

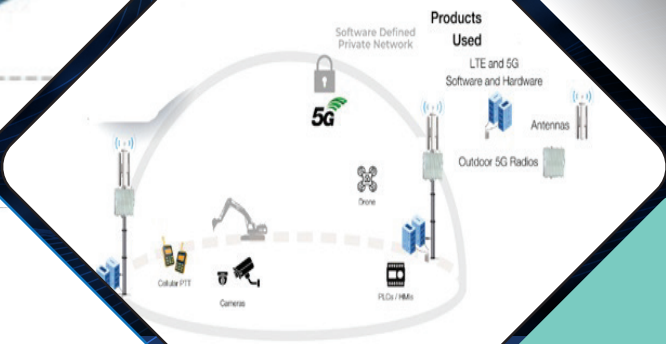
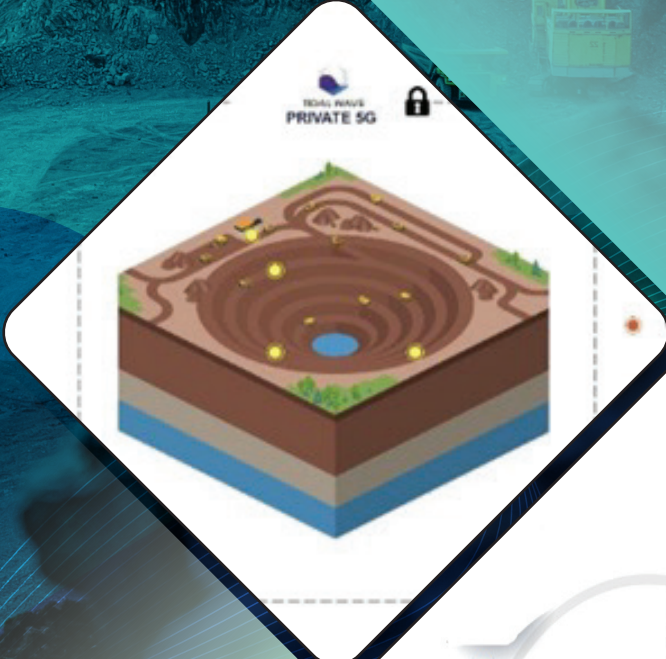


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नोट: पत्रिका में प्रकाशित रचनाओं की मौलिकता एवं उनमें व्यक्त विचारों के लिए रचनाकार स्वयं उत्तरदायी हैं। पत्रिका में व्यक्त विचारों के लिए संपादक मंडल तथा सीएमपीडीआई प्रबंधन किसी भी प्रकार से उत्तरदायी नहीं होगा।

**The views expressed are of the authors  
and not necessarily of the organization they belong to or that of CMPDI.**

# From Pit to Policy: Understanding Coal Price Influences on India's Energy and Mining Landscapes

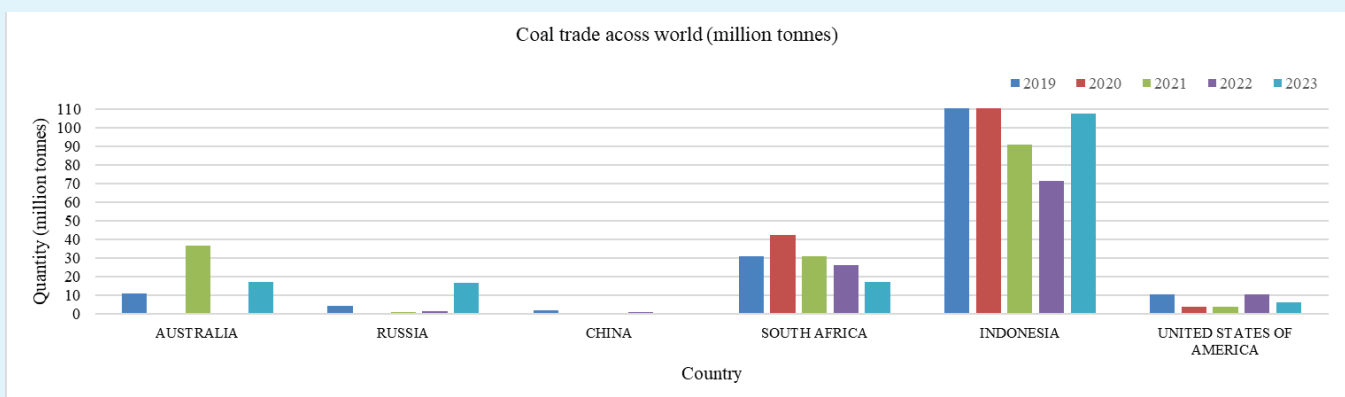
Rahul Upadhyay<sup>1</sup>, Subodh Kumar<sup>2</sup>

## 1. Introduction

Coal has long been a basis of the global energy sector, serving as a vital resource for power generation. The significance of coal lies in its abundance and widespread availability, contributing to its historical role as a reliable and cost-effective source of energy (Chikkatur et al., 2009). As a fossil fuel, coal is burned to produce heat, subsequently used to generate steam that drives turbines, ultimately producing electricity. Its versatile application extends beyond electricity generation, as coal is also a crucial component in various industrial processes such as steel production and cement manufacturing (Zhao and Chee, 2012). Despite increasing emphasis on renewable energy sources, coal remains a key player in meeting the world's energy demands, providing a stable

and continuous power supply. However, the environmental impact of coal combustion, marked by greenhouse gas emissions and air pollution, highlights the ongoing challenge of balancing its utility with the imperative for sustainable energy practices (Dorian et al., 2006).

Coal plays a crucial role in India's energy landscape, accounting for nearly 67 percent of the total commercial energy consumption (Rajak et al., 2019). The country aims to further strengthen this position by adding 220,000 MW of thermal power by 2030. However, the challenge of coal pricing looms large, particularly for the coal mining and power industry. The low calorific value and higher ash content of Indian coal reduce the operational efficiency of coal-fired power plants, leading to increased costs (Xie, 2012; Yang et al., 2012). This



**Figure 1: Coal export across the world**

<sup>1</sup>Indian Institute of Technology, Kharagpur, India

<sup>2</sup>Bharat Coking Coal Limited, Dhanbad, India

pricing concern is expected to escalate in the future as the demand for electricity is projected to grow rapidly, with coal remaining a primary fuel to meet this demand (Mathur et al., 2006). The annual coal consumption in India has been on the rise, increasing from 304 MT before the 1990s to a dynamic surge of 662 MT after 2000. Figure 1 shows the coal export (quantity) over the years across the world.

Coal has garnered significant attention in recent months, particularly in the context of the power crisis unfolding in India. The country heavily relies on coal as the primary fuel for its thermal power plants, crucial for ensuring uninterrupted and base load capacity electricity supply to meet the escalating demand fueling India's economic growth (Guo et al., 2016). As the world's third-largest electricity producer with an installed capacity of 399 gigawatts and an annual generation of 1,490 billion units, coal presently constitutes approximately 70% of the total generation, dominating India's energy mix. Any disruptions in the demand-supply dynamics leading to a coal shortage could have cascading effects on India's energy markets and overall economy (Cui and Wei, 2016).

Historically, the pricing of coal in India was subject to government regulation under the Colliery Control Order of 1945 and the Essential Commodities Act of 1955 until the 1990s. However, gradual deregulation commenced in 1996 and was fully implemented with the Colliery Control Order 2000, relinquishing the government's power to fix coal prices. Despite this, Coal India Limited (CIL) collaborates with the government to determine coal prices, striving to avoid increases, particularly for lower-grade coal, by enhancing cost efficiencies. CIL's decision-making considers factors such as general inflation, rising production costs, the necessity for internal resource generation, and the comparative landed cost of imported coal. While CIL sells coal to power plants at prices lower than those in Indian and international markets, additional fixed costs during transportation, beyond CIL's control, often constitute more than 50% of the coal cost. Consequently, CIL prioritizes the production and supply of low-quality coal to maintain overall

thermal coal prices at a lower level, contributing to increased pollution from coal-based power plants and raising the expenses associated with pollution abatement.

Coal pricing in India underwent significant changes until the year 2000. Before this period, the Government of India (GOI) regulated the price of coal based on its grade and colliery under the Colliery Control Order of 1945 and the Essential Commodities Act of 1955. Amendments in 1994-1996 aimed to adjust prices, considering factors like transportation charges and additional prices for specific mines. The concept of Useful Heat Value (UHV), criticized in the 1990s, was introduced to encourage the use of lower-grade non-coking coal. Deregulation commenced in 1996, and by 2000, the GOI had no authority to fix coal prices. Coal India Limited (CIL), in consultation with the GOI, determined prices, factoring in inflation, production costs, and the need for internal resources. Grades D to G, used for power generation, remained regulated due to power tariff regulation. Deregulation extended to certain coal grades in 1996, resulting in a significant price increase compared to regulated grades. In 1997, the GOI deregulated the price of soft coke, hard coke, and D grade non-coking coal. CIL and SCCL were permitted to set prices for E, F, and G grades based on cost indices every six months. Attempts to shift to a Gross Caloric Value (GCV) system in the late 1990s faced protests, but CIL adopted it in 2012. The delivered price of coal, inclusive of various charges and levies, can be around twice the pit-head price. Over 50% of the delivered price is beyond CIL's control, pressuring them to prioritize lower-quality coal to maintain lower prices. This approach, while economically beneficial, leads to increased pollution control costs. The structure also disincentivizes the use of higher-quality coal, impacting shareholder value and reinforcing the need for a comprehensive approach to coal pricing and usage.

During the third quarter of 2021 in India, the thermal coal market witnessed a significant surge in prices, driven by a combination of constrained supply and persistent demand. However, a

pivotal shift occurred in late October when the National Development and Reform Commission implemented intervention measures, leading to a subsequent decline in the price of thermal coal, which stabilized at a lower level. Coal plays a crucial role in India's energy landscape, accounting for a substantial proportion of the country's primary energy consumption. In 2021, the ratio of coal consumption to total energy consumption was 56%, reflecting a decline from the peak of 75% observed from 1994 to 2021. Thermal coal, vital for power plants, is a key player in sustaining energy needs, and fluctuations in its price have ripple effects on downstream industries such as power generation and steel production, impacting economic stability.

## 2. Literature review

Coal is among the world's three largest fossil energy sources and nonrenewable energy sources. Numerous researchers have extensively studied coal prices. Various studies have examined the factors influencing coal prices using different methodologies. Fan et al. (2019) employed Detrended Cross-Correlation Analysis to explore the relationship between coal and carbon prices over time and time-scale intervals. Guo et al. (2016) focused on the years 2012 to 2017, considering factors such as economy, supply, demand, substitutes, and port inventory, concluding that coal prices are likely to continue declining in the short term. Li et al. (2017) used econometric methods to analyze the connection between coal and natural gas prices on the international market. Kaufmann and Hines (2018) investigated the impact of natural gas on U.S. coal prices using a vector autoregression model. Mohammadi (2011) examined the long-term and short-term dynamics among coal, natural gas, and crude oil prices in the United States, emphasizing the influence of long-term contracts on coal prices. Batten et al. (2019) identified the dominant forces determining global coal prices, pointing to the Australian coal market, followed by Mozambique and South Africa. China, while a major source of volatility in the global coal market, has limited significance in terms of price

transmission. Kai et al. (2014) analyzed China's coal price factors and found that international oil prices, coal import/export volumes, and other factors had no significant impact. Ding et al. (2017) developed a system dynamics model predicting a future trend of declining and then rising coal prices, with a small gap between supply and demand, indicating market equilibrium.

Several studies have analyzed coal price dynamics, focusing on the interplay between supply and demand. Ellerman (1995) and Kanamura (2009) emphasized the influence of supply changes on long-term price fluctuations. Ding et al. (2017) and Punzi (2019) predicted trends in coal prices, considering supply and demand uncertainties. Ma et al. (2009) highlighted growing role in shaping energy prices. Liu et al. (2013) observed a weak long-term relationship between Chinese coal and electricity prices, while Cui and Wei (2017) examined the determinants of China's thermal coal price. Stern (2000) and Adrangi et al. (2001) linked energy use, GDP, and fuel prices, while Asche et al. (2003) explored market integration driven by crude oil and refined oil prices. Guo et al. (2016) and Chen (2014) studied coal price impacts on general price levels and Chinese economic indicators, respectively. Bejbl et al. (2014) proposed methods to determine lignite benchmark prices, and Edelstein and Kilian (2009) discussed energy price shocks' effects on US consumption growth. He et al. (2010) analyzed coal price adjustments' impacts on the power industry, contrasting with Wang et al. (2013) who questioned coal prices' direct influence on thermal power industry costs. Yang et al. (2012) suggested that fluctuations in coal prices could indicate broader shifts in the global fossil fuel market.

Guo et al. (2016) focused on the period from 2012 to 2017, considering economic, supply, demand, substitutes, and port inventory factors, predicting a short-term decline in coal prices. Li et al. (2017) employed econometric methods to analyze the connection between coal and natural gas prices globally. Kaufmann and Hines (2018) investigated the impact of natural gas on U.S. coal prices using a vector autoregression model. Batten et al. (2019)

identified dominant forces determining global coal prices, emphasizing the Australian coal market. While China contributes to volatility, its significance in price transmission is limited. Kai et al. (2014) analyzed China's coal price factors, concluding that factors like international oil prices and coal import/export volumes have negligible impacts. Ding et al. (2017) developed a system dynamics model predicting a future trend of declining and then rising coal prices, indicating market equilibrium with a small supply-demand gap.

Despite this research, gaps remain, particularly regarding policy effects on coal prices and the impact of varying policy measures. Addressing these gaps is crucial for refining policy measures and advancing coal industry development.

### 3. Coal Market Dynamics

Coal prices have begun to decline since mid-2022, although they remain notably higher than their five-year average. Benchmark prices in Australia and South Africa have dropped by around 50% from their peaks in 2022. This decrease is attributed to increased production and milder weather, narrowing the gap between these benchmarks caused by previous supply disruptions. Global demand hit a record high in 2022, with significant increases in India and Europe as electricity generation shifted from natural gas. China saw modest consumption growth, while the United States experienced a decrease in coal consumption due to less significant natural gas price increases. Global production also reached a peak in 2022, notably in China and India, with the United States observing a slight rise despite domestic consumption decreases. Trade patterns shifted, with South African exports to Europe surging while Russian exports redirected to China and India. Looking ahead, coal prices and demand are expected to decrease in the medium term, with potential obstacles including trade diversions and gas price hikes affecting coal prices. Geopolitical risks may further accelerate the transition away from fossil fuels, with global coal demand expected to peak in 2023.

### 4. Factors influencing coal price

The price of coal is influenced by both market dynamics and policy decisions. National policies focusing on coal supply and imports can affect short-term coal prices, while factors like capacity and power plant demand have long-term impacts. Other energy prices, inventory levels, economic growth, and imports also influence coal prices through supply and demand dynamics. In summary, coal price determinants can be categorized into three main aspects: supply and demand, other energy markets, and policy interventions. These can be further broken down into eight elements, including output, consumption, import quantity, stock levels, imported crude oil prices, domestic natural gas prices, economic policy uncertainty (EPU), and generating capacity.

### 5. Implication on mining industry

The rising prices of coal have profound implications for the global mining industry, with far-reaching effects on various aspects of mining operations, economics, and sustainability. Rising coal prices directly translate into higher operational costs for mining companies, impacting exploration, extraction, and transportation expenses. Mining companies face challenges in maintaining profit margins as higher coal prices squeeze their profitability, especially if they are unable to pass on the increased costs to consumers. The elevated cost of coal extraction impacts the competitive position of mining companies in the market, potentially leading to a redistribution of market share. Rising coal prices often influence end-users to explore alternative energy sources, leading to shifts in demand patterns that can affect the overall coal market. Mining companies may invest in technological innovations to improve efficiency, reduce extraction costs, and mitigate the impact of rising coal prices on their bottom line. The pressure to address environmental concerns could drive mining companies to invest in cleaner and more sustainable mining practices, thereby reducing their reliance on traditional coal extraction. The impact

of rising coal prices varies across different mining regions, depending on their reliance on coal, local economic conditions, and regulatory frameworks. The role of government policies becomes crucial in either mitigating or exacerbating the impact on regional mining industries. Higher coal prices may prompt increased scrutiny on mining companies to adopt sustainable practices, both in terms of environmental impact and community engagement. The industry might experience a push towards cleaner coal technologies to address environmental concerns associated with traditional coal extraction methods. Mining companies may implement cost management strategies to offset the impact of rising coal prices, such as optimizing operational efficiency and negotiating favorable contracts with suppliers. Some mining companies may explore diversification strategies, moving towards other minerals or commodities to reduce dependence on coal.

## 6. Conclusion

Analysts and industry experts might predict future trends in coal prices, influencing strategic planning and investment decisions. Anticipating potential policy shifts and regulatory changes can be crucial for mining companies to adapt to evolving market conditions. In conclusion, the impact of rising coal prices on the mining industry is multifaceted, affecting operational dynamics, market competitiveness, and sustainability practices. The industry's response will likely involve a combination of cost management, technological innovation, and strategic diversification to navigate the challenges posed by fluctuating coal prices.

In conclusion, declining coal prices have significant economic implications. They can lead to reduced revenue and profitability for coal mining companies, resulting in cost-cutting measures such as layoffs, reduced investments in safety and environmental protection, and the postponement or cancellation of new projects. Lower profitability can make it challenging for these companies to attract investment or secure financing, diminishing the sector's growth potential and hindering its adoption of cleaner technologies. Moreover, countries heavily

reliant on coal mining for revenue, like India, may experience reduced tax and royalty income, which can impact public spending capacities.

To address these challenges, governments may respond by providing subsidies or financial support to stabilize the sector, safeguard employment, and maintain energy security. However, such measures could strain public finances and potentially delay the transition to renewable energy sources. Another potential response involves adjusting regulations to reduce operational costs or easing environmental compliance requirements for coal mines, albeit at the risk of long-term negative impacts on the environment and public health. Implementing policies that encourage diversification of energy sources and investment in renewable energy, along with supporting coal-dependent communities through re-skilling programs and economic diversification initiatives, could be part of the solution.

While the decline in coal mining activity can yield environmental benefits, such as reduced greenhouse gas emissions and diminished environmental degradation, it can also pose social challenges. Job losses and economic difficulties experienced by coal-dependent communities can worsen poverty levels, limit access to public services, and potentially lead to social unrest. However, the reduced mining activity might improve air and water quality, directly benefiting the health of local populations, although the indirect negative health consequences resulting from economic impacts on communities should also be considered.

The transition away from coal mining could impact India's energy security, given its reliance on coal for electricity production. If alternative energy sources are more expensive or less reliable, a significant reduction in coal mining activity could lead to increased electricity prices. Nevertheless, declining coal prices could accelerate the transition to renewable energy sources, as it makes coal less economically attractive. This transition can be facilitated through policy measures like incentives for renewable energy development and grid



improvements to accommodate variable renewable energy sources.

Additionally, global factors such as international demand and supply dynamics, technological advancements in mining and renewable energy, and international policy frameworks aimed at reducing carbon emissions play crucial roles in shaping the future of the coal industry and its strategic direction. Understanding the multifaceted dimensions of

this issue requires a multidisciplinary approach, incorporating economic analysis, policy studies, environmental science, and social research. By doing so, we can navigate the immediate economic impacts of declining coal prices while considering the long-term implications for the energy sector, environmental sustainability, and socio-economic development.

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# Showcasing First Private 5G Network Deployment in Indian Coal Mines in Amlohri Opencast Mines of NCL at India Mobile Congress (IMC)-2023, New Delhi

*Rahul Kumar<sup>1</sup>*

The coal mining in India has experienced remarkable development in the past few years and its contribution are very crucial in the growth of Indian economy. Coal mining is considered one of hazardous task in the mining business. 5G technology can aid in the growth of coal production by offering improved connectivity, ensuring safety, high reliability, efficient and large data transmission capacity and seamless communications with low latency. Implementation of the private 5G network in coal mines can help in real-time communication between mining vehicles, improving fleet management and coordination while reducing human intervention. Private 5G network is need of the hour for remote operations of mining equipment and for leveraging advanced technologies such as autonomous HEMMs, offering benefits such as improved safety, increased productivity, enhanced efficiency, and cost savings through reduced on-site staffing and logistics. By implementing remote operations, mining companies can optimize operations, reduce personnel exposure to hazardous environments, make data-driven decisions, and achieve higher levels of safety, productivity, and sustainability in their mining operations. Real-time monitoring of mining operations powered by 5G technology enables continuous data collection, analysis, and decision-making, leading to improved

operational efficiency, predictive maintenance, and enhanced safety measures in the mining industry. 5G-powered mining demonstrates the potential for real-time monitoring, including remote equipment tracking, environmental monitoring, and worker safety monitoring, enabling mining companies to optimize operations, mitigate risks, and ensure regulatory compliance.

The deployment of communication infrastructure for the rollout of 5G services is progressing effectively in the country. The introduction of 5G Technology will act as a catalyst for the convergence of Operational Technology (OT) and Information Technology (IT) systems in coal mines. 5G technology will play a crucial role in the digitization transformation journey and introduction of industry 4.0 projects of coal mines. 5G technology aims to reap the benefits of the fourth industrial revolution (Industry 4.0) which is essential for wireless applications, remote control, telemetry, and automation in the mines, by delivering efficiencies, reducing costs, and improving profitability and safety in the coal mines. Further, the coal sector can leverage 5G technology to advance the digital revolutions in Coal mines.

The 5G network's primary benefits are high-speed broadband connectivity, ultra-reliable low

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latency communication (URLLC)- a prerequisite for remote execution, a large number of connected devices, and the potential to deploy virtual networks (network slicing)-offering more customized connections to meet particular demands. The deployment of 5G network provides uninterrupted operation and real-time data transfer across large areas of coal mining. The 5G network solves problems that many people had with Wi-Fi during the early stages of wireless deployments. The 5G ecosystem makes it possible to see and manage wireless data performance more effectively. It also optimizes vehicle performance and safety through continuous monitoring, improves worker safety and asset security, and better environmental monitoring, all of which contribute to efficiency and safety in coal production. The distant location of coal mines allows for the deployment of private cell sites that may be optimized and modified on a regular basis without presenting a risk of interference with neighbouring public cellular networks.

It is challenging to provide the always reliable, high data throughput wireless access required for mission-critical applications in the coal mines. The criteria for smart mining, which is based on high-resolution video and IoT, may be met by 5G technology, which can offer high speeds, low latency, and massive capacity. Furthermore, 5G technology will investigate and support the deployment of next-generation advanced use cases such as digital twins for coal mines, automated guided vehicles (AGVs), augmented reality (AR), and virtual reality (VR) applications in the coal industry. These applications will help the coal industry optimize productivity and various field operations.

A private 5G network is a wireless local area network that uses 5G-enabled technologies to create a network with dedicated bandwidth and infrastructure that meets a company's specific connectivity needs. Private 5G is revolutionizing telecom services and paving the path for corporate digitalization. The dense scale and delivery of massive machine-type communications (mMTC), ultra-reliable low-latency communications (URLLC), and improved mobile broadband

(eMBB) are made possible by key radio and core characteristics of 5G. This allows to offer new services that are oriented to developers of high-performance industrial applications and enables the introduction of new commercial models. Faster speeds, ultra-low latency, security techniques, and cost savings are just a few of the enhanced features offered by 5G Radio Access Networks (RAN) and Core optimizations. These 5G characteristics are critical in industries like coal mining, where the challenges of geographic coverage and the expanding use of IoT applications require enhanced network characteristics. It will also help to explore the requirements for smart mining based on high-resolution video and IoT providing the always available, reliable, high speed, low latency, and massive capacity throughput wireless connectivity needed to support mission-critical applications in Coal mines.

The coal sector is expected to benefit from the deployment of 5G network by connecting multiple IoT applications, such as surveillance cameras, sensor-integrated machines for real-time monitoring and predictive maintenance, digital twins of coal mines, automated trucks, shovels, dozers, drills, etc. The coal industry's actual need for the establishment of a private network can be summed up as

a) Public network coverage is inadequate, b) the high expense of implementing several technologies at one place (e.g. LAN, WAN, public wireless, etc.), c) Absence of on-site/local data processing and storing and d) Data security issues and an inability to manage traffic flow and prioritization. With its dedicated spectrum and improved capabilities, the private 5G network promises to transform coal mining operations with a) Enhanced Safety and Security-Worker safety and asset security will be greatly enhanced by real-time monitoring and remote control capabilities. b) Optimized Productivity-Productivity will rise and resource utilization will be optimized with improved data analytics and real-time decision-making. c) Improved Environmental Monitoring- Improved environmental management will be made possible by real-time monitoring of the water, dust, and air quality. d) Accelerated



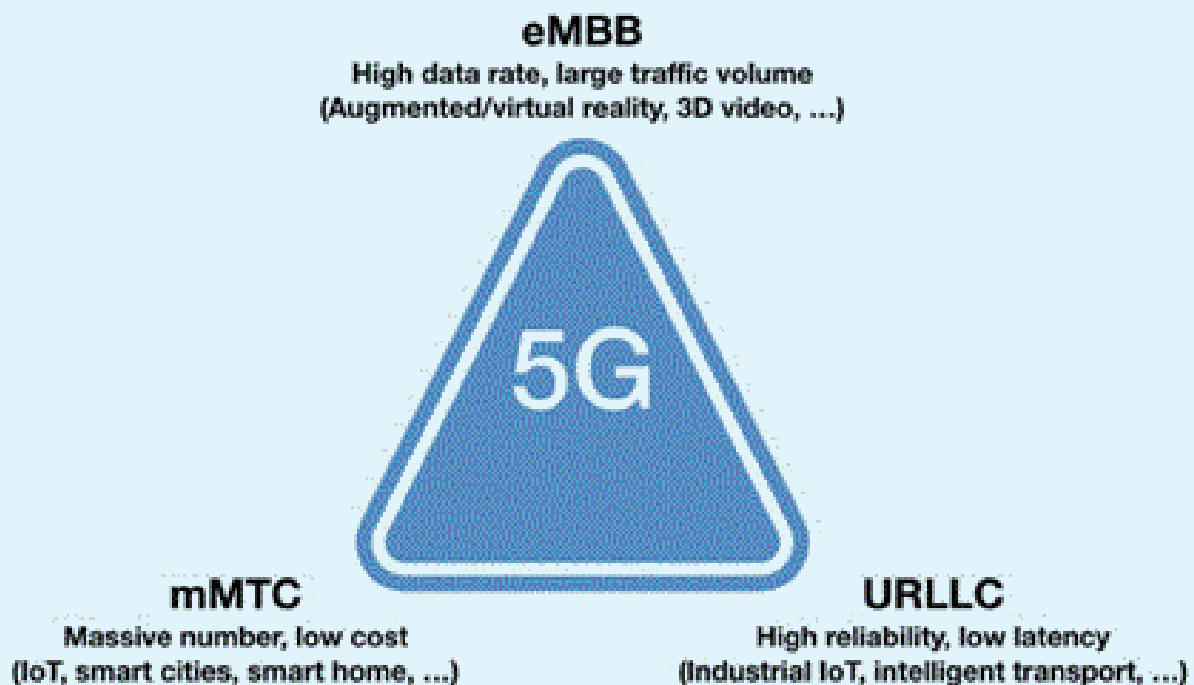
Digitalization-The integration of cutting-edge technologies like robotics, augmented reality, and artificial intelligence into coal mining operations will be made possible by private 5G.

## I. Introduction:

The advanced mobile telephony system (AMPS), which was the first commercialized wireless telephone system in the United States, became operational in late 1983. Around once in ten years, an updated set of mobile communications technologies has been released, with the initial version (1G) being deployed in the 1980s. During 1G to 3G, cellular voice communication was the primary application driving the evolution of cell phone technologies. Mobile broadband data applications have emerged as the driving force behind the continued development of wireless communication systems since the advent of 3G. At present, the fourth generation (4G) wireless networks, also known as the Long-Term Evolution (LTE), are being extensively implemented in order to provide mobile high-speed data services. The advancement

from 4G to 5G will facilitate a wider range of applications and utilization circumstances. Three domains of utilization and implementation have been designated by the International Telecommunication Union’s radio communication sector for the 5G era: enhanced mobile broadband, low-latency, massive machine-type communications, and ultra-reliable communications [1] as shown in Figure 1. In order to facilitate an extensive variety of scenarios for use and applications in the era of 5G, it is imperative to develop mobile communications systems for the next generation that integrate more sophisticated technological solutions. Such systems should strive for increased data speed, decreased delay, expanded capacity, and improved efficient spectrum use [2]. The next generation of wireless access technology is outfitted with these more sophisticated features.

The forthcoming version of communication technology is outfitted with these more sophisticated features. Although wireless services for data and wireless voice telephony continue to be the main uses for wireless communication systems, new uses for IoT and the industrial revolution are beginning to propel the industry's upcoming expansion. To



**Fig. 1: 5G usage scenarios [3]**

attain faster data speeds, reduced delay, higher capacity, and more effective spectrum application, 5G communication systems will require an updated mobile communications system that combine more sophisticated technological explanations. The subsequent generation of wireless access technology is crucial allowing skill for facilitating the various usage scenarios and applications that are anticipated for the 5G period. At the core of 5G lies a collection of essential technologies that enhance network efficiency and facilitate the introduction of novel services, ecosystems, and revenue streams.

The coal-mining sector has experienced an important change in paradigm in recent times, largely driven by enhancements in technology. One significant development is the integration of 5G wireless technology, which has the potential to greatly change operations in coal mines worldwide. Due to the increasing demand for coal in power generation and manufacturing sector, there is a pressing need for mining methods that are efficient, safe, and environmentally friendly. However, traditional communication infrastructure often does not meet the evolving needs of modern mining operations. Implementing 5G infrastructure provides a ground-breaking opportunity to overcome limitations and create new possibilities for the coal mining industry.

### **India Mobile Congress [4]**

India Mobile Congress(IMC) provides Asia's largest stage for tech exposition, conference, and demonstrations, boasting intellectual contributions from industry leaders worldwide. The goal of the global tech fest is to showcase the best and newest innovations in digital technology. Since its inception, IMC has made a name for itself as a premier platform for bringing together academic institutions, government agencies, business leaders, and other ecosystem participants to debate, showcase, and discuss the newest developments in TMT (Technology Media & Telecom) and ICT. The IMC is not only the largest technology gathering in Asia, but it's also the largest technology-related networking event in India. Its goal is to catapult

India into the spotlight and establish it as a leader in the broad digital revolution that is reshaping the future through an immersive exhibition showcasing ground-breaking innovations. Connecting media, technology, and telecommunications, the IMC has established itself as a pioneering platform and is now Asia's leading digital technology event. Since its inception, IMC has been an ideal meeting point for industry leaders, government officials, academics, and other key stakeholders in the tech ecosystem. It's a platform where provocative discussions, demonstrations, and displays of the test technological advancements take place. Honourable PM introduced India's 5G services during IMC-2022, pushing the country's digitization and connectivity to new heights. Since then, India's 5G network has expanded quickly. As of now, 5G services are available in maximum state and territory in the country.

*“The new India will not remain a mere consumer of technology, but will also play a significant role in the implementation of technology for the growth of the country.”-*

**Hon'ble Prime Minister Shri Narendra Modi**  
IMC-2023. [5]

Co-organized by the Department of Telecommunications (DoT) and the Cellular Operators Association of India (COAI), the 7th edition of the India Mobile Congress was the largest telecom, media, and technology gathering in Asia, taking place from October 27 to 29, 2023, at Bharat Mandapam in New Delhi. IMC-2023, with the theme of "Global Digital Innovation," aimed to give startup companies and the TMT industry an opportunity to showcase their creative ideas and solutions in view of the immense benefits and need for innovation.

Inaugurated by the Hon'ble Prime Minister, Shri Narendra Modi, the IMC 2023 was a landmark gathering of tech enthusiasts, policymakers, and industry leaders to talk about the newest developments in the mobile and technology sector. With the introduction of 5G and other emerging technologies, this sector has the potential to significantly boost India's GDP in the years to come.



The occasion demonstrated digital transformation across a range of new technologies, embracing the Hon'ble Prime Minister's aim to propel India to the forefront of technological innovation and paving the way for India to be ranked among the top 3 economies in the world. The government's commitment to accelerating India's digital transformation and its vision for a technologically advanced nation was emphasized along with the importance of technological innovation in revolutionizing sectors such as healthcare, education, agriculture, and industry.

The event demonstrated India's leadership in technology, international regional cooperation, inclusive and sustainable development, entrepreneurship and innovation via startups, and attracting both domestic and foreign investment, among other areas. It provided key industry participants with a distinctive platform to present their technological innovation and state-of-the-art solutions across a range of industries, bringing together partners and exhibitors.

#### Showcasing India's First Private 5G Network Deployment in Indian Coal Mines at IMC 2023

At IMC 2023, Central Mine Plan & Design Institute Ltd. (CMPDIL) successfully demonstrated live Use Cases for 5G technology at the Amlohri Coal Mines of Northern Coalfields Limited (NCL), showcasing its technological readiness in the implementation of new technology in the coal sector. CMPDI conceptualized and played an instrumental role in the deployment of India's first

Private 5G Network in Amlohri Coal Mine's, NCL. In this Congress, 5G Use Cases such as 5G enabled Drones, AI-powered cameras, Vehicle Tracking Systems (VTS), and Mission Critical Voice and Video communications were demonstrated.

Shri Amrit Lal Meena, Secretary (Coal), Shri M. Nagaraju, Shri Sanjiv Kumar Kassi, Smt. Vishmita Tej, Additional Secretary, Smt. Santosh, Jt. Secretary, Shri Anandji Prasad, Advisor Coal, Shri P. M. Prasad, Chairman, CIL, and other dignitaries from the Ministry of Coal(MoC), DoT, TCIL, etc., visited the MoC pavilion and applauded the deployment of 5G technology in coal mines. Shri Manoj Kumar, CMD, CMPDI along with his team represented CMPDI in this Congress.

CMPDI was nominated by the Ministry of Coal as the Centre of Excellence (CoE) to take forward the objective of the establishment of 5th Generation (5G) Communication Technology for the Coal industry. In order to demonstrate 5G Use Cases in the coal industry, CMPDI took part in IMC 2023. CMPDI in collaboration with TCIL, played a pivotal role in the deployment of India's First Private 5G Network in Coal Mining. This remarkable accomplishment represents a major advancement in the digital transformation journey of Coal India. Reliable, high-performance communication is essential in the mining sector due to its harsh and dynamic conditions. These demands are frequently beyond the capabilities of traditional communication infrastructures, which leads to operational inefficiencies and higher costs. Private 5G network implementation, however, offers a possible solution. The successful rollout of the nation's first private 5G network at NCL Amlohri OCP is evidence of CMPDI's ingenuity and commitment to Coal India's digital transformation journey. This demonstration will open up opportunities for the coal mining industry to widely adopt private 5G, boosting productivity, security, and sustainability throughout the sector. This demonstration at IMC 2023 will further help in the practical understanding of the 5G technology & the potential Use Case for the Coal Industry before they become part of the ecosystem.

Countries that are already developed have shown that the 5G network can work well in different areas. The IMC event in 2022 and the steps that followed to make more things digital have led to many government departments showing how they can use 5G at the IMC in 2023. These departments are also setting up special labs or trial projects to see how 5G can help in their specific work. Additionally, the PMO is watching how well 5G is being used, especially how different government sectors are adopting it. Since 5G can really speed up digital change and help the government work faster and more efficiently, the Prime Minister's office is very interested in how it's being rolled out and used.

At the IMC in 2023, various departments and organizations were invited to showcase their creative 5G projects by getting a special area or booth. The Ministry of Coal was chosen to display its 5G projects there too. To find and test new 5G ideas in the coal sector, there was also a special competition before the IMC in 2023. Some of the best ideas from this competition were also presented at the IMC to encourage more people to use them.

Right now, Coal India is working on increasing its coal production to one billion metric tonnes by 2025. This is a chance for India to make the most of its coal resources before it's too late, especially since there's a big demand worldwide. Although there's a lot of coal available, the price for coal might not go up much, and the costs to take it out of the ground need to be watched carefully. Safety regulations must be followed at all times. Several issues need to be addressed in order to boost productivity and reach production targets, reduce the cost per MT via Process Improvement Optimization of sequence of activities. Also, as we rapidly upscale mining operations, we must make sure that the environment and workers safety are maintained. The key questions are: (1) How can we use a private 5G network to boost production? (2) How can we lower production costs? and (3) How can we achieve all of this without sacrificing people's safety and well-being?

During coal mining, ensuring safe production is

of utmost importance. However, there exist several obstacles to this goal, including high concentrations of gases, ashes, and dusts, seepage and flooding risks in mines, extended working hours, and heavy workloads. Smart mining powered by IoT and high-resolution video is the path to safer practices, however, cellular technologies such as 3G and 4G networks and traditional wireless technologies like Wi-Fi have limited capacity to handle this effectively. The majority of coal mining sites are located in more isolated areas, which means that they are severely underserved in terms of internet connectivity and the ability to maintain adequate communications within the mining campus and, consequently, with their headquarters, suppliers, and customers. The best way to deal with the aforementioned issue is to provide wireless communication within the mines.

There are vulnerable areas (areas with no radio signal) in transmission over wireless networks. Both coverage limitations and data rate fluctuations are possible. This may result in incomplete or delayed data for mining applications, decreased application performance, or even the application ceasing to operate altogether. Specific problems with cellular IoT for the mining sector are a) Providing stable bandwidth and video uplink connectivity for supporting automation and remote control applications. b) Providing connectivity to an extensive number of vehicles and equipment with changing orientation and mobility – requiring a number of properly and well-positioned antennas. c) Providing wireless network underground or in big open pit mines requires network reconfiguration and re-optimization due to the progressing nature of excavation and overburden growth. The consequences and impact of getting it wrong increases as connected applications become more mission-critical.

Moreover, there are numerous wired and wireless communication networks within the mine premises, which cater to various applications within the mine premises. The majority of these networks are implemented in isolation and lack any sort of interoperability, which diminishes their effectiveness. The mining firm must also allocate



more funds in order to maintain and manage a variety of communication networks. The aforementioned issues with bandwidth, re-configurability, and connectivity are addressed by utilizing 5G technology to provide wireless connectivity in the mining area.

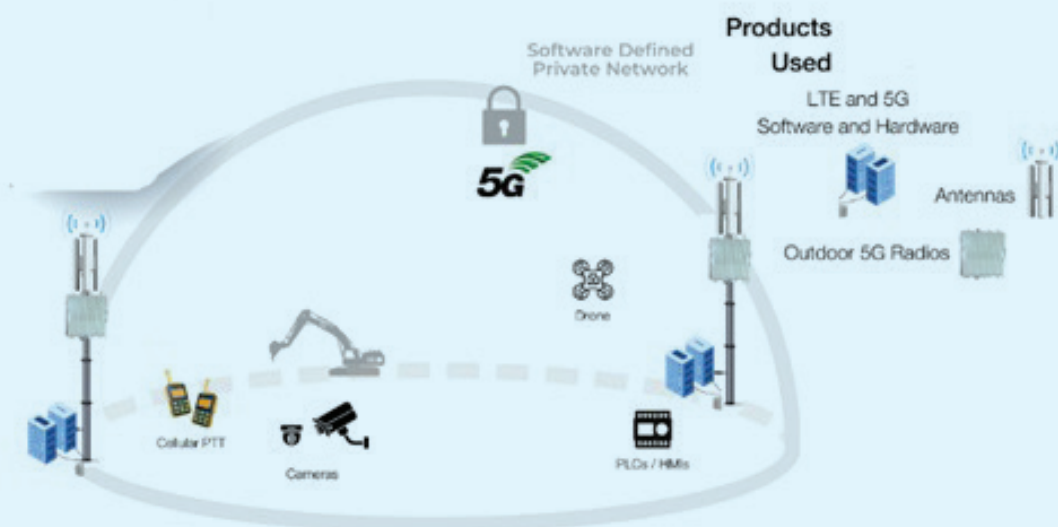
The diverse effects and broader implications of the 5G captive network within coal mines can be summarised as (a) Better Wireless Coverage- In the case of private network, connectivity may be ensured more thoroughly. Before installation, proper site survey and appropriate wireless radio survey can be conducted. Installing cellular radios in the right places will be made possible by this. Also, this will guarantee the best possible signal availability for demanding applications. (b) Data confidentiality and other security requirements - Choosing a private deployment strategy may be influenced by a number of factors, including the capacity to manage which data is kept locally and the management of devices and applications. Although standalone models are thought to be the safest, it is becoming more and more obvious that system isolation alone is insufficient to provide security. (c) Device-centric use cases: - Most private cellular deployments have a smaller number of devices that require lower latency as well as higher throughput.

(d) Performance per device: - Different vertical scenarios, Use Cases, and applications have varying QoS requirements for data paths for each vertical. Several demanding data paths may be in play for control of complex machinery. The available radio and spectrum can be tuned to meet these data pathways in order to ensure effective performance. (e) Enterprise-friendly profile:- Businesses usually want solutions that are simple to implement, integrate, and manage and that are capable of evolving to meet their needs while enabling the delivery of long-term economic value.

At IMC-2023, the deployment demonstrated a variety of cutting-edge use cases, such as:

1. 5G Drone, with Camera based streaming- Drone live feed, and view of drone flying.
2. 5G Cameras streaming operations- over separate cameras i.e. on dragline, and from view point
3. Vehicle Tracking Systems showing GPS coordinates - installed on Vehicle and VTS dashboard with GPS.
4. MCX based communication - showing Group call, Group video Call, and Dispatcher Dashboard

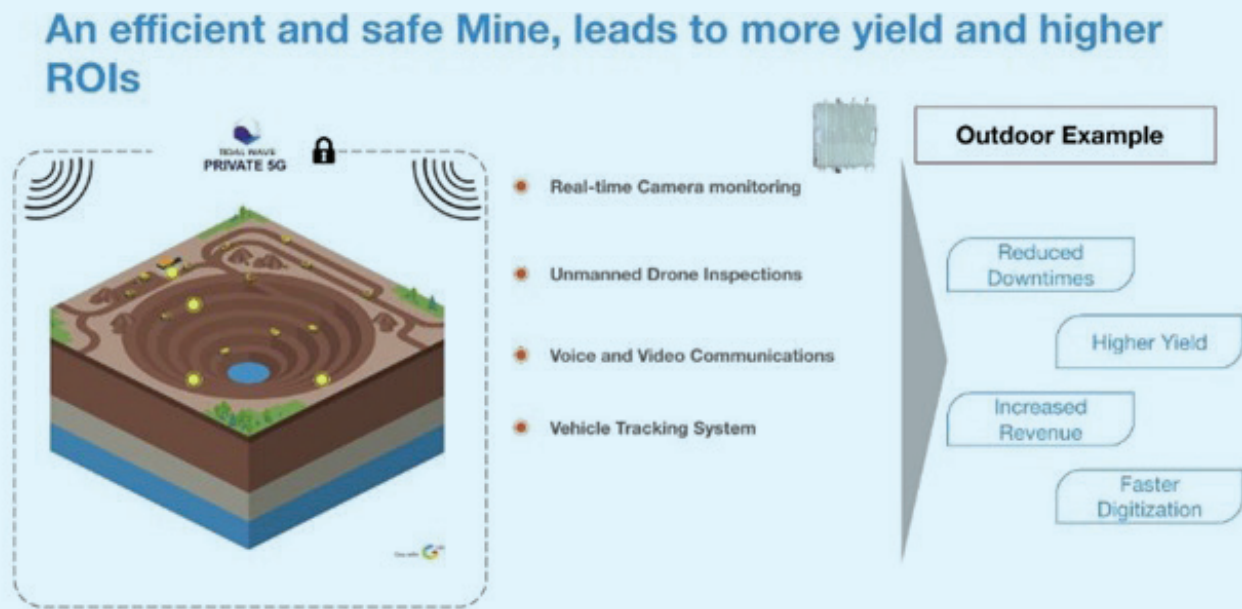
5G Drone, with Camera based streaming:- Drone live feed, and view of drone flying: - The



**Fig 2: Representative diagram Showcasing Private 5G Network for Mines at IMC-2023.**

utilization of unmanned aerial vehicles (UAVs) in several open cast mining operations has witnessed a significant increase [4–11]. Terrestrial remote sensing methods like photogrammetry and LiDAR have become more common in the past ten years. However, a significant challenge with terrestrial remote detection is the occurrence of occlusions

5G-enabled high-resolution drones provide for real-time aerial surveillance outside visual line of sight which can be used for stockpile inventory management, mine operations, and inspection of difficult-to-reach places. 5G-enabled cameras feed high-definition video and allow for real-



**Fig 3: Representative diagram Showcasing Application of 5G Network at Mines at IMC-2023.**

[12]. Occlusions are regions that are not visible to remote detecting, either because of the geometric configuration or because of obstructing materials. Furthermore, by minimizing the amount of hazardous field environments that mine workers are exposed to, remote sensing helps allay a number of the security worries related to architectural modeling and fragmentation assessment. Mine Manager may decide whether to perform or not structural modeling at the foot of the bench. Utilizing UAVs can help to overcome obstructions though ensuring protection. Moreover, UAV systems provide improved proximity to the blasted rock piles or rock mass, which enhances the potential resolution of the created models. By combining top-notch aerial sensing data like 2D photos and high-speed video footage with digital photogrammetry and image analysis techniques, a sophisticated monitoring system may be developed for overseeing the blasting procedure in mining operations.

time equipment and critical area monitoring at the mining site. Security staff may monitor activity, identify intrusions, and quickly address possible threats by integrating the cameras with the central monitoring system. Using 5G drones, coal fragment sizes can be analyzed using the capabilities of 5G networks and drone technology. Drones with the appropriate camera and other specialized sensors can transmit real-time high-definition video and image which can be used to measure coal fragment dimensions and distances precisely. The cameras and sensors on the drone can also send data for real-time analysis to remote servers. Coal fragment sizes can be automatically classified and blasting parameters can be identified using machine learning algorithms. Predictive analysis is made possible so that analysts and decision-makers can make prior decisions through AI ML models, which is the created by the processing of collected data.



## Remote Monitoring with 5G Surveillance

**Camera:** - over separate cameras i.e. on dragline and from view point: - High-definition video surveillance of key locations is made possible by 5G-powered cameras, which improve security and safety throughout the mining site. The method is intended to change how Coal mines monitor and safeguard their mining operations by utilizing this cutting-edge technology to extract and evaluate useful data from video feeds. By integrating the cameras with the central monitoring system, security staff will be able to keep an eye on activity, spot incursions, and react quickly to any threats. The issues encountered during coal mining are proper fragmentation, which may also be resolved by 5G networks in conjunction with AI/ML technologies. Studying the geological characteristics of the area, including the coal seam's depth, thickness, and quality will help in:

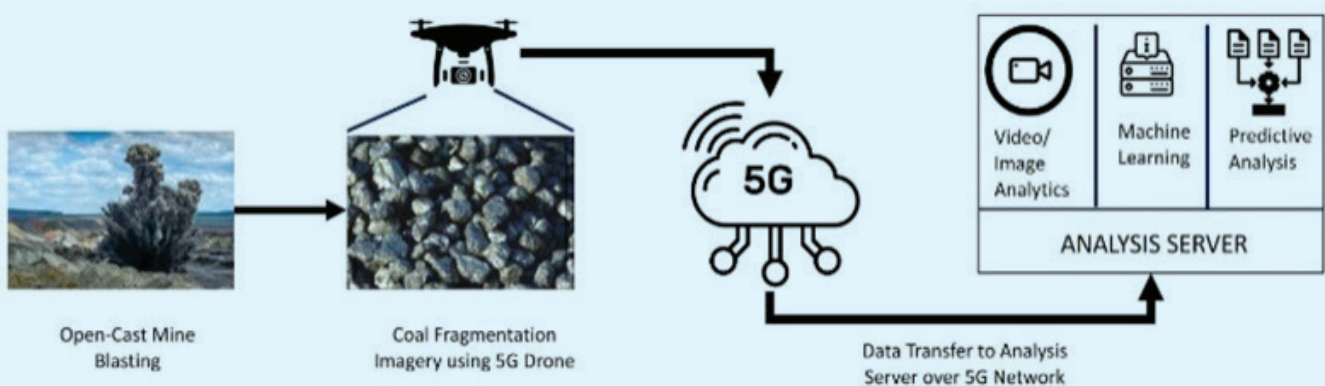
- deciding the most appropriate places to drill depending on the local geological features
- determining the drill hole spacing and pattern in accordance with the intended coal fragmentation.
- Selecting the right explosives based on the area's geology and the particular needs of the blasting process.
- Blasting circuit ready for either a sequential or simultaneous detonation.
- Examining the overall efficiency of blasting.

## VTS/VHMS Data Transfer on 5G

**Network:** - Vehicle Tracking Systems showing GPS coordinates - installed on Vehicle and VTS dashboard with GPS: - Vehicle tracking systems implemented with 5G technology provide continuous insight into the precise location and health of mining vehicles, enhancing the efficiency of operations and streamlining logistics. Data communication between vehicles and the control centre can be made seamless by integrating VTS and VHMS systems with a 5G network. This configuration improves mine safety and operational efficiency by ensuring the real-time interchange of vital information, including vehicle locations, weather, conditions, and health status.

## Mission-Critical Communications -

showing Group call, Group video Call, and Dispatcher Dashboard:- The high bandwidth and very low latency of 5G network allow for uninterrupted communication between mine workers, facilitating emergency response and real-time coordination. With the implementation of voice and video communication over private 5G network, uninterrupted and secure communication for critical operations can be implemented. 5G networks may be used to deploy voice and video applications, providing high-quality, low-latency communication that is crucial for everyday duties and emergency response in mines.



**Fig: Application of 5G Network in realtime Coal fragment size analysis and its classification with blasting parameters using machine learning algorithms**

## Conclusion:

Since the beginning of the twenty-first century, the coal enterprises have advanced to a new phase focused on building inherently safe, smart, and environmentally friendly mines. Intelligence is essential for the advancement of coal-mines. It is a scientific and methodical idea that involves a dynamic and ongoing process. 5G technology will play a crucial role in advancing the development of smart coal mines. Smart coal mining and the integration of 5G technology in the coal mining industry have demonstrated the potential to enhance the information and intelligence capabilities

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# Decoding the trace of the “Plunging Anticlinal” Geological Subsurface Structure of Wardha Valley Coal Field, based on MINEX modelling— A case study of East of Ekarjuna Block.

Gaurav Sharma<sup>1</sup>, Arpita De Sharma<sup>1</sup>

## ABSTRACT

वर्धा वैली कोलफील्ड, महाराष्ट्र राज्य का सबसे बड़ा कोलफील्ड है, जो लगभग 4500 वर्ग कि०मी० क्षेत्र में फैला हुआ है। यह कोलफील्ड मुख्य रूप से चन्द्रपुर जिले में पड़ता है, जिसका एक छोटा हिस्सा यवतमाल जिले में भी पड़ता है। ऐसा माना जाता है कि वर्धा वैली कोलफील्ड की क्षेत्रीय संरचना उत्तर-पश्चिम की ओर अवनमन वाली एक विस्तृत एंटीक्लाइन है। इस एंटीक्लाइन के पश्चिमी और पूर्वी दोनों अंग कोयला धारण करने वाले सिद्ध हुए हैं। प्रस्तुत लेख पाँच रिफ्ट बेसिनों में वर्धा वैली कोलफील्ड के वर्गीकरण और ईस्ट ऑफ़ एकार्जुन ब्लॉक, वर्धा वैली कोलफील्ड की भूवैज्ञानिक संरचना की उपसतह की विवेचना से संबंधित है, जो यह दर्शाता है कि एंटीक्लाइन फोल्ड की धुरी का झुकाव उत्तर-पश्चिम दिशा की ओर है और कोयला-धारक बराकर का डीप-रिवर्सल पूर्वी और पश्चिमी दिशा में है।

*The Wardha Valley Coalfield, covering an area of approximately 4500 sq.km, is the largest coalfield in the state of Maharashtra falling largely in the Chandrapur district, with a small part in the Yeotmal district. It is believed that the regional structure of the Wardha Valley Coalfield is a broad anticline plunging towards NW. Both the western and eastern limbs of this anticline have been proven to be coal-bearing. Present paper deals with the classification of the Wardha Valley coalfield in five rift basins and interpretation of the subsurface geological structure of East of Ekarjuna Block, Wardha Valley Coalfield that shows the axis of anticline fold plunging towards NW and dip reversal of coal-bearing Barakar in easterly & westerly direction.*

**Keywords:** Wardha Valley Coalfield, Rift basin, Plunging Anticline, Limb, Barakar, MINEX, syndepositional faults, Coal.

## Introduction

The Wardha Valley coalfield is bounded within the Latitude N – 190 30' & 200 27' and Longitude E –780 49' & 79049', as per GSI Bulletin Series–A, No.–45, Vol.–II. It forms a part of northwest-

southeast trending Pranitha-Godavari Valley Gondwana basin. The drainage is controlled by the Wardha River and its distributaries flowing through the coalfield. Wardha Valley Coalfield is the main

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source for coal extraction due to availability of Composite Seam and its splits viz. Top, Middle & Bottom Sections. The thickness ranges from 10m to 25m with average GCV grade varying from G12 to G9. The regional structure of the Wardha Valley Coalfield is interpreted by scholars as the anticline plunging towards NNW and both the western and eastern limbs of this anticline have been proven to be coal-bearing based on vast exploration completed by GSI, DGM (MS), MECL & CMPDI. Nevertheless, no concrete subsurface evidence has been found before, for the folded axis and its plunging nature. Moreover, if this concept is true than there rises the

need of scientific explanation for the depositional environmental set up. This paper deals with the subsurface structure deciphered, based on the drilled exploratory boreholes by CMPDI, DGM(MS) & