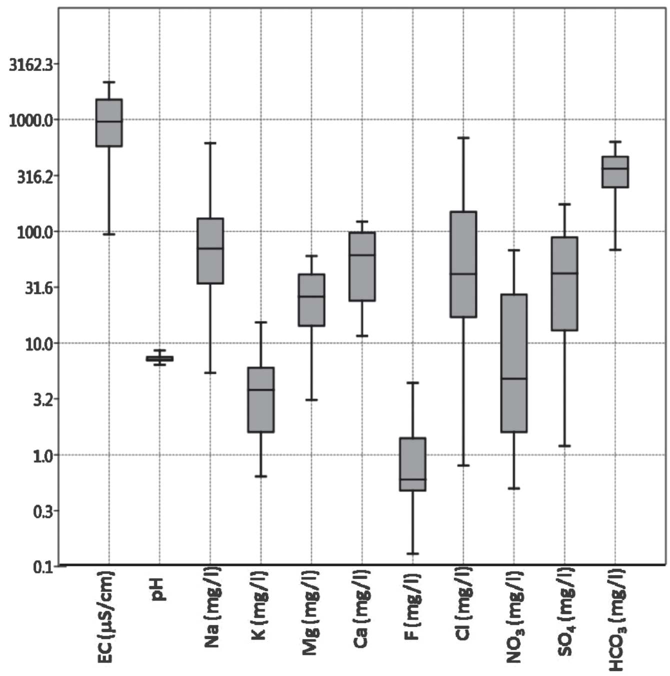

Fig. 3. Box and Whisker Plot Showing the Variation of Major Cations and Anions Concentration in Groundwater.

Processes Controlling Groundwater Chemistry Ionic Ratios and Mineral Dissolution

Different ionic ratios are being used to evaluate the geochemical processes controlling the chemistry of the groundwater. The Na/Cl ionic ratio of most of groundwater samples in the study area are more than 1 suggest either weathering of silicate mineral or cation exchange during the transit time (Figure 6a). Some of the samples fall above the equiline (1:1), indicates evaporative enrichment of Chloride. The Ca+Mg vs SO_4+HCO_3 a scattered plot is used to evaluate whether ion-exchange process is controlling the chemistry of groundwater or not (Figure 6b). It has been observed that most of the samples are having high values of SO_4+HCO_3 indicates ion exchange and silicate weathering is the dominant factors responsible for chemical evolution of most of the groundwater in the study area (Ledesma-Ruiz et al, 2015). To further confirm this, we have used bivariate plots of Ca/Na vs. Mg/Na and Ca/Na vs. Mg/Na (Figure 7). It has been seen that in both the plots most of the groundwater samples are lies nearer or within the global average values of silicate weathering. The higher EC in most of the groundwater may promote the rock-water interaction consequently dissolutions of fluoride bearing minerals enhanced.

Additionally, the groundwater that have abnormally high NO_3- are having a very low fluoride (0.5 to 2.6 mg/l) indicates minimal role of anthropogenic contamination in the enhancement of fluoride in groundwater. It was also observed that groundwater that have high fluoride (>3.5 mg/l) are of Na-HCO_3 type indicates soda water (Na-HCO_3 type) favor the fluoride enrichment by the dissolution of fluoride mineral (CaF_2) (Fu et al., 2018). From the above discussion, It is clear that the processes such as geogenic and anthropogenic are controlling the solute content in the groundwater of the study area.

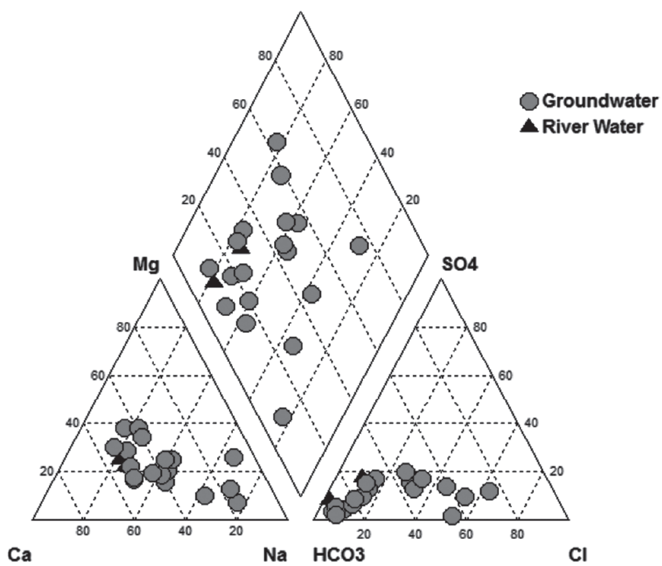

Figure 4 : Piper Diagram Showing Major Cations and Anions Composition of Groundwater and River Water

Correlation Analysis

The Pearson's correlation analysis is performed between the different analyzed parameter to evaluate the relation among them (Fig. 8). It has been observed that EC is positively correlated with Cl^-, Na^+, SO_4^{2-}, Ca^{2+}, Mg^{2+} indicates that these ions are responsible for the higher EC. The strong correlation between Na^+ and Cl^-, SO_4^{2-}, F^-, HCO_3^- and Ca^{2+} indicates that these ions are having a common source of origin.

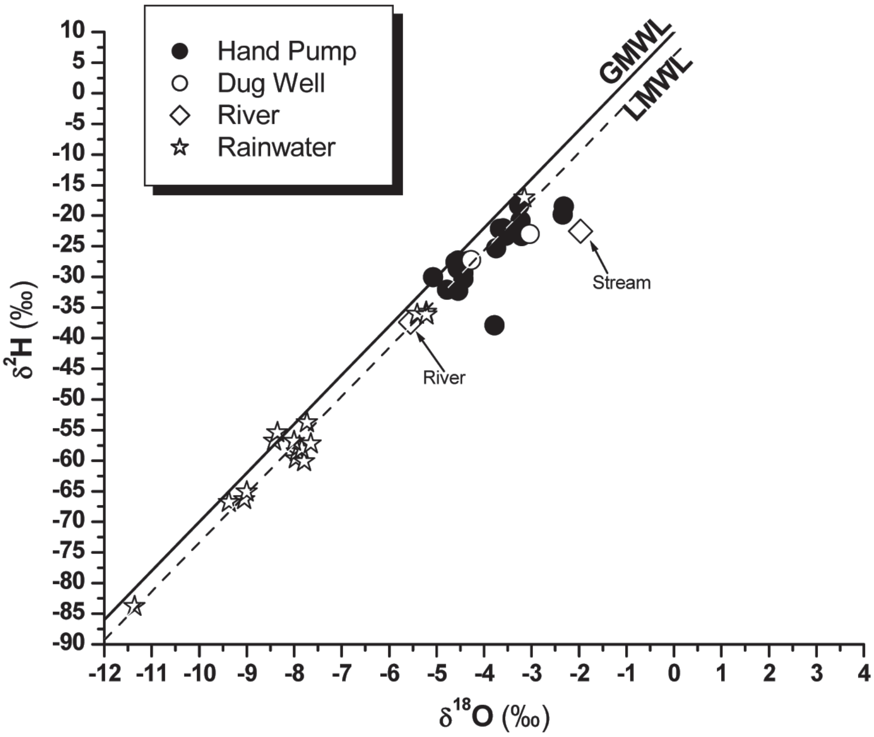

Figure 5 - Plot of $\delta^{18}O$ versus δ^2H of Groundwater River Water, and Rain Water

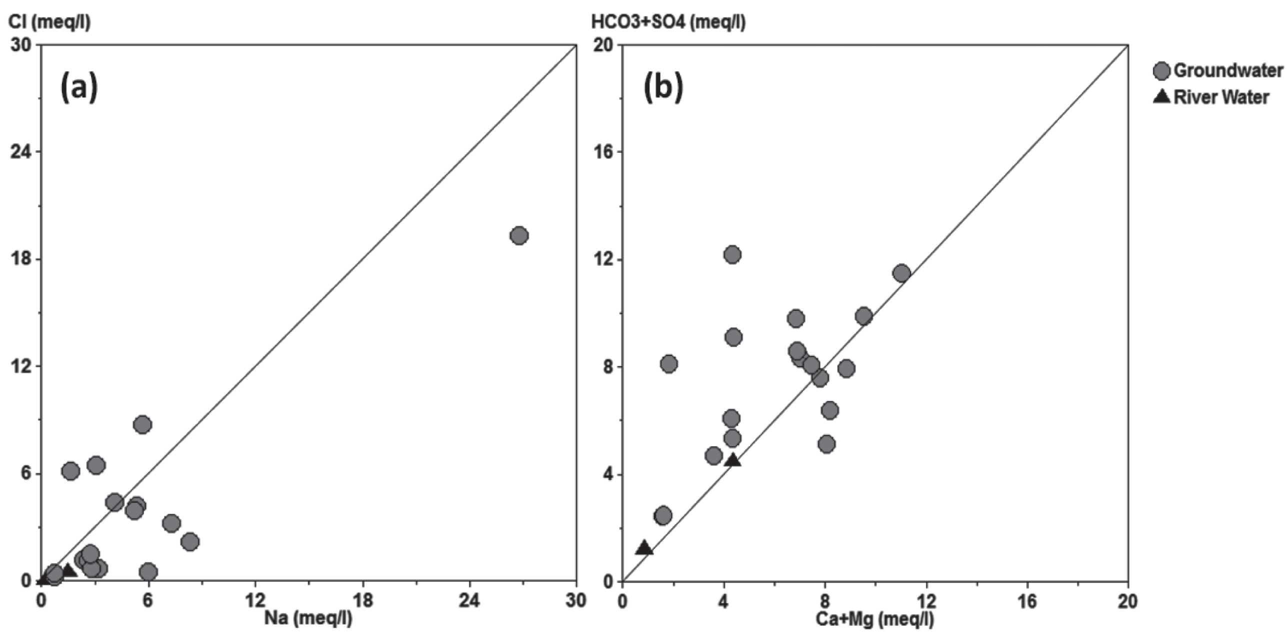

Figure 6 : Bivariate Plot Showing the Relationship Between (a) Na^+vs. Cl^- and (b) Ca+Mg vs. Na+K

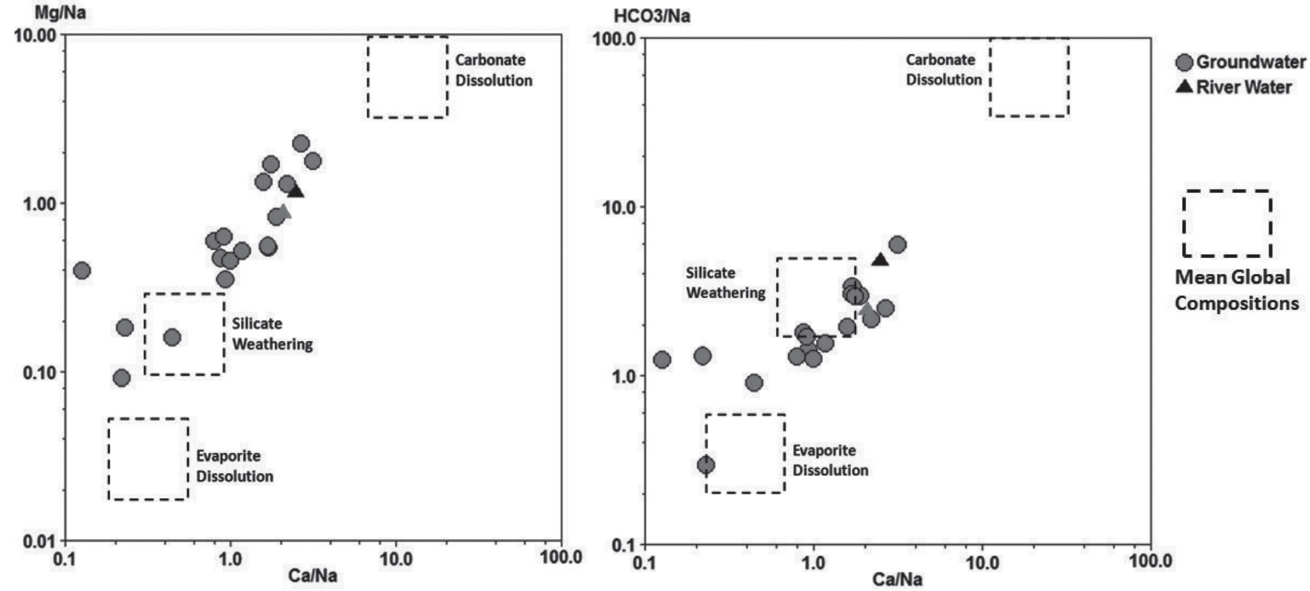

Figure 7 : Bivariate Plot Showing the Relationship Between (a) Ca^{2+}/Na^{+} vs. Mg^{+}/Na^{+} and (b) Ca^{2+}/Na^{+} vs. HCO_3^-/Na^+

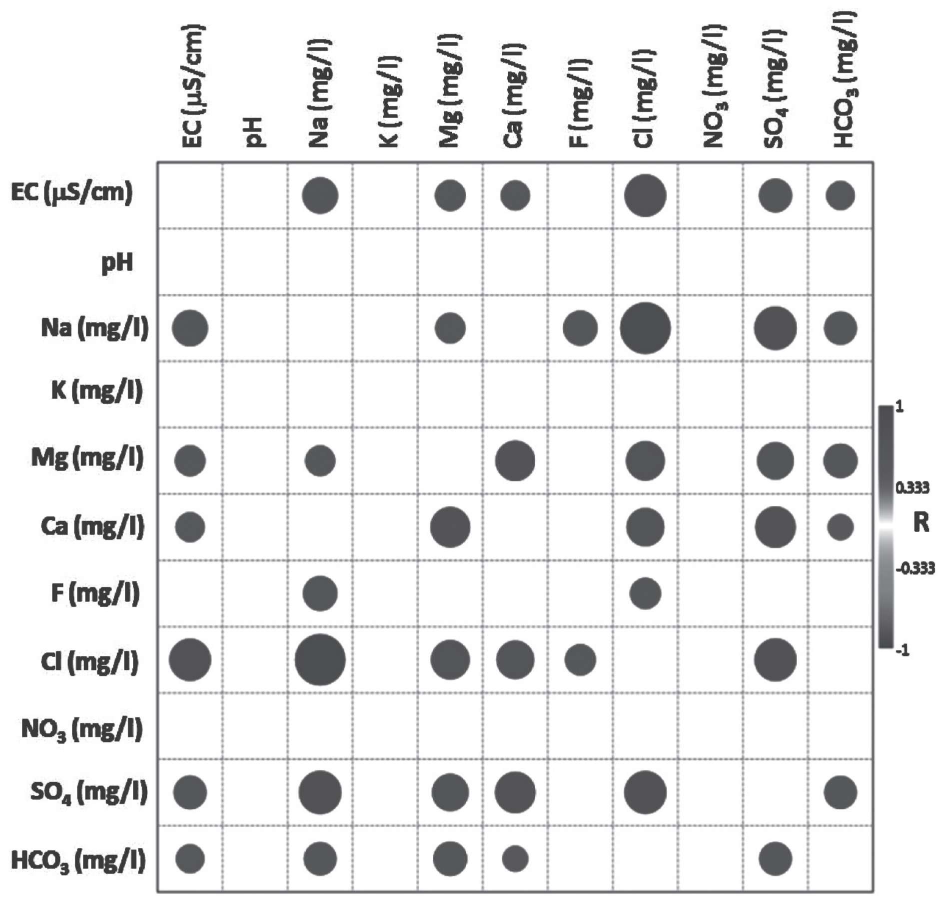

Figure 8 : Pearson Correlation Matrix of the Hydrochemical Variables in Groundwater
(Insignificant Coefficients at Level 0.05 are Removed)

Principle Component Analysis (PCA)

The water quality parameters (11 Nos) were evaluated using PCA to indentify the processes controlling the hydrochemistry of the groundwater. Three principle components were selected on the basis of eigen values (>1) and they together constitute about 70% of the total variance. The loading plot of the three principle components of the hydrochemical variables is shown in Figure 9. The Kaise-Meyer-Olkin (KMO) test has been performed to check the adequacy of the data for PCA and which yield a value of 0.691. PC-I constitute 42.72% of the total variance whereas PC-II and PC-III explain 16.24% and 11.09% of total variance respectively. PC-I has significant loading of Cl-, SO_4^{2-}, Na^+, EC, Mg^{2+}, Ca^{2+} and HCO_3^- and they are the prime culprit for the geochemical evolution of the groundwater in the study area. High loading of Cl in PC-I may be because of anthropogenic impact such as industrial effluents, use of fertilizer, domestic sewage and evaporative enrichment whereas high loading of Na indicates weathering of silicates minerals such as albite and orthoclase feldspar. The significant loading of SO_4^{2-} along with Cl- in PC-I indicates that they are probably derived from the anthropogenic sources such as from mining waste, sewage and fertilizer input. Whereas moderate loading of Mg^{2+}, Ca^{2+} and HCO_3- in PC-I may be because of the natural processes such as weathering and dissolution of feldspar, clay and biotite minerals.

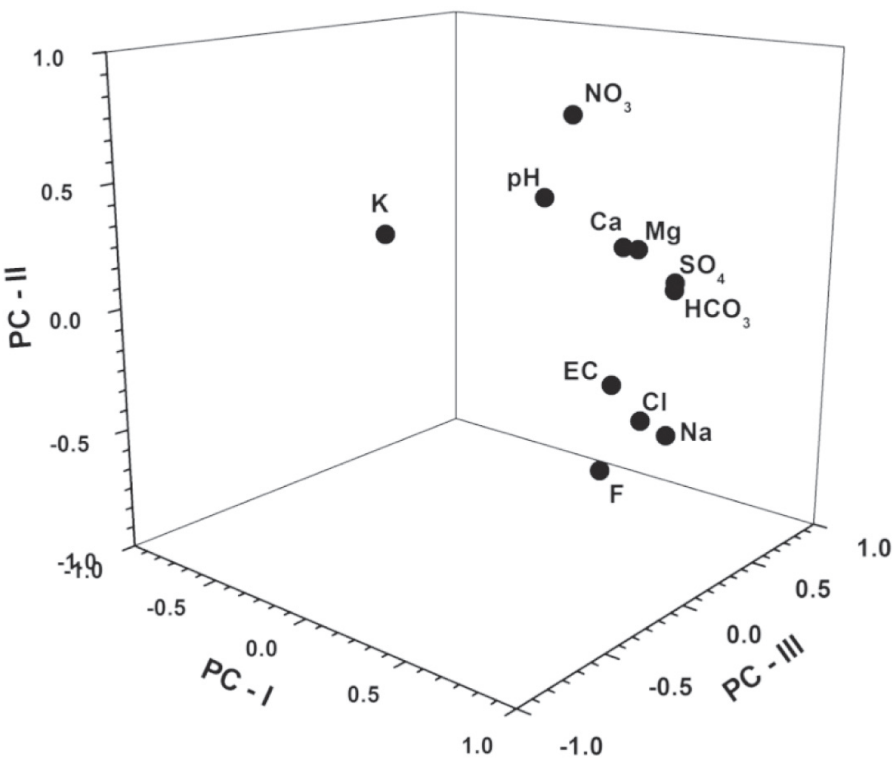

Figure 9 :
Tri-plot of the First Three Component Explained 70% of the Total Variance of the Water Samples

The significant positive loading of EC in PC-I is because of the cations (Ca^{2+}, Mg^{2+}, Na^+) and anions (Cl-, SO_4^{2-}, HCO_3-) and it shows both the natural and anthropogenic sources controlling the groundwater chemistry. Moreover, PC-II has strong positive loading of NO_3- and negative loading for F-. A significant high loading of NO_3- may be because of the anthropogenic input such as use of fertilizers and sewage. Whereas high loading of fluoride might be because of the geogenic processes such as dissolution of fluorite

(CaF_2). Similarly, high loading of K^+ along with pH in PC-III indicates silicate weathering is prominent in region.

CONCLUSIONS

Mining activities is usually believed to have adverse impact on hydrological systems. Some of these impacts include groundwater and surface water contamination by the rocks and mineral waste, mine water and sludge generated during the mining. Under this reference, an isotope hydrogeochemical study was carried out in the intensive coal mining area of Talcher, Odisha to assess the impact of mining on groundwater and surface water. It was observed that F- and NO_3- in some of the groundwater in the region are above the drinking water permissible limit and the higher content of fluoride is found in the sodic groundwater (Na-HCO3) reflect that it is derived from the geogenic sources like weathering of fluoride containing mineral. The isotopic data revels that rainwater is the dominate source of recharge to the groundwater and contribution of surface water is insignificant in recharge. The principal components analysis indicates that rock-water interaction, silicate weathering, and impact of anthropogenic activities are the important components that are responsible for the overall hydrochemistry of the groundwater in this mining region. This study will give better insight for the effective management to mitigate the poor water quality in mining region.

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Technical Note

GEO-MECHANICAL NARRATIVES OF FITTING ENGINEERING WITH ROCK-MASS, STRESS CONDITIONS, DEPTH AND THICKNESS FOR EFFICIENT UNDERGROUND COAL MINING

Rajendra Singh[1*]

INTRODUCTION

India is the second largest coal producing country in the world. The growing demand of energy to support economic growth of the country is being met, primarily, by coal. Coal production in the country is increasing year after year, which is being achieved, mainly, by opencast mining. In fact, at the moment, the share of coal production from opencast is almost 96 per cent. There are many geo-technical and economic reasons for the dominating role of opencast mining in Indian coalfields. Heavy mechanization and some automation too have played key role in the success story of the opencast mining. Now, different adverse environmental impacts of this method are being seriously noticed by the society and the volume of coal reserve, suitable for opencast mining, is shrinking. Therefore, a scenario is emerging in favour of the underground coal mining but the success of underground mining also requires mechanization and automation. Mining industry is attempting to make underground coal production safe and efficient through introduction of different modern technologies. Introduction of modern approach to improve underground production is challenging as it needs to be fitted with the existing site conditions. It may be mentioned here that there is an abundance of good mining machineries and technologies around the globe the globe and, accordingly, the industry is going for different international collaborations to improve the condition of underground coal mining. Some of these collaborations have experienced mixed results, mainly, due to the encountered adverse behavior of the associated rock-mass and stress fields. In fact, foreign technologies and machines for the underground mining lack good understanding of Indian site conditions. Attempts are made here to address the uniqueness of Indian coal measures through Coal Mines Regulations (CMR), which is an extremely rich compilation of experiences to guide the design of underground structures. CMR has a proven track record to provide safe design but, sometimes, the CMR needs to be supplemented by the basic strata mechanics principles during an interfacing of the modern underground mining approach with the existing geo-mining conditions of our coalfields. This technical note presents different experiences of applications of some basic strata mechanics principles for suitable adoption of the modern mining engineering approach in tune with the surrounding rock-mass, stress conditions, depth and thickness of the coal seam.

THICK SEAM MINING

An increase in thickness of a coal seam multiplies the resource volume but it also introduces difficulties in its safe and efficient underground mining (Kang et al., 2018). A mining engineering effort for efficient underground extraction of a thick coal seam needs to be fitted as per the anticipated rock mechanics conditions at the site. Geo-mining conditions of Indian coalfields have favoured development of thick coal seams on Bord and Pillar (B&P) method, where single lift depillaring of total thickness (SLDTT) is preferred (Singh et al., 2008) during their final extraction. If a thick coal seam is developed along floor, then well known techniques like Cable-bolting or Blasting gallery are adopted for SLDTT. As Indian coal measure formations are quite competent, occasions are not rare when thick seams are developed along the roof. Presence of competent roof strata creates complex geo-mining conditions due to formation of large overhangs inside the goaf and

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makes depillaring difficult. Final extraction during such situation needs stronger and stiffer natural support at the goaf edge to arrest violent failure of the strong and massive roof strata. Single lift working of a complete thickness of a thick coal seam is preferred due to its techno-economical superiority (Singh, 1988) over the conventional multi-sectional working. Development of the thick seam along the floor is must for its SLDTT.

The development along the floor of such a developed (along roof) thick coal seam along floor comes under the ambit of contiguous coal section of the CMR. As per this, the bottom section development should be superimposed to that of the top section. Further, the regulation also imposes a condition that the parting between the two closed superimposed developments should not be less than 3m in thickness. But field experience indicated that the superimposition of two sections is not suitable for SLDTT below massive strong roof conditions. At GDK8 incline colliery, a thick coal seam developed on pillars along the roof first adopted superimposed development along the floor for SLDTT by blasting gallery method. The gallery junction of the bottom section near the goof edge experienced roof failure after dynamic loading of pillars during depillaring. As the height of the resulted void was considerably more and the superimposed development provided sufficient free face for the pillars facing goaf line (Figure 1), the effective width to height ratio of the natural supports dropped considerably resulting an increase in the chance of pillar overriding during the strata equilibrium dynamics (Singh et al., 1996). Presence of strong and massive overlying roof strata caused high value of mining induced stress over pillars facing goaf line during the SLDTT at GDK8 resulting massive collapse ahead of the depillaring face.

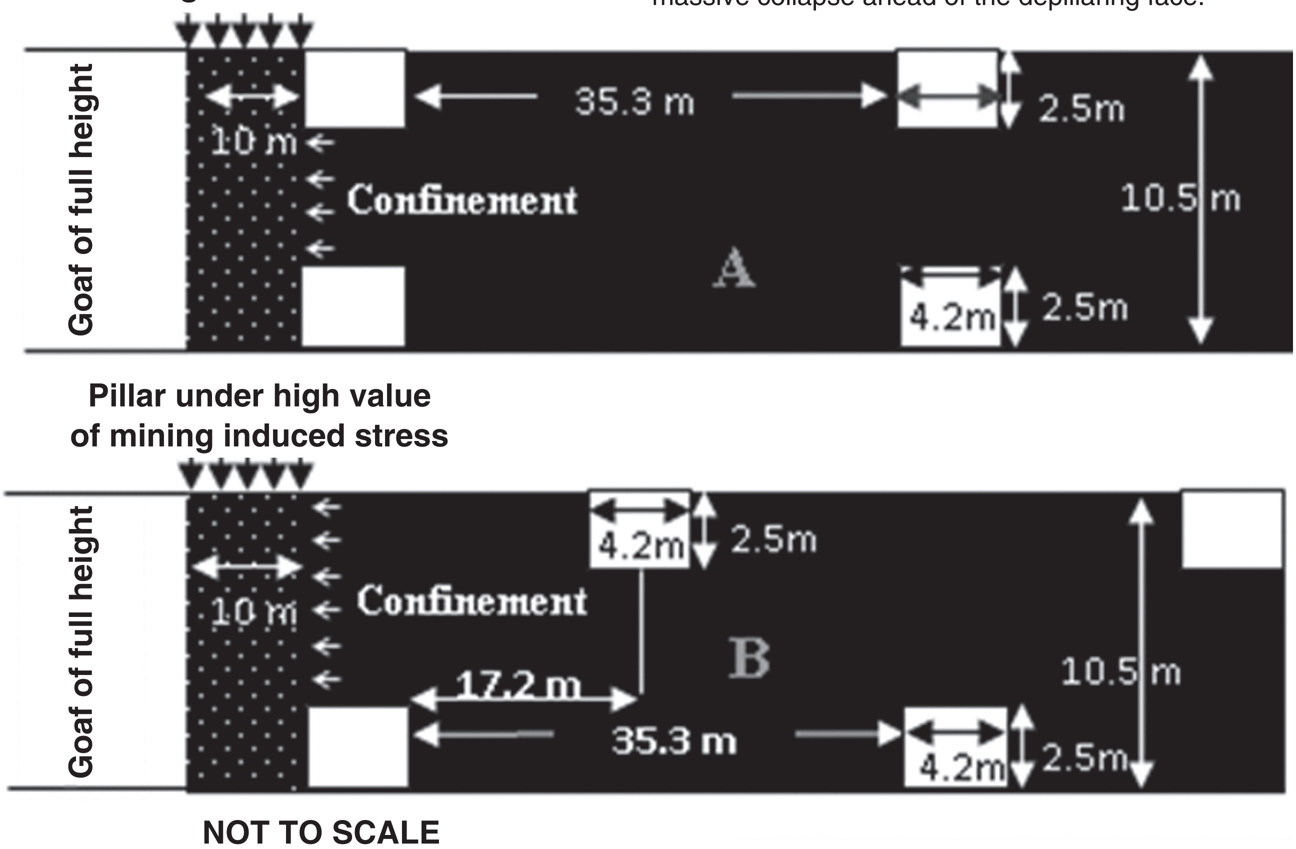
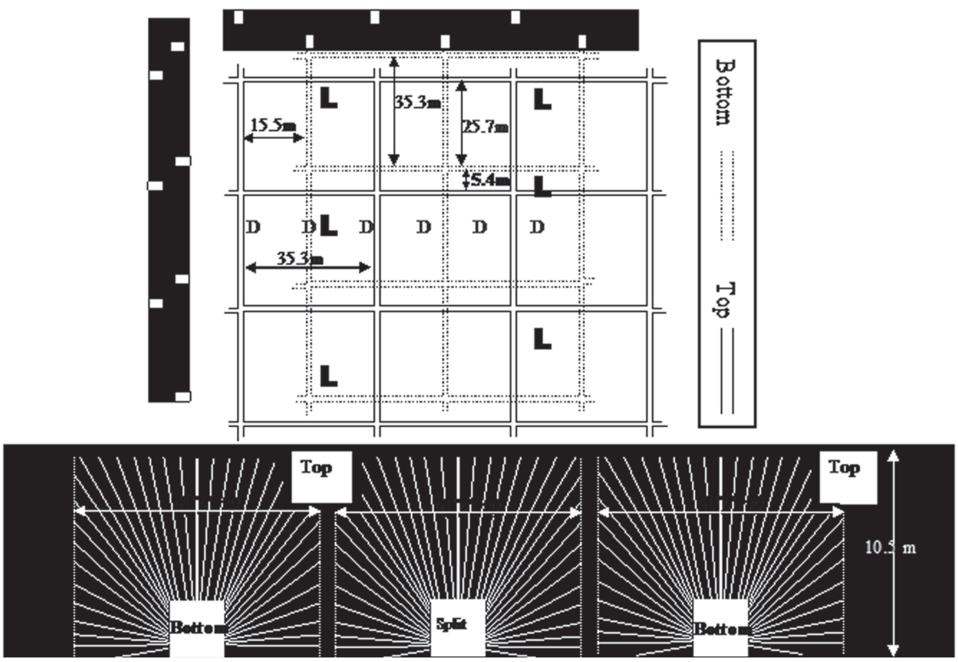


Figure 1 :
Two different goaf conditions for SLDTT of a thick coal seam developed along roof :
A) superimposed bottom section development & B) staggered bottom section development.

Based on simple ideas and results of laboratory investigations on simulated models, conventional superimposed development of the thick seam was replaced by staggered one (Figure 2) for SLDTT by the BG method (Singh, 2004). The performance of staggered development-based depillaring by the BG method was monitored during an actual field trial. Underground extraction of a 10.5 m thick seam in single lift by the BG method with staggered bottom section development (Figure 2) did not experience any strata control problem even during the major roof fall. However, a proposal and experimentation of the staggered development based SLDTT received considerable resistance, mainly, due to its deviation from the conventional approach. Although staggered development based depillaring was adopted at a number of mines successfully and the idea (with investigation results) was published in the best mining journal and received appreciation from top rock mechanics experts, it kept attracting critical comments from many senior professionals in the country, mainly, due to the habit of following set rules of superimposed development. In fact, it becomes necessary to fit the engineering with the site conditions considering the strata mechanics scenario in and around the line of extraction.

DEPTH OF COVER

Depth of cover influences stress regime and nature of the rock mass, which play important role for the design of an underground mining structure. The coal mining industry could envisage this influence of depth even before any actual field measurement of the stress. On the basis of experience, CMR provides increase in pillar size with depth of cover, which could also receive some theoretical support too (Sheorey, 1992). An experience of core sample logging found poor rock quality designation (RQD) of the first 50 to 80m of cores from the surface. Generally, an improved value of RQD is obtained for deeper strata. This observed change in, both, RQD and pillar design practices show a difference in rock mass characteristics with depth cover. It is difficult to find a universally acceptable definition of deep coal seams. A number of different



Section showing ring hole drilling from level and split galleries

Figure 2 :
Appropriate Strategy of Staggered Bottom Section Development (plan & section) for the BG Based SLDTT of No. 3 Seam of GDK-8 incline

limits of a deep coal seam exist but each is related to a specific factor. Coal-bump/rock-burst problem of underground mining is, generally, noticed after 300m (Sheorey & Singh, 1988) depth of cover but the pothole formation, for normal geological conditions, occurred only if the depth of cover is less than 100m (Singh, 2000). American legislation defines "deep cover" to be greater than 1,500 ft (457.2m) but for practical purposes, it is considered to be 1000 ft (304.8m) only (Mark, 2009).

During coal pillar extraction process (Chase et al. 2002), the property is called to be located at deep cover if the overburden exceeds 750ft (228.6m). As per field understandings, Deshmukh (1987) defines a deep coal seam if it is >200m below the surface. This value is close to the above reported American experiences of actual pillar extraction. CSIR-CIMFR observed that if the cover of a depillaring panel exceeds 200m, pillars around the face starts experiencing side spalling. In fact, an observed anomaly in nature of mining induced stress development (Singh et al., 2011a) could reasonably be resolved after considering 200m as demarcation line for deep pillars. Therefore, for an underground pillar extraction, 200m seems to be a reasonable value of cover to demarcate deep coal seams in Indian coalfields. When we go deep for mining we move from a structure controlled regime to stress controlled regime. Here, the design approach should emphasize global stability issue than the local one (Mark et al., 2002).

Although Bord and Plillar (B&P) is not a recommended method of mining at deeper cover, this is the dominant underground mining method in India due to different geo-economical reasons. Since introduction of a fully mechanized depillaring (MD) operation at Anjan-hill mine in February, 2003 (Leeming, 2003), a number of coal mines have adopted this approach and many of them are at deeper cover. Tandsi, GDK 11 and VK 7 mines practiced MD at nearly 260, 325 and 377 m depth of covers respectively. In chronological order, Tandsi was second and VK 7 was third MD mines. MD at Tandsi encountered a roof, which is difficult to be controlled, even over the galleries but an introduction of smart-bolting practices effectively controlled the roof strata (Oldroyd et al., 2006). Further, to arrest strata control problems during depillaring, alternate large size stooks were left inside the goaf. This resulted partial nature of the depillaring process at this site but it did not receive any strata control issue. MD at VK 7 experienced massive collapse in the first depillaring panel and, therefore, the depillaring method of this deep coal deposit was reviewed. To support the

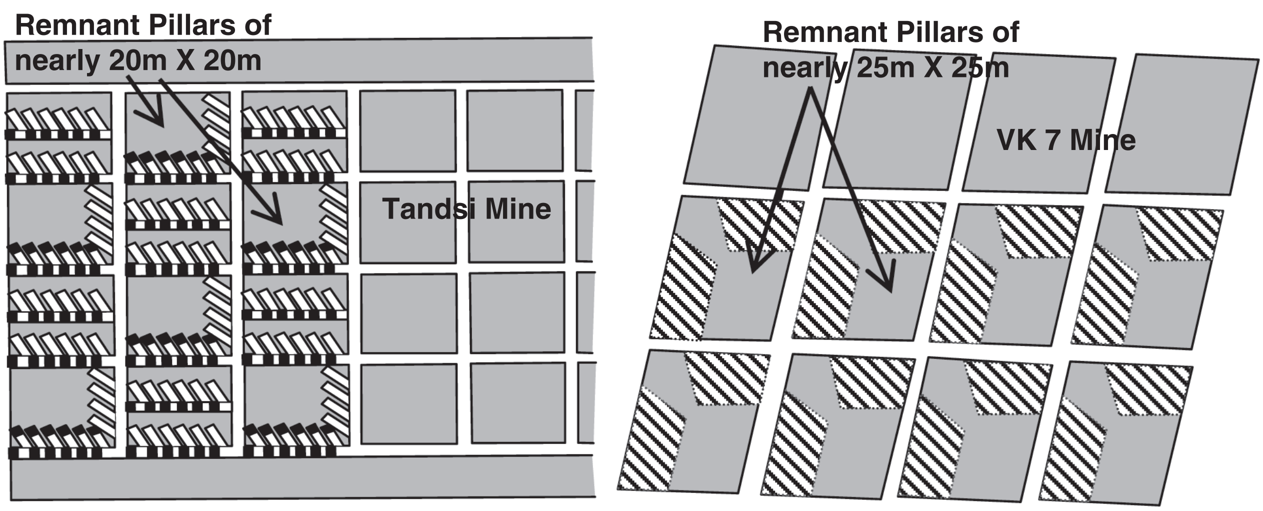


Figure 3 : Adopted Partial Extraction Methods at Tandsi and VK 7 Mines at Deep Cover (>200 m).

potential of full extraction, CSIR-CIMFR successfully conducted extraction of pillars from country's deepest (414m) depillaring panel 26 of VK7 (Singh et al. 2011b). CSIR-CIMFR, with a good understanding of the site and stress regime, submitted a technical report for full extraction at this mine (CIMFR Report, 2010). However, the foreign experts associated with the MD package of VK 7 submitted a report of partial extraction similar to that of Tandsi. Ultimately, as per the advice of foreign experts, a partial extraction method (Figure 3), similar to the Wide-stall mining (Singh & Singh, 1999) was adopted at the site.

It is to be noted here that the adopted partial extraction at Tandsi did not cause any strata mechanics problem after exhaustion of the panels at deeper cover. Highly caveable nature of the roof strata of this mine stabilized each individual void, created during the depillaring by partial extraction. Such stabilization seized any chance of accumulation of potential energy for catastrophic failure of the left-out pillars/stooks inside the goaf. However, the partial extraction at VK 7 did not experience any roof caving in the created voids inside the goaf. This caused considerable built-up of potential energy. In fact, the left out stooks inside the goaf started experiencing stress concentration with time due to the extraction of surrounding coal. Such a condition becomes apprehensive for global instability as failure of one stook (due to a combined effect of the stress concentration and its inherent geological weakness) may trigger rhythmic crushing and leading to massive collapse. While second panel of the partial extraction was in progress at VK 7, heavy sound and seismic activities were noticed from the sealed neighbouring panel of partial extraction. This resulted withdrawal of man and machine and termination of the partial extraction method. Finally, CSIR-CIMFR suggestion was appreciated realizing that only full extraction and caving is suitable for the deep cover and roof conditions of VK 7 mine. Again, at GDK 11, where MD was planned just after the VK7 collapse in the first depillaring panel, there was a conflicting technical suggestion in CSIR-CIMFR and foreign expert's reports. However, here full extraction and caving as per CSIR-CIMFR report (2008) was implemented, which proved to be one of the most productive MD depillaring operations in the country.

STRESS CONDITIONS

Underground coal mining encounters, generally, two types of stresses; in situ stress and mining induced stress. On the basis of extensive field measurements in different coalfields of different countries, the nature of variation of ratio of horizontal to vertical in situ stress with depth cover has been brought to the notice of the practicing mining engineers (Figure 4). The design of underground structures of coalmines brings importance of orientation and magnitude of high value of major horizontal stress, which has been highlighted by a number of planners. Attempts are being made by different research organizations to produce a map of in situ stress field of different coalfields of our country. This effort has produced some data but the available field data are scanty. However, these data of in situ stress field shows good agreement with its value estimated by the theoretical model of Sheorey (1994). The state of in situ stress remains nearly same at a mine site but the underground mining disturbs natural state of strata equilibrium, which introduces redistribution overlying strata load and causes development of mining induced stresses. The nature and value of mining induced stress keep varying as per dimension and condition of underground extraction (Singh et al., 1996).

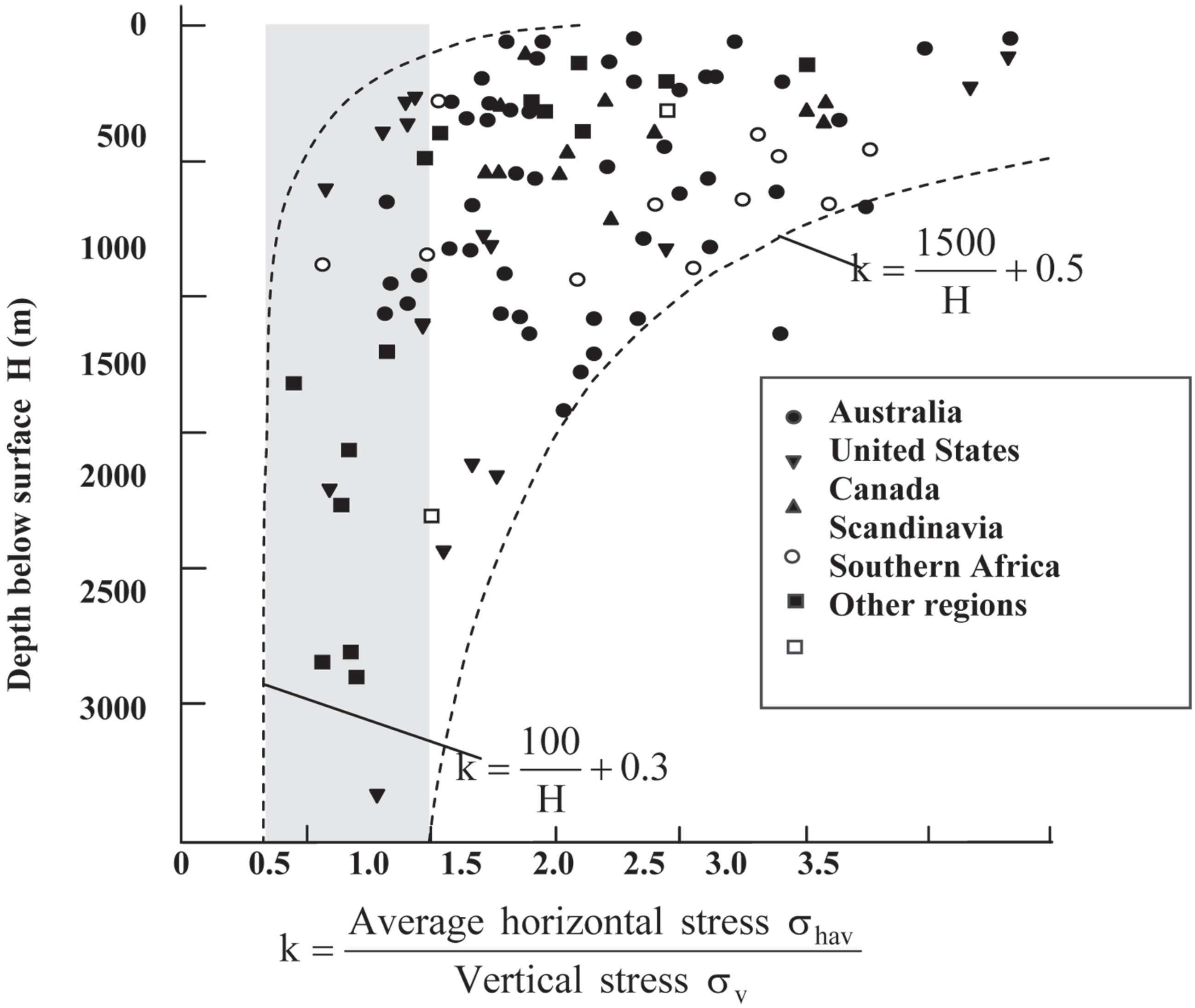


Figure 4 : Collated Worldwide in Situ Stress Data (after Hoek and Brown, 1980)

The rock load, directly above an opening, shifts onto surrounding pillars leaving a destress zone in the roof strata. Up to some extent of the opening width, the roof strata remains intact and the tributary area method can easily be adopted to estimate the value of mining induced stress till the excavation is symmetrical without roof fall. Once the caving of overlying strata occurs with an increase in the width of extraction, the scope of tributary method ends with the formation of cantilever after the roof strata failure. Figure 5 shows the general nature of vertical stress redistribution around a coal mining face. In addition to the nature dimension of the excavation, nature of roof strata and depth cover are the two major parameters to influence it (Singh et al. 2011a). An extensive study of these parameters in and around a depillaring operation not only helped and explaining the apprehension about the role of cable bolts in further strengthening the overlying competent strata inside the goaf (Singh et al. 2001) but also provided basis to apply high capacity, pre-tensioned, stiff and resin grouted roof bolts at the goaf edge (Ram et al., 2017) for MD operations. An idea of

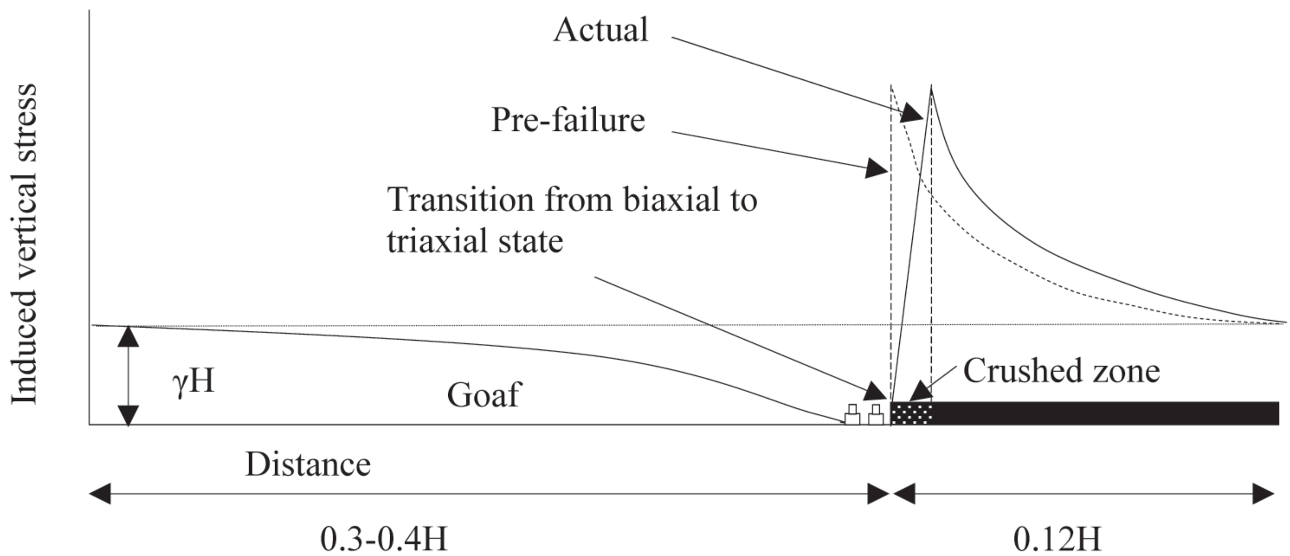


Figure 5 : Mining Induced Stress Redistribution Around a Coal Mining Face

using a grouted steel rope under tension was used for SLDTT of a thick coal seam. The cable-bolt supported a high roof and overlying coal band, which improved safe span of overhanging strata near the goaf edge of the SLDTT. A 6.5m thick coal seam (developed along floor with 2.5m gallery height), standing on pillars, at New Chirimiri Ponri Hill (NCPH) colliery of the Chirimiri area of the South Eastern Coalfields Limited (SECL) was extracted in single pass. Here, massiveness of the coal seam and pattern of stress redistribution around the depillaring face supported field application of cable-bolting technique, which could extract full thickness (6.5m) of the seam in single pass. Conducted field trial demonstrated that the redistribution of stresses in and around the depillaring face creates a favourable situation for the application of cable bolts/roof bolts (Singh et al., 2001). Field performance studies of roof bolt-based breaker line support (RBBLS) in MD operations found that it works effectively under the shadow of stable natural supports. It is also found that position of RBBLS needs to be varied from 0.5-2 m out-bye side from the goaf edge. This variation is to adjust the observed extent of spalling/loosening (Figure 6) of the surrounding natural supports, mainly, due to mining induced stresses (Ram et al., 2017).

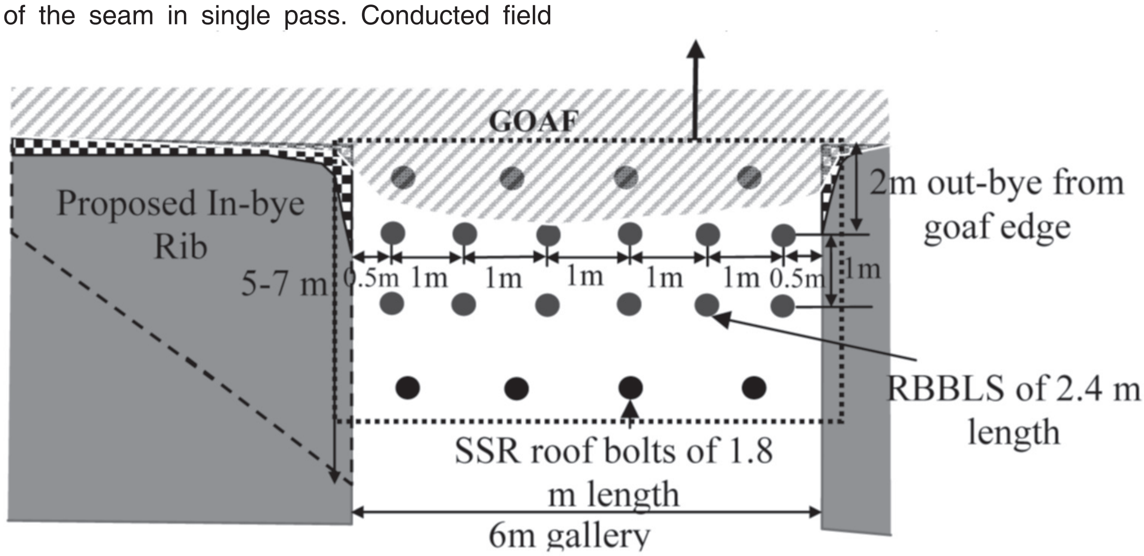


Figure 6 : Control of the Goaf Encroachment beyond the RBBLS Position in a MD Panel

ROCK MASS

Coal seams of India, mostly, belong to Lower Gondwana age, which are of competent nature and are surrounded by a rock mass similar quality. This is the most important reason for the process of pillar formation and dominance of B&P method for underground mining. Most of the Indian coalfields possess multi-seam mining conditions, where many of the close seams/sections have even less than 9m thick inter-burden parting. Final extraction in B&P mining of contiguous seams/sections becomes very difficult due inherent broken nature of the depillaring operation. Here, thickness and quality of the parting between two close seams becomes important for safe and efficient depillaring. When the parting between the two close seams is fragile, it requires to improve its inherent weakness and simultaneous depillaring is found to be the best option. CSIR-CIMFR offer against an open tender for underground extraction of contiguous sections (3.5 m top and 6.0 m bottom) of 12.5 m thick Zero seam of Chirimiri colliery underneath Bartunga hill of M/s South Eastern Coalfield Limited (SECL) became successful to prepare technical feasibility for the site. Highly laminated parting of only 3m thickness between the two sections is found to be comprised of alternate layers of shale, carbonaceous shale, coal and mudstone. This parting was found to be fragile and problematic for safe and clean underground extraction of both the sections. Top and bottom sections of the mine were developed on pillar along floor (Figure 7) maintaining superimposition and applying roof bolts to support the openings.

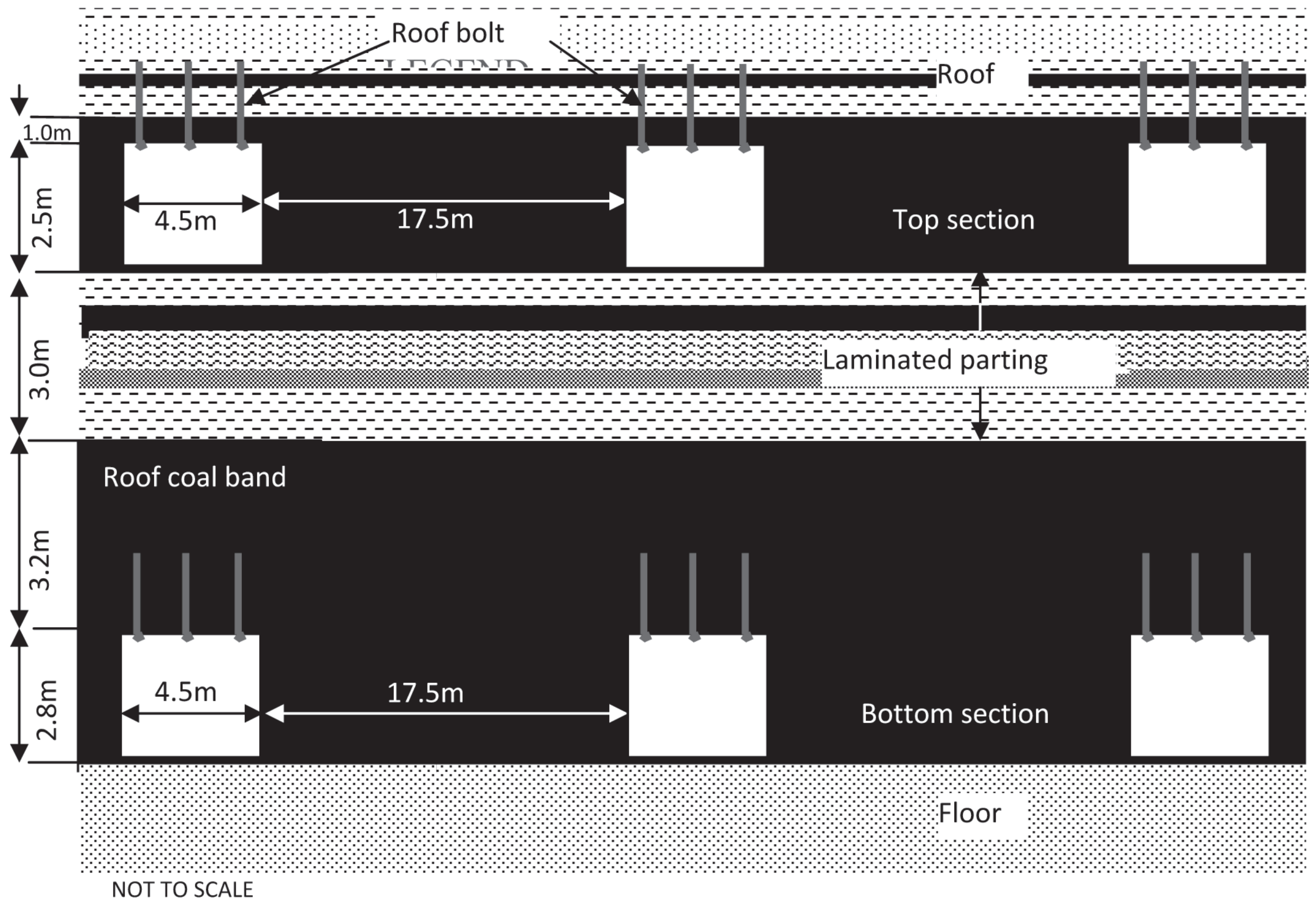


Figure 7 : A Sectional View of Superimposed Development of Pillars in Both Sections of Zero Seam.

For this site, an idea of underpinning was derived from our cable-bolting experiences, which was tested on simulated models first before an attempt to validate in the field. Study on simulated model suggested simultaneous extraction of the two sections of the Zero seam (Figure 8). On the basis of laboratory testing and investigations on simulated models, the underpinning approach was applied for simultaneous depillaring of both the sections successfully (Mandal et al., 2008). Taking advantage of the top section development, laminated parting and roof coal band of the bottom section was reinforced simultaneously by a full column grouted cable bolt of suitable length from the floor of the top section. This process of reinforcement called underpinning, which consolidated parting stability and provided additional thickness to the critical parting thickness as the roof coal of bottom section was attached with the parting. Depillaring in both the sections was conducted by splitting and slicing and maintaining superimposition of workings in the two sections. The reinforced overlying roof coal band with parting by underpinning did not cause any strata control issue in splits and slices of the thick bottom section, whose roof coal band was won during retreat. In fact, the underpinning worked like cable-bolting for the thick bottom section.

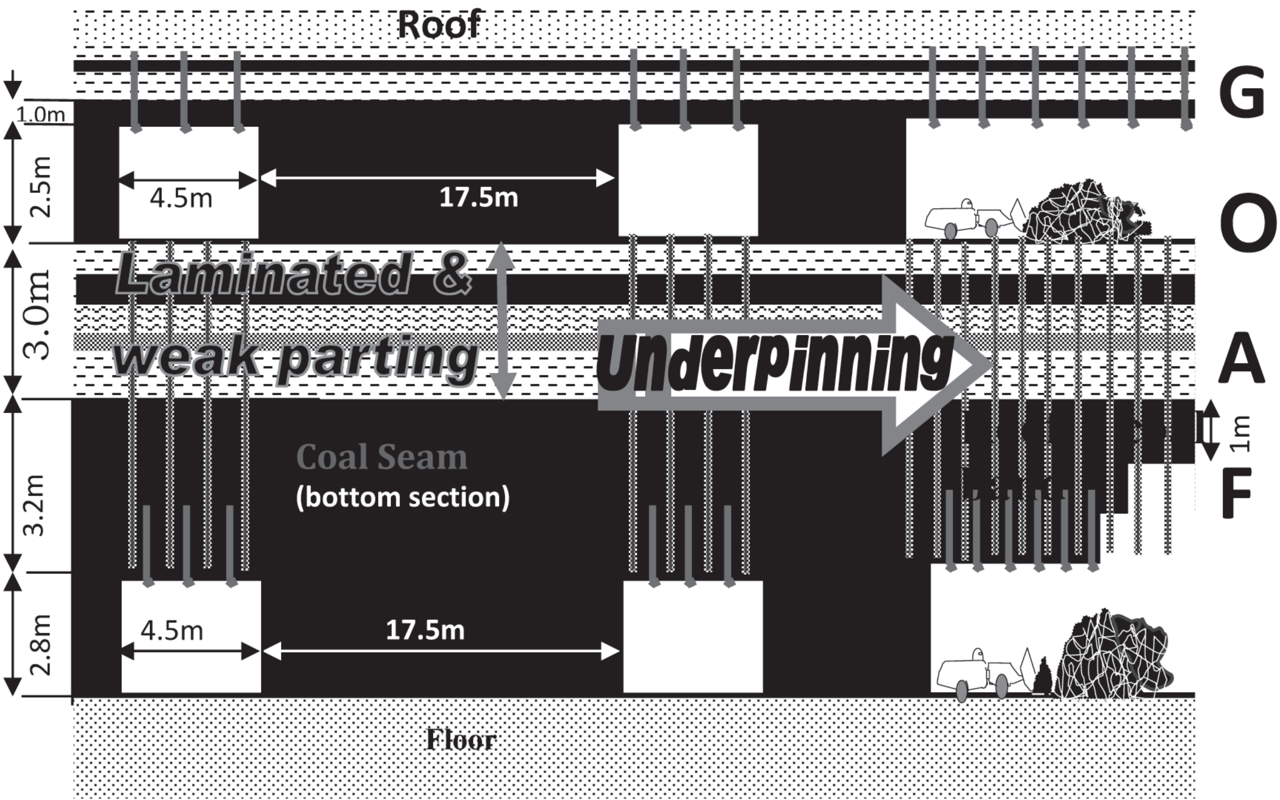


Figure 8 :
Schematic Diagram Showing Simultaneous Depillaring
of Top and Bottom Sections with Underpinning and Roof Bolt Support.

CONCLUSION

Underground coal mining is facing an uphill task of efficiency and safety. These issues require a large scale application of the modern technologies. However, the application of modern technologies in Indian coalfields is difficult without good understanding of the site conditions. The given examples in this article depict importance of application of the basic rock mechanics principles to improve efficiency and safety during introduction of the new mining approaches. Uniqueness of the rock mass and stress field for application of the rock mechanics principles can be dealt with the geo-mechanical experiences, gained during different conducted investigations at these sites.

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SELF-ADVANCING GOAF EDGE SUPPORT (SAGES) FOR DEPILLARING OPERATION IN UNDERGROUND COAL MINES

Upendra K Singh*, Dheeraj Kumar[1], NVN Reddy[2], John Anand[3]

INTRODUCTION

An S&T project tilted “Development of Self-Advancing (Mobile) Goaf Edge Supports (SAEGS) for Depillaring Operations in Underground Coal Mines” was awarded by the Ministry of Coal, Government of India vide letter No. 34012/2010-CRC-I, dated 12th August, 2010 to IIT (ISM), Dhanbad.

A Mobile Roof Supports (MRS) was developed jointly by IIT (ISM), Dhanbad and Jaya Bharat Equipment Pvt. Ltd., Hyderabad with the help of a patented concept of “Base lift mechanism” that solves constraints of the supports at the Goaf Edges and associated safety concerns. To differentiate them from the conventional Mobile Roof Supports, they are named as “Self-Advancing Goaf Edge Support” (SAGES). The unique design of SAGES facilitates substantial reduction in their weight and cost up to 70% of the mobile Goaf Edge supports available in the international market. In the conventional mobile supports, the crawlers are designed to withstand the rated capacity of support including its weight. In the present support (SAGES), Figure 1, the base and the crawlers are designed such that the support load is transferred to the base only and crawlers are free. After release of load and lowering of canopy, the base is lifted and the support weight is transferred to the crawlers.

Thus, the crawlers in the present support system are designed to carry the weight of the support only. This feature of the SAGES makes it lighter and cheaper compared to that of the mobile supports available in the international market. Further, the SAGES uses two hydraulic cylinders with canopy stabilizers compared to that of four to seven hydraulic cylinders in conventional mobile supports.

With the application of the above mentioned unique features i.e., the base lift mechanism and canopy stabilization, the SAGES has become compact, light weight and cost effective with minimal maintenance. The hydraulic circuit of SAGES is operated by a self-contained power pack through solenoid valves. The solenoid valves are operated by a RF based remote hand set unit from a distance up to 30 m. The SAGES are covered from three sides by foldable steel plates for preventing the coal and rock debris entering inside the support during side spalling and rock falling from the roof. An electronic data logging and display system having battery backup unit, facilitates continuous monitoring of the roof load and convergence. An audio-visual warning system is in-built into the system for giving warnings related to status of strata load on supports.

FEATURES AND ADVANTAGE OF SAGES OVER CONVENTIONAL GOAF EDGE SUPPORTS

Important Features of SAGES

1. **Major sub-assemblies (Figure 1).**
   a. Crawler driven under carriage with an integral Power Pack, Electrical control box, Links and Plough.
   b. Base with Double Telescopic Legs.
   c. Canopy with Stabilizers.
2. The unique design of the Support permits the “Base” to slide inside the under carriage.
   a. In “Support mode”, when the Support Legs are extended, the base gets lowered and rests on the floor. Further, leg extension lifts up the canopy till it touches the roof.

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b. In “Mobile mode” when legs are lowered, first the canopy gets lowered and later the base gets lifted up.

c. In “Support mode” the roof load directly gets transmitted to the floor through canopy, legs and base.

3. **Remote Control**

The solenoid operated direction control valves can be actuated by a remote radio-transmitter through a radio-receiver located inside the F.L.P control box

4. **Digital Display and Monitoring.**

a. Continuous digital Load and convergence display.

b. A push button switch pressed twice in one second to initialize the convergence to zero.

c. Dial type load level indicator for each leg is installed above the FLP box.

d. Audio visual warning as given in Table 1. The warning conditions can be rest. Continuous Load and convergence data logging unit in side FLP enclosure.

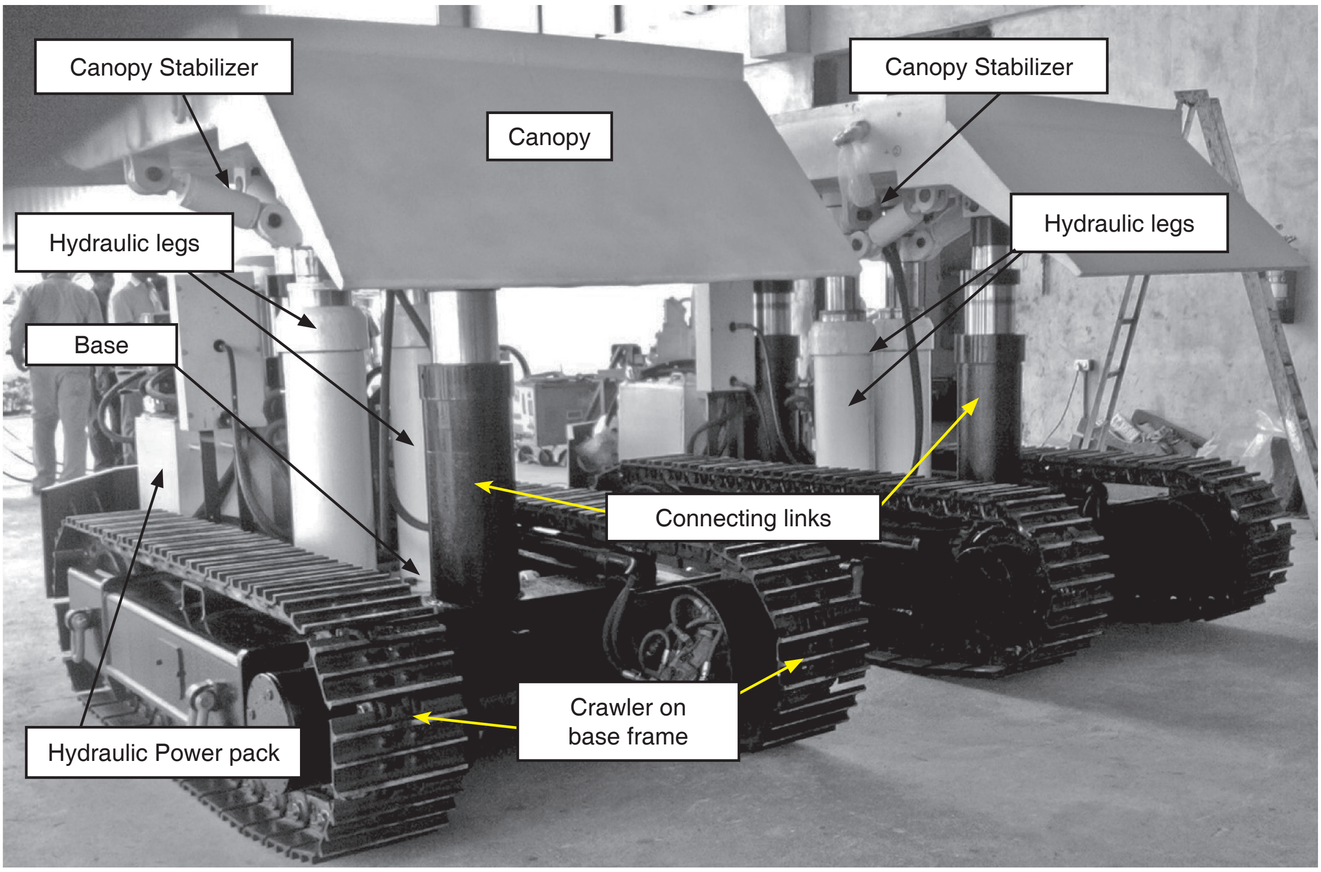

Figure 1 Components of SAGES

Table 1 : Audio Visual Warning Matrix

Sl. No.	Condition	LEDs			Audio
		Green	Yellow	Red	
1.	50 t < Load < 150 t	Glow	OFF	No action	No action
2.	150t <= Load <190 t	OFF	Glow	No action	No action
3.	Load > = 190 t	OFF	Glow and blink	No action	No action
4.	10 mm < Conv <20 mm	No action	No action	Glow	Slow Beep
5.	Conv >= 20 mm	No action	No action	Glow and blink	Fast beep

e. Battery backup for the data logging system for duration of 10 days.

5. **Other features**

a. A pilot operated non-return valve (NRV) is fitted in each leg. This NRV ensures positive pressure in the legs when the pumping is stopped and power to the support is disconnected (Figure 2).

b. A yield valve in each leg allows the support to yield at the rated load of 200t.

c. The two through axial piston motors and planetary reduction gear boxes, wet multi disc parking brakes are integral to the drive modules. The parking brakes prevent inadvertent support movement on steep gradients. The tracks are powered by two independent pump outputs.

d. The support under carriage, canopy and base are box type fabrications using high tensile welded steel plates. The legs are made out of high strength cold drawn Steel (CDS) Tubes.

e. 550 volts 3-phase electrical supply to the SAGES is fed by a flexible trailing cable from a remotely placed Gate End Box.

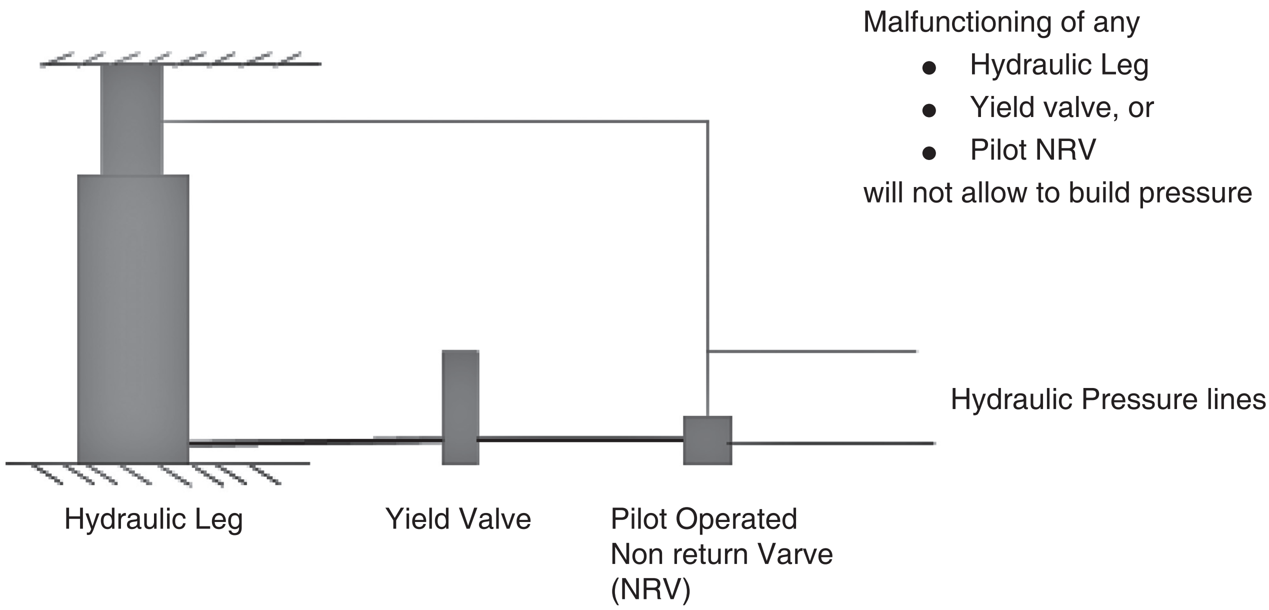

Figure 2 : Hydraulic Circuit of a Leg in SAGES.

Distinct Advantages of the SAGES over conventional Goaf Edge supports

1. At a Goaf Edge, two SAGES provide positive setting load of 100 × 2 = 200 t equivalent to 0.35 MPa to roof. This prevents early separation of layers of strata in the roof.

2. Further, during yielding, two SAGES continue to apply 200 × 2 = 400 t, equivalent to 0.70 MPa thrust to the roof allowing its controlled deformation. This prevents deterioration of working place at the Goaf Edge till SAGES are withdrawn, advanced and set to next Goaf Edge. Yielding of supports occurs when strata deformation imparts load on the support exceeding their capacity. Progressive extraction of slices usually leads to excessive deformation of the strata in its vicinity.

3. Performance of SAGES is superior as a breaker line support compared to that of the rock bolts type installed at a Goaf Edge. A rock bolt type breaker line support loses its efficacy once the adjacent rib pillar yields and bed separation takes place in roof. In such cases, the SAGES remain effective in supporting the roof.

4. SAGES eliminate workers from the exposure to the hazardous roof conditions associated with withdrawal and setting up of the conventional supports.

5. SAGES eliminate the usage of timber. Therefore, the workmen are not required to transport and set up the timber supports at the Goaf Edges.
6. SAGES can be set instantaneously within few minutes as compared to the conventional supports systems consisting of chocks and props requiring a shift time. Thus, available time for production is substantially increased.
7. SAGES facilitate higher percentage of recovery of the coal pillar.

FIELD TRIAL OF SAGES

First field trial of two numbers of SAGES was undertaken in II-D panel, seam no. 2, Victory pit, Bastacola underground mine, BCCL (Figure 3). Based on feedback data from the field trial, another two SAGES were modified and their field trail was conducted in I-D panel, seam no. 1 in Victory pit. The seam thickness was 4.5 m. Development galleries were 2.5 m high, 4.2 m wide driven along the floor leaving 2 m coal in roof. Two SAGES were installed against the coal roof at a Goaf Edge as seen in Figure 3.

Some problems in operation were identified during the field trial such as poor traction and blockage of the control valves. A few shortcomings in design of SAGES were also identified during the field trial in Bastacola.

All six SAGES were refurbished on the basis on feedback from the field trial in Bastacola, BCCL. The final trial began on January, 2017 in panel 2AN13 (Figure 4) in RK7 Incline mine, SRP area, SCCL under project SAGES Phase–II of the Ministry of Coal (MoC), Government of India. Figure 5 shows two SAGES installed in Block B of panel 2AN13. Details of the panel 2AN13 are given in Table 2.

Table 2 : Details of Pillars and Slices in Panel 2AN13

Sl. No.	Average Size of Pillars (Centre to Centre)	30 m × 30 m
1	Panel width	30*3 = 90 m
2	Depth of cover	192 m – 244 m
3	Split width not more than	4.50 m
4	Slice width not more than	4.0 m
5	Rib width not less than	2.0 m
6	Last (out bye) rib width not less than	3.0 m
7	Average seam thickness	2.4 m
8	Date of commencement of panel	09.01.2017

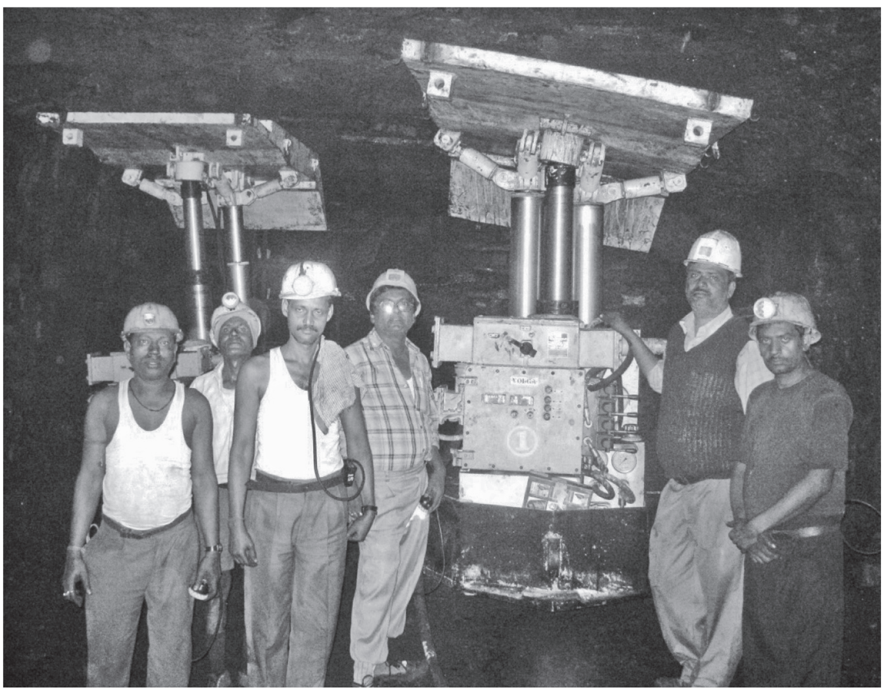

Figure 3 : SAGES at installed at a Goaf Edge in II-D panel, seam no. 2, Victory pit, Bastacola underground mine, BCCL

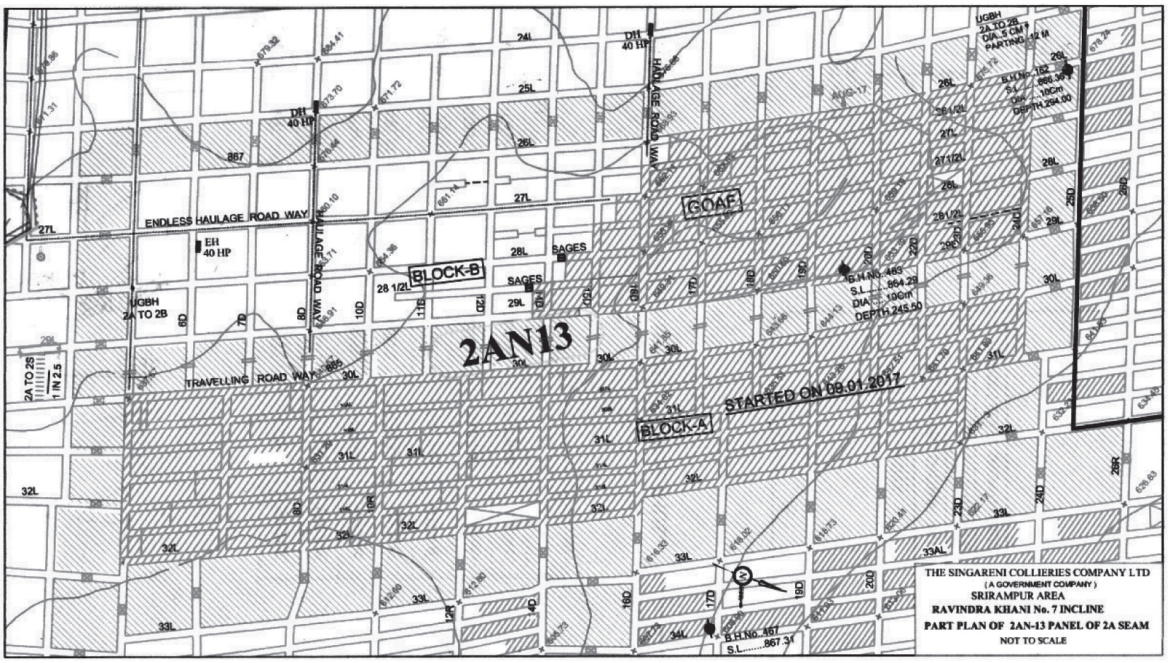

Figure 4 : Plan of Block A and Block B of Panel 2AN13, RK7 Underground Mine

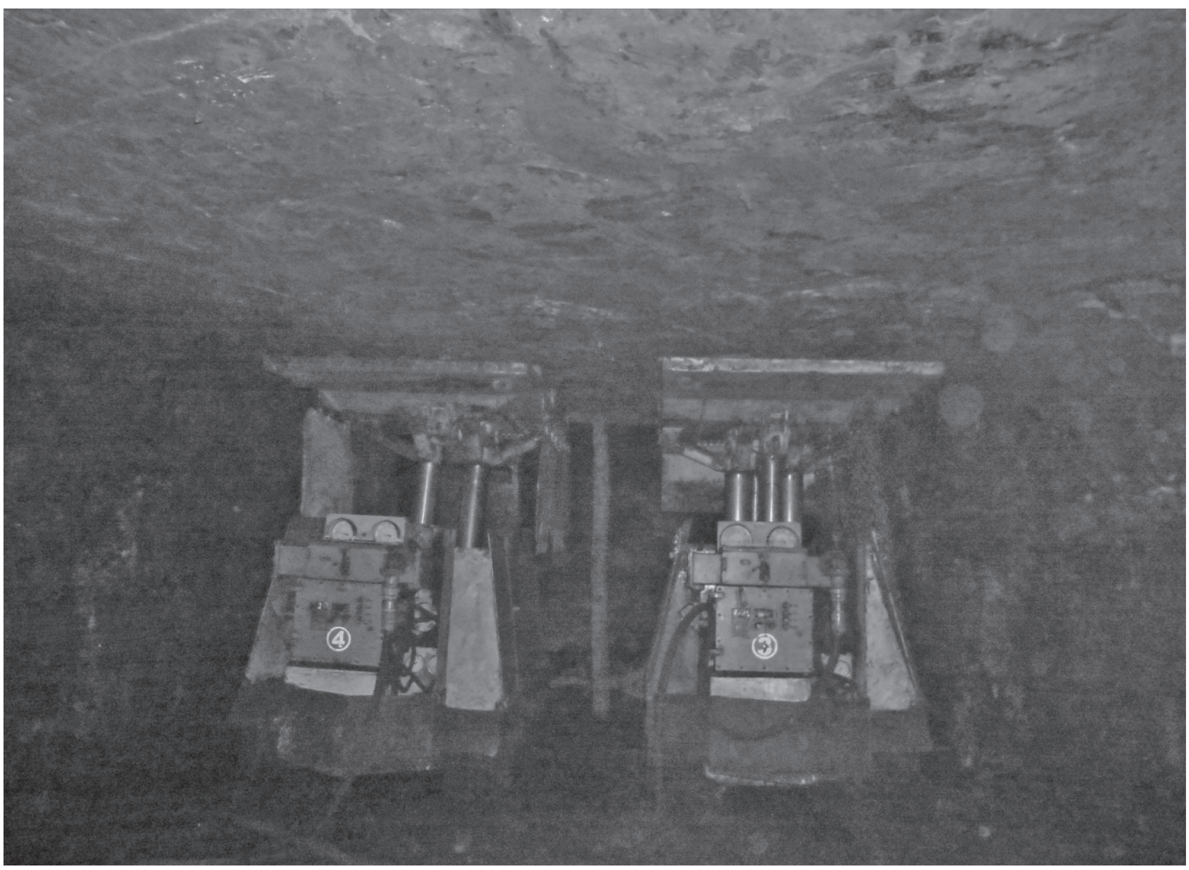

Figure 5 : SAGES 3 & 4 installed at a Goaf Edge in Block B of Panel 2AN13

Response of SAGES at Goaf Edges were continuously recorded at an interval of 1 minute using a Data logger installed in each SAGES. Once in a month, data, load and convergence of SAGES were finally downloaded using a field computer and data storage memory in the logger was emptied for storing the data for next one month. A typical response of SAGES with time is given in Figure 6. We observe, in Figure 6 that yielding of legs in SAGES-1 begin at mid night of 28th September, 2017. The yielding process continued till morning of 30th September till it was withdrawn from the Goaf Edge. SAGES-1 & 2 were installed in morning shift of 26th September at the Goaf Edge of slice no. 57 in Block A. SAGES-1 was set on the dip side and SAGES-2 was on rise side.

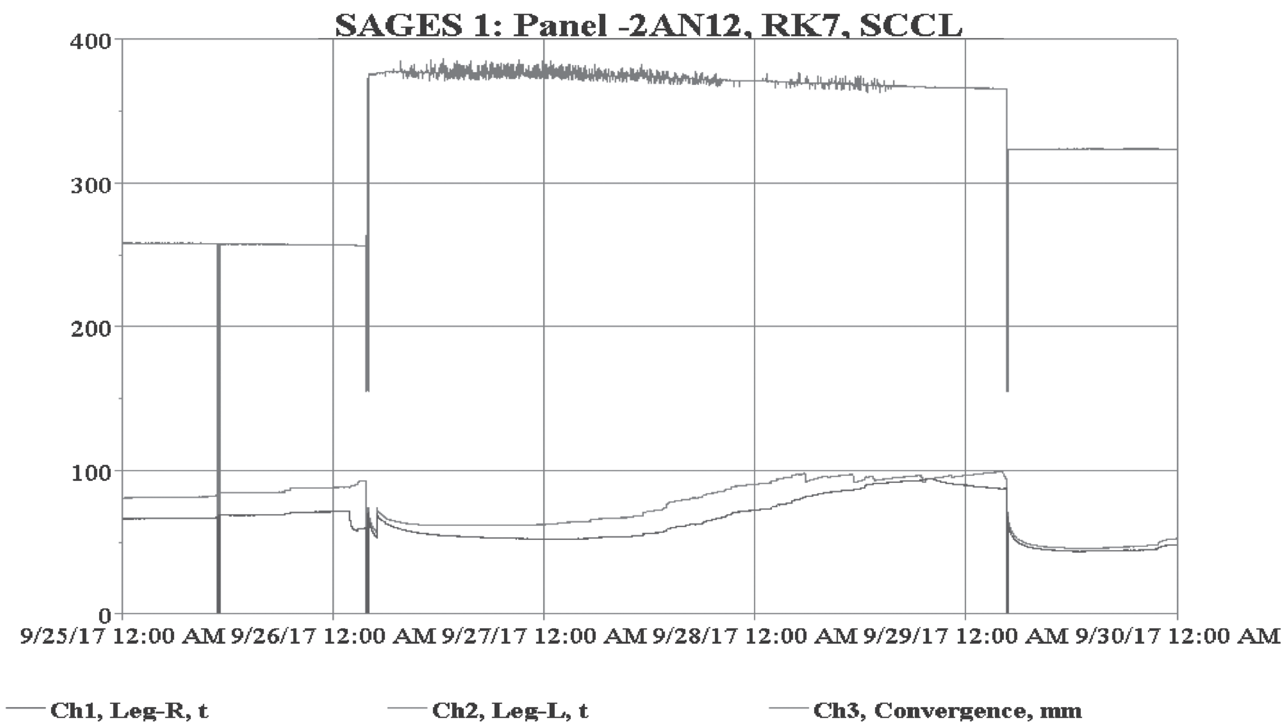

Figure 6 :
Plots of strata load and roof floor convergence showing yielding of SAGES - 1 during extraction of slices in Slice no. 57, Block A.

The setting load and load at time of withdrawal of the SAGES are plotted in Figure 7 as function of slice number. SAGES 1 and 2 have been used as Goaf Edge support in 67 slices, i.e. they are subjected to 67 cycles of loading and SAGES 3 and 4 have been used as Goaf Edge support in 36 slices. The load and convergence data downloaded from the SAGES have been analyzed. The responses of SAGES to strata behaviour at Goaf Edges are summarized in Tables 4, 5, 6 and 7 respectively. We find that

(a) In almost all slices, the setting loads were close to the specified setting load of 100 t (Table 3 and Figure 7).

(b) The mean value of strata loads on the SAGES was 130 t after completion of slices. However, more than 190 t load close to it capacity was observed only in 6% and 14 % of slices in rise and dip side SAGES respectively.

(c) Yielding of rise and dip sides SAGES have been observed in 8% and 19 % of slices respectively.

(d) Mean value of roof floor convergence was 3 mm on rise side and 7 mm on dip side. More than 15mm convergence was observed only in 1% slice on rise side and 8% on the dip side.

(e) Ground condition at the working area remained normal and do not deteriorated up to 15 mm convergence at the Goaf Edges. Spalling of coal from ribs and galleries, fractures in roof and sounds of rock fracturing do occur when convergence increases more than 15 mm at the Goaf Edges.

(f) Average slice extraction duration was 4 days.

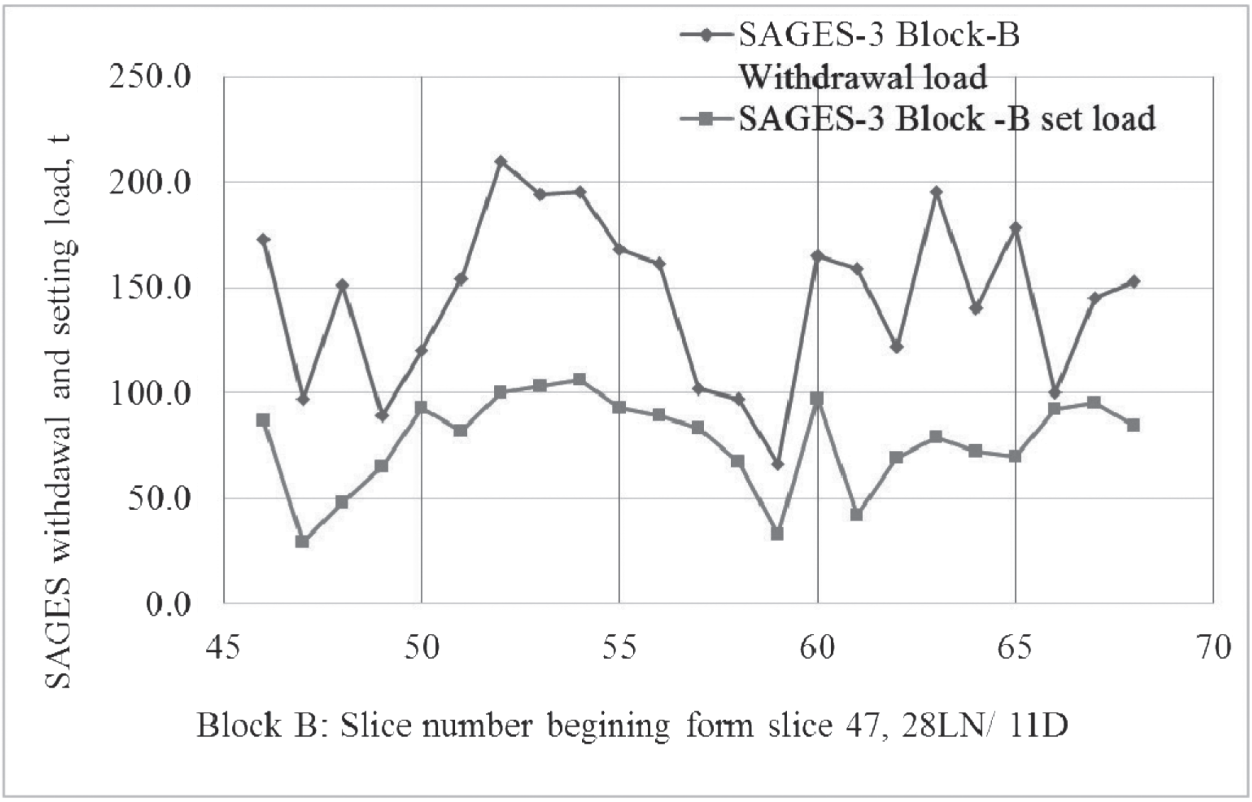

Figure 7 : Withdrawal and Setting Loads of SAGES-4 in Slices, Block B, Level 28LN

Table 3 : Response of SAGES to Strata Load at Goaf Edges

Sl. No.		Location of SAGES in Level Drive at Goaf Edges					
		Dip Side	Rise Side	Dip Side	Rise Side	Dip Side	Rise Side
		1	2	3	4	1 & 3	2 & 4
1	**Setting Load of SAGES**						
(a)	Mean value, t	77	101	77	101	98	105
(b)	>95t, %	82	72	22	65	60	69
(c)	>50t, %	100	100	83	96	94	98
2	**Load at Withdrawal of SAGES**						
(a)	Mean value, t	129	120	129	120	132	125
(b)	>190t, %	3	3	14	6	8	4
(c)	>100t, %	85	77	64	61	75	69
3	**Yielding Events of SAGES**						
(a)	In no. of slices	6	1	6	4	12	5
(b)	% of no. of slices	15	3	26	17	19	8
% - percentage of numbers of extracted slices							

Table 4 : Roof-floor Convergence of Strata at Goaf Edge Supported by SAGES

Sl. No.	Roof Floor Convergence Recorded by SAGES	Location of SAGES in a Level Drive at Goaf Edge					
		Dip Side	Rise Side	Dip Side	Rise Side	Dip Side	Rise Side
		1	2	3	4	1 & 3	2 & 4
(a)	Mean Value, mm	6	3	7	3	7	3
(b)	>10 mm, %	18	10	25	6	21	8
(c)	>15 mm, %	8	0	8	3	8	1
% - percentage of numbers of extracted slices							

Table 5 : Slice Extraction Duration with SAGES at Goaf Edge

Sl. No.	Slice Extraction Duration	SAGES in a Level Drive at Goaf Edge		
		1&2	3&4	1, 2, 3 & 4 combined
(a)	Mean value, days	4	5	4
(b)	>5 days, %	28	33	31
(c)	>8 days, %	8	14	11
% - percentage of numbers of extracted slices				

Table 6 : Duration of Withdrawal, Movement and Setting of SAGES at Goaf Edges

S. No.	SAGES Withdrawal and Setting Duration	SAGES in a level drive at Goaf Edge		
		1 & 2	3 & 4	1, 2, 3 & 4 combined
(a)	Mean value, min	22	40	31
(b)	>40 min, %	15	25	20
(c)	>60 min, %	3	17	9
% - percentage of numbers of extracted slices				

COST BENEFIT ANALYSIS

Direct Cost Benefit

There is direct cost benefit of using SAGES at Goaf Edges. By using SAGES in each slice, we save in manpower required for withdrawal and setting of conventional Goaf Edge supports, loss of timer in Goaf and, breaker line support consisting of 'W' strap and bolts. Savings in one slice, in Rupees, are

i. Saving of Manpower = 18,000

ii. Saving of 10% loss of timber = 3,283

iii. Saving of 'W' Strap and bolts = 2,454

iv. Total saving per slice = 23,737

Direct Annual Saving in using SAGES at all Goaf Edges in a Panel

(a) Pillar size, corner to corner = 26 × 26 m

(b) No. of slices in the pillar = 6

(c) Saving in using SAGES at all the Goaf Edges of 6 nos. of slices in a pillar @ Rs. 23,742 = 6 × 23,737 = Rs. 142,452

(d) Amount of coal in the pillar in seam of thickness 2.4 m = 26×26×2.4×1.4 = 2, 271 t

(e) Amount of coal extracted from the pillar assuming 70% extraction = 1,590 t

(f) Production per day from a sub panel of size 3 × 15 = 45 pillars = 500 t/day

(g) No. of pillars extracted in 300 working days in a year = 500 × 300/1590 = 94

(h) Annual saving in using SAGES at Goaf Edges in 94 pillars = 94 × 142,452 = Rs. 134 Lakhs.

Indirect Cost Benefit

(a) Higher rate of production due to saving in time of

- Withdrawal and setting conventional supports,
- Regular practice of drilling and blasting holes in each slice for inducing caving.

(b) Shortening in duration of completion of a slice prevents deterioration of working area. It means we will be able to abandon the slice before ground condition deteriorates.

(c) Increase in percent of extraction from the ribs.

(d) Increase in size of a panel for a given incubation period due to higher rate of production with SAGES as Goaf Edge support. Thus, saving in cost of isolation stopping of panels.

(e) Safety aspects outlined above.

These benefits have bearing on cost saving in depillaring operations. It is expected that these benefits will lead to 2-5% increase in production with the present setup of depillaring operations in underground coal mines. Thus, for a daily production of 500 t from a panel, there will be 10 to 25 t of additional production per day with SAGES installed at all the Goaf Edges of a panel. This could be easily achieved by one to two extra rounds of drilling, blasting and loading in view of indirect benefits of SAGES stated above.

Discounted Cash Flow (DCF) Analysis of the Direct and Indirect Cost Benefits of SAGES

A DCF analysis of cost benefit of use of SAGES at Goaf Edges has been performed over a period of 10 years accounting direct and indirect cost benefits stated in above section. Discount rate of 12% and linear depreciation over a period of 10 years have been accounted. Maintenance and operation costs increase as SAGES becomes older. Income Tax of 30% on profit and royalty of 14% on sale value of coal are accounted. Table 7 contains results of the DCF analysis. It reveals that NVP (Net Present Value) over a period 10 years is positive for all the three cases of 0%, 2% and 5% increase in production. It means that even if there is no increase in production, the use of SAGES at all the Goaf Edges in a panel will lead to economic benefits to the mines besides enhanced safety of work places near the Goaf Edges

Table 7 : Discounted Cash Flow Analysis of Cost Benefit of SAGE

Sl. No.	Item	Increase in extraction of coal using SAGES		
		0	2%	5%
	Initial Investment in Sages			
1	No. of SAGES in a sub panel of size 3 × 15 = 45 pillars	12.0	12.0	12.0
2	Price of SAGES in Lakhs (unit cost of SAGES, Rs. 39 Lakhs)	468	468	468
Saving from using SAGES at all the Goaf Edges, replacing breaker line bolts and conventional timber supports.				
3	Annual saving in using SAGES, Rs. Lakhs [Direct Annual Savings (h)]	134.0	134.0	134.0
	Increase in Extraction			
4	Annual increase in production, t (annual production [Direct Annual Savings (f)] : 150,000 t)	0	3,000	7,500
5	Sale realization @ 2700/t, Rs. Lakhs	0	81.0	202.5

Sl. No.	Item	Increase in Extraction of Coal Using SAGES		
		0	2%	5%
6	Expected reduction in loss after deducting 50% operational costs and 14% royalty on sale value of coal, Rs. Lakhs.	0	29.2	72.9
	Saving in Strata monitoring instrumentation cost, Rs. Lakhs/yr.	20.0	20.0	20.0
	***NPV over 10 years, Rs. Lakhs at discounted rate of 12%**	**76**	**191**	**364**
	PVR (Present Value Ratio) : Return per unit investment	**1.16**	**1.41**	**1.78**
	* SAGES operating and maintenance cost : Year 1-3 = 5%; Year 4-6 = 8%; Year 7-10 = 12% of price of SAGES (2); Linear depreciation of SAGES over 10 years and Income Tax 30%.			

Outcome of the Field Trial

On the basis of field trial of SAGES, DGMS has accorded approval of this support for use in underground coal mines vide letter no. S 29023/435/2012/S&T(HQ)/398 dated 30.07.2019. A summary of outcome of the field trial is given as follows :

(a) The SAGES have been found suitable for use as a Goaf Edge support in underground coal mines for extraction of pillars.

(b) Technical and operation details of SAGES have been standardized and they are ready for commercial manufacturing (Table 8).

(c) With SAGES at Goaf Edges, a safe practice has been formulated for drilling and blasting in slices for inducing caving. This may be required when roof is not easily caving and causing stress buildup in working area.

(d) This is safe and cost effective over conventional supports being used at present. A Discounted Cash Flow (DCF) analysis shows that use of SAGES at all the Goaf Edges in a panel will lead to economic benefits to mines.

(e) The SAGES are techno-economically viable for commercial use in underground coal mines.

Future Development of Higher Capacity SAGES for use with Continuous Miners

The 200t SAGES which specifications are given in Table 8 have been found technically and economically viable for use at Goaf Edges in depillaring panels in seam height up to 3m, using LHD and SDL for loading of blasted coal. For seams of thickness more than 3m and using continuous miners (CM), SAGES of 500t capacity are required. The development and field trial of SAGES of 500t capacity shall be under taken as project SAGES – III.

S. No.	Item	SAGES-200t-M02
1	Support capacity	2 × 200t
2	Hydraulic legs	2 nos, 200mm dia bore
3	Hydraulic pressure in legs at 200t load on support	318 kg/cm^2
4	Setting load of the support	100t
5	Hydraulic pressure in legs at the setting load	150 kg/cm^2
6	Support Closed height	1850mm

S. No.	Item	SAGES-200t-M02
7	Support Extended Height	3200mm
8	Overall Length x width	2500 × 1500mm
9	Canopy Length x width	2000 × 1400mm
10	Canopy Tilt	Axial : 15^{o} , Lateral : 15^{o}
11	Base Length x width	720 × 680 mm (in contact with the floor
12	Support Density	71.4 t/m^{2} (7.1 kg/cm^{2})
13	Floor Pressure of the base at full load	400 t/m^{2} (40 kg/cm^{2})
15	Traction max. gradiability	35 degrees
17	Electric Motor	18.5 KW
18	Hydraulic Pump	2 x 31 LPM
19	Crawler Speed	800 m/h
20	Track Drive Torque at Sprocket	12,440 N-m
21	Drawbar Pull	10,080 kg
22	Support weight:	9 t
23	Support operation:	RF remote control

CONCLUSION

A medium duty 2×200t capacity Self Advancing Goaf Edge Support (SAGES) has been designed and developed for depillaring operations in underground coal mines jointly by Indian Institute of Technology (ISM), Dhanbad and Jaya Bharat Equipment Pvt. Ltd., Hyderabad. DGMS has accorded approval of this support for use in underground coal mines vide letter no. S 29023/435/2012/S&T(HQ)/398 dated 30.07.2019. Financial support was provided by the Ministry of Coal, Government of India.

SAGES are operated by radio remote control which eliminates workers from exposure to hazardous roof conditions associated with withdrawal and setting up of conventional supports. They facilitate higher percentage of recovery of coal pillars. They can replace the prevailing system of closely spaced cogs erected on steel frames with corner props backed up by a guard row of closely set props at each Goaf Edge during depillaring operations in underground coal mines. The SAGES has been successfully undergone field trails in depillaring panels of (a) Bastacola underground coal mine, Bharat Coking Coal Limited (BCCL), Dhanbad and (b) RK7 Incline underground coal mines, Srirampur Area, SCCL. During the field trials, several modifications in design were incorporated in SAGES. The final design specification is given in Table 8 above.

Technical Note

APPLICATION OF ENVIRONMENTAL STABLE ISOTOPES TO CHARACTERIZE GROUNDWATER RECHARGE SOURCES IN THE MINING REGION OF MUSABANI, JHARKHAND, INDIA

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S Chakrabarti[2], Susnata Ray[2]

INTRODUCTION

Groundwater is the most important water resources available to humanity worldwide. They are known to be vulnerable to pollution especially in mining region and may have adverse impact on environment. Groundwater degradation, acid mine drainage (AMD), release of toxic elements and their mixing with the nearby water resources are some of the common phenomenon that takes place in mining region. The acidic water that generated from AMD, corrodes the surrounding rock and releases toxic metals consequently contaminate the unconfined aquifer and badly affect the groundwater resources in the mining region. Therefore, understanding of the recharge mechanism and hydrogeological functioning of the mining region is important for the protection and sustainable management of the groundwater resources. There are numerous techniques available for groundwater recharge evaluation includes environmental stable isotopes, physical and numerical modeling approaches etc (Ansari et al., 2014). However, the tracer technique such as use of $\delta^{18}O$ and $\delta^{2}H$ is the most successful approach that is largely used to trace water provenance and recharge processes (Noble and Ansari, 2019). These stable isotopes ($\delta^{18}O$, $\delta^{2}H$) are considered as ideal conservative tracers that provide better insight into the groundwater recharge and flow path as their composition remain same within the groundwater.

The objective of the study was to understand the recharge source of the groundwater and to evaluate the interactions between the surface water and the groundwater in the mining region of Musabani, Jharkhand.

LOCATION AND GEOLOGICAL SETUP

The study area is located in the East Singhbhum district of Jharkhand (Figure 1). The area is mainly drained by the Subernrekha River. About 54% of the total area is characterized by an uneven topography having numerous hills and residual mountains. The altitude of the area is range from 48 m to 850 m amsl. The average annual rainfall is approximately 1300 mm (June to September). Geologically, the area is largely covered by Chhotanagpur plateau consisting igneous, metamorphic and sedimentary rocks of Dharwarian period. Granite, schist, gneiss and basalt are the major rock type found in the region. The study area is also having rich deposits of minerals such as chromite, chalcopyrite, iron, copper, gold, kynite and uranium. The Mosabani and Rakha copper mines are located in the study area.

The groundwater reservoir in the area lies in hard crystalline igneous and metamorphic rock. The weathered and inter-connected fractured constitute good aquifer. Groundwater occurs under water table condition in the weathered zone and under semi-confined condition in the fractured zone. The depth of majority of the wells ranges from 27 m to 300 m bgl (CGWB, 2013).

METHODOLOGY

Environmental stable isotope ($\delta^{18}O$ and $\delta^{2}H$) can be used to evaluate the groundwater supply sources, based on their characteristic signatures (Saravana Kumar et al., 2014). Water samples were collected from the groundwater, Subernrekha River, pond, nalas,

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and reservoir for the analysis of environmental isotope (δ^2H and $\delta^{18}O$).Physico-chemical parameters such as electrical conductivity (EC), temperature, and pH were measured in-situ. Analysis of Chloride was carried out using Dionex-DX-500 Ion chromatography. The stable isotope ratios of oxygen and hydrogen were measured using isotope ratio mass spectrometer (Isoprime-100) by gas equilibration method. The result of the stable isotope is reported in the standard δ-notation (Sarvana Kumar et al., 2001) and is defined in relation to Vienna Standard Mean Ocean Water (VSMOW), as given by the following equation :

$$\delta^2H \text{ (or } \delta^{18}O) = \left(\frac{R_{sample} - R_{standard}}{R_{standard}} \right) .10^3 \qquad (1)$$

where, R represents the isotope ratio of the sample ($^2H/^1H$ or $^{18}O/^{16}O$) and R_{std} represents the corresponding ratio of the standard, VSMOW). The δ values are expressed in parts per thousand (permil, ‰). The precision of measurement for δ^2H is ± 0.5‰ and that of $\delta^{18}O$ is ± 0.2‰ at 1σ.

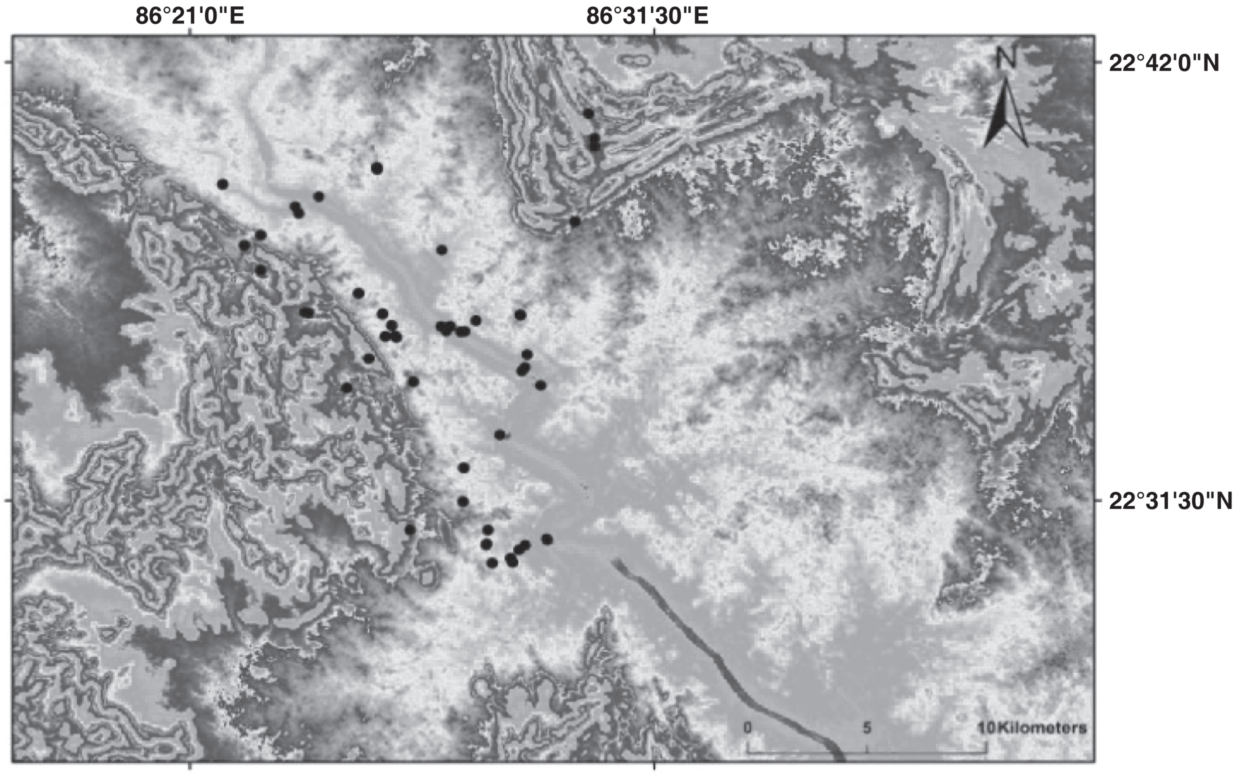

Figure 1 : Digital Elevation Map Showing Sampling Points in the Study Area

RESULTS AND DISCUSSION

In-situ physicochemical parameters show that the temperature of the groundwater and surface water varies from 15 to 29.1°C and 18.8 to 36.6°C respectively. The electrical conductivity of the groundwater ranges from 101 to 2160μS/cm where as it ranges from 196 to 2290μS/cm in surface water. The pH of groundwater is acidic to alkaline (5.6 – 7.6) whereas the surface water is acidic to highly alkaline (5.8 – 10.2). The $\delta^{18}O$ and δ^2H of the groundwater water varies from -6.3 to -2.7‰ and -42.4 to -14.8‰ respectively. The $\delta^{18}O$ and δ^2H of the surface water varies from -5.2 to -1.9‰ and -35.3 to -15.3‰, respectively.

The Cl^- of groundwater ranged from 49.9mg/l to 309.9mg/l while in surface water it ranged from 40mg/l to 120mg/l. It has been observed that majority of groundwater and surface waters are having higher Cl^- composition (Figure 2). From the Figure 2, it can be deduced that the samples which are having depleted δ18O values are having lower Cl^- while the samples having enriched $\delta^{18}O$ values have higher Cl^- (except few samples). This shows that enhancement of Cl^- in majority of the samples is because of the evaporative enrichment. Some of the samples are depleted in isotopic composition and also having very high Cl^- indicates influence of Nala or AMD on groundwater.

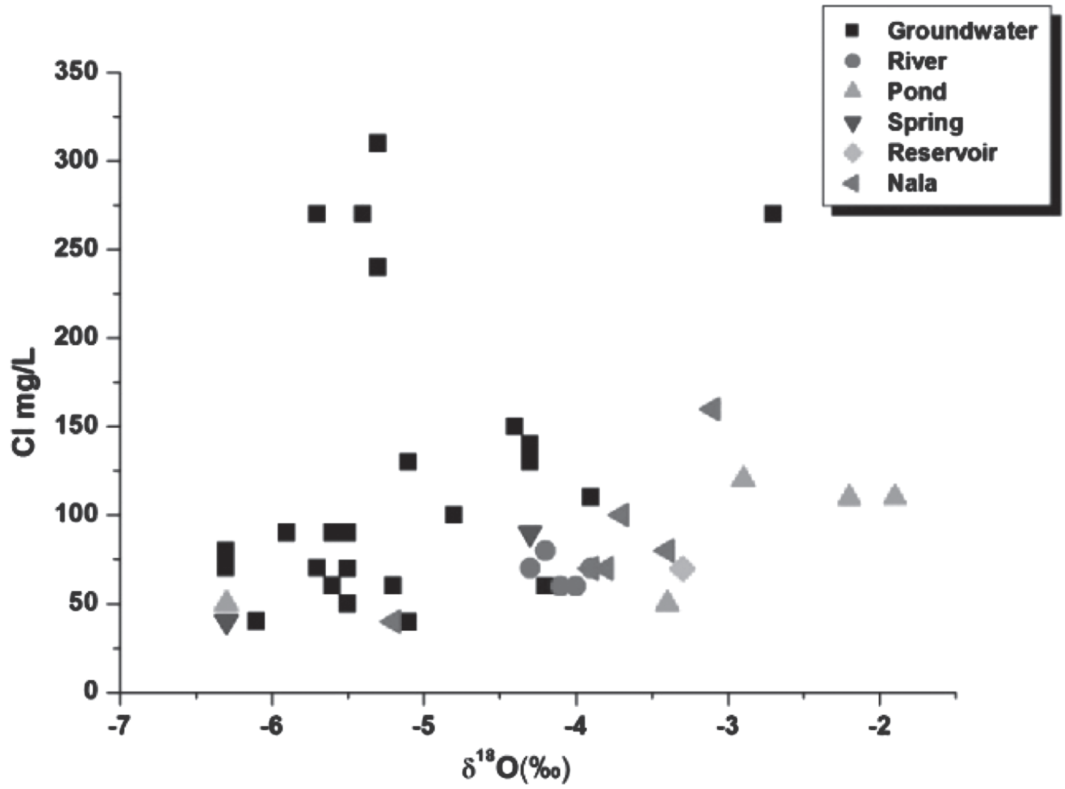

Figure 2 : $\delta^{18}O$ vs. Cl^- plot

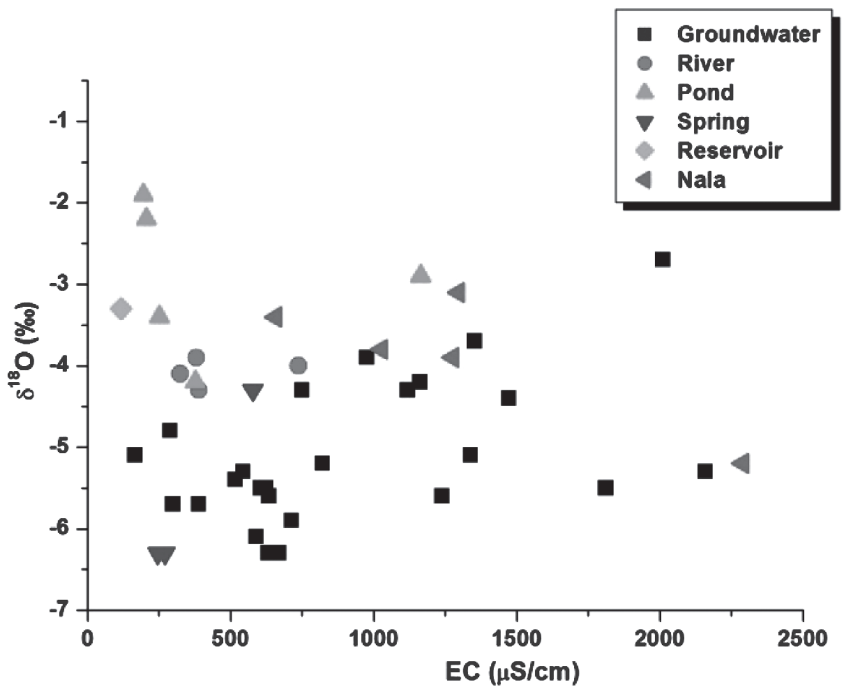

Figure 3 : EC vs. $\delta^{18}O$ plot.

From EC vs. $\delta^{18}O$ plots (Figure 3), it is found that the isotopic values of most of the groundwater is more or less same (between -5‰ to -6‰) but their EC is increasing significantly, which indicates either intensive rock-water interaction or influence of AMD on groundwater. Furthermore, it is also observed that a few groundwater samples that having higher EC are isotopically identical to the nala water indicates influence of nala on groundwater.

It has been observed that majority of the groundwater samples are falling on the Global Meteoric Water Line (GMWL) $\delta^{2}H = 8\delta^{18}O + 10$ (Craig, 1961) indicates they are getting recharge from rainwater (Figure 4). While majority of the surface water (Subernrekha River, nala, reservoir, ponds) falls away from the GMWL indicates they have undergone intensive enrichment because of evaporation. The isotopic signature of some of the groundwater samples are enriched and falls away from GMWL nearer to the Subernrekha River and pond, demonstrating a strong interaction with the river and ponds and indicating that these waters could be recharged by surface water sources (rivers or ponds). It is seen that the stable isotopic composition of pond water is highly enriched whereas the river and nala are moderately enriched.

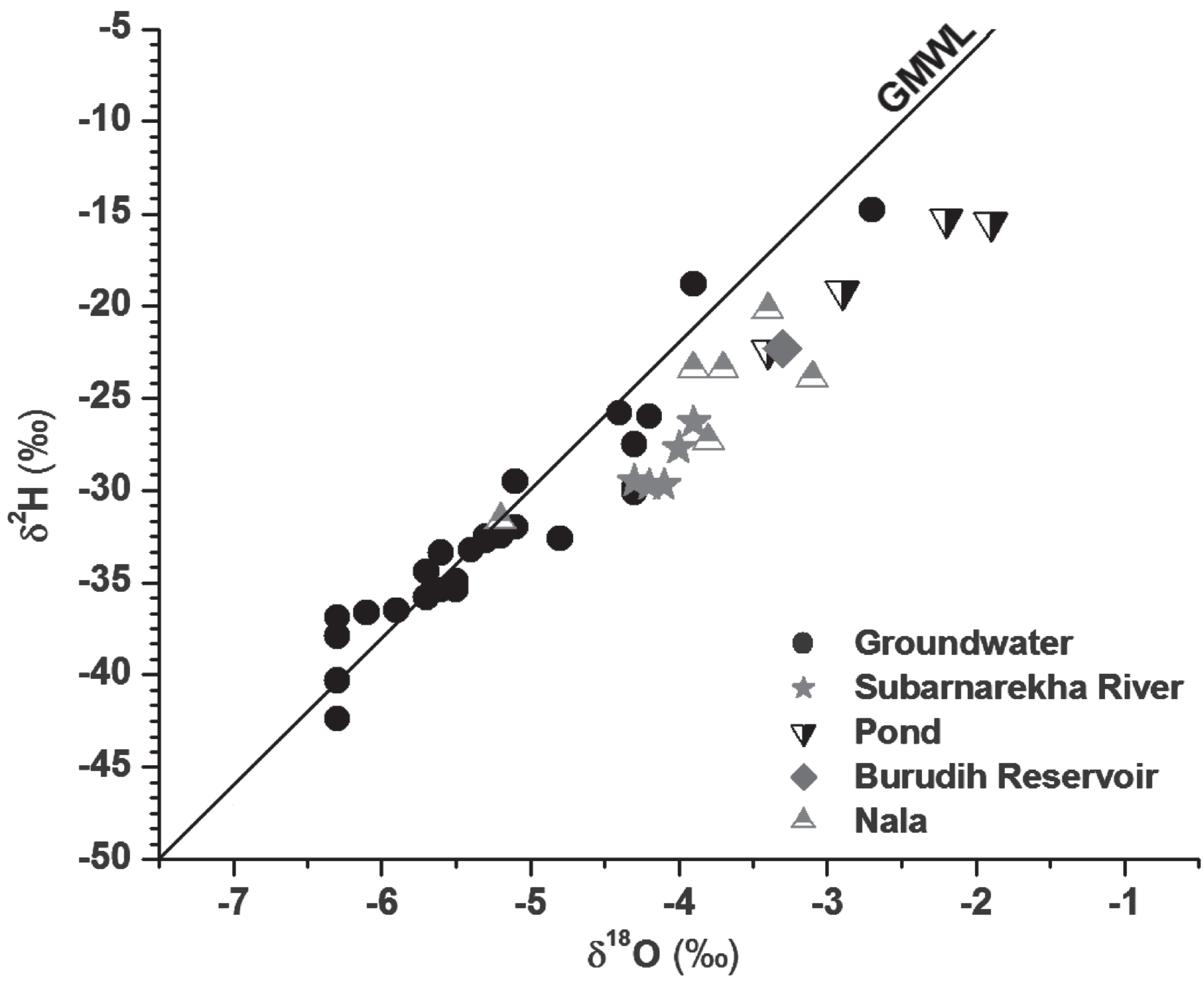

Figure 4 : $\delta^{18}O$ vs. $\delta^{2}H$ Plot

CONCLUSION

From the study, it is concluded that the most of the groundwater are getting recharged from the rain, while few groundwater wells are recharged from surface water bodies such as Subernrekha river and pond. The high chloride in some of the groundwater samples may be because of the impact of acid mine drainage whereas abnormally high EC in some of the samples may be because of the intensive rock-water interaction or influence of nala.

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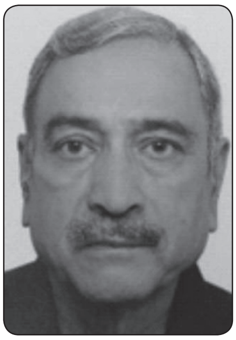
DOWN THE MEMORY LANE

SC Agarwal



As per provisions of Coal Mines Regulations 1957 every mine shall be operated under the control of a qualified Mines Manager. Regulation No 31 of Coal Mining Regulation, 1957 says "No mine shall be opened, worked or re-opened unless there is manager of the mine, being a person duly appointed and having such qualifications as required by these regulations.

Reg. 31(2) further specify" No person shall act or be employed as Mines Manager of a mine producing on an average in excess of 2500 T per month, unless he holds a First Class Manager' Certificate. Mines producing + 600 but less than 2500T will be under the control of of a person holding Second Class Manager Certificate/First Class Mine Manager Certificate. In other cases it will be under control of a person holding either First Class/Second Class Manager Certificate/ Manager Permit granted by DGMS.

These examinations were conducted annually, by DGMS, Ministry of Labour, GOI. In sixteese examinations were conducted only at Dhanbad, HQ, DGMS. For each of these examination, candidate had to appear and qualify in 5 subject papers, both written and orals. The subjects included, Method of Working, Mine Machinery, Survey, Ventilation and Legislation.

Examination were conducted by Board of Mining Examination constituted by Chief Inspector of Mines. Chief Inspector of Mines, used to be Chairman, Regional Inspector of Mines as Secretary and 4 prominent mining officials from industry were appointed as Examiners. During the year, I appeared for First Class Mines Manager Certificate exam, Mr GS Jabbi being Chief Inspector of Mines, was Chairman, Mr HB Ghosh being Regional Inspector of Mines, was Secretary and Mr JJ Evans, Mr RN Singh, Mr Sinclair and Mr BR Marwha were the other 4 examiners. To pursue a strong career in mining industry, it was mandatory for me to qualify and obtain both the Certificates.

Qualifying for Second Class Mines Manager Certificate of Competency, to manage a coal mine :

A graduate mining engineer had to equire at least 2 yrs of field experience in underground coal mine, besides passing Mining Sirdar examination and obtaining Gas Testing examination. It was followed by written examination in above 5 papers. Having passed the written I had to appear before examiner for oral test. Results were declared on obtaining qualifying marks in both examinations. Normally a graduate mining engineer used to qualify this examination in first attempt or in next 2/3 attempts definitely. I qualified for this examination in first attempt in 1965. Latter through a notification Board/Coal/I/1374/74 the eligibility was amended. A graduate mining engineer, after 1 year of experience, is now eligible to be granted Second Class Mines Manager Certificate without appearing for any examination.

Qualifying for First Class Mines Manager Certificate of Competency (to Manage a Coal Mine)

Candidate after obtaining Second Class Mine Manager certificate, had to work in a Coal Mine for one year before being eligible to appear in First Class Mines Manager Certificate of Competency examination. Here also candidate had to appear for 5 papers both written and oral. This examination was also held in Dhanbad under the control of DGMS. I appered for this exam in 1965-66 when I was working as Under Manger at Damra colliery belonging to Bengal Coal Company of Andrew Yules in WB. Late Shri HB Ghosh, the then Regional Inspector of Mines at Sitarampur, WB was the Secretary of Board of Examinations. After submitting form I was informed that my First aid certificate was provisional, hence would not be allowed to appear for the exam.

Qualifying for First Class Mines Manager Certificate of Competency, (to Manage a Coal Mine) in Early Sixties : A Challenging Experience.
Er. SC Agarwal, FIE

On approaching Shri HB Ghosh in his Sitarampur office with a request to issue Admit card, he asked of my then employment. Being employed in BCCL, the best managed and most mechnised mining company, he had agreed to issue Provisional Admit card with condition that I had to submit original First aid certificate before entering examination Hall. It was a big CHALLENGE for me to arrange original from the Delhi office of St John Ambulance Association, I made my relatives in Delhi to run about this office and send me original certificate. Miracle happened and received the original certificate just on day when I was to leave for Dhanbad for taking written examination.

At Damra colliery I along with another friend Mr Verma as under manager were rotating in 2nd-3rd shift alternate week. Both were appearing for Manager's First Class Certificate of Competency examination and applied for one month leave for preparation. Mr Verma, a field student was quite senior to me and had accumulated leave was granted 15 days preparation leave. I being junior one, was granted only 3 days leave just to appear for examination spreading over 3 days. Further I was directed to manage both night shifts. My duty time was from 8pm to 4am, managing two night shifts 4 hours each. It was underground gassy mine. Yet another big CHALLENGE.

The situation stood tough for me, working 8 night hours and preparing for examination in day time. I made sincere efforts to discharge my responsiblity as Under Manager. Had fixed study time between 11AM to 6PM. Just before the exam day I took cab carrying me from Asansol to ISM Dhanbad. Slept overnight at ISM hostel to take exam next day.

Yes, I faced all the challenges boldly and succeded in qualifying for Oral examination. On appointed day, appeared for oral exam before 5 senior examiners including Secretary Board of Examination Shri HB Ghosh from DGMS for Legislation. I did very well in 4 subjects before appearing for the last oral before Mr Ghosh. Still remember that he had asked only one question, "A time rated miner is to be converted into peace rated. How you will convince him that his wage/ earning are secured." My answer was time study, but he was not convinced. He repeated the question and I repeated my answer. He did not allow me to be seated. Appeared that he was not convinced with my answer and asked me to "Get out". I was lost as if the sky had fallen down. Faced yet another CHALLENGE in my life of 24 yrs wherein I had never failed in any exam. I prayed God to help me.

Meanwhile I was transferred to Chanch Colliery after the exam. I returned back to my new work place. Next day when I met mine manager Mr Jetli. On his query about my performance in exam, I narrated how Shri Ghosh had asked me to GET OUT. MR Jetliex claimed, Agarwal you are through. His words poured on me like AMRIT. Mr Jetli's exclamation proved to be true when results was announced. I was diclared to be successful. I cried on top of my voice with extreme happiness. Almighty has blessed me what I prayed for.

Qualifying for First Class Mines Manager Certificate of Competency examination was no less than qualifying for IAS. Lucky were the candidates who could qualify in first attempt, I was one of them. List was on record when candidates didn't qualify even after number of attempts. Many in desperation left trying. Instead they felt satisfied with their job as Second Class Mine Manager. Later through amendment vide Notification Board/Coal/I/1317/74 dated 13.08.74/14.09.74 which became effective from 14 th December 1974, a graduate mining engineer has been exempted from appearing in all 5 papers but only one" Mine Management, Legislation , General Safety". Still now it is nightmare for many to qualify for Manager's First Class Certificate of Competency to Manage a Coal Mine.

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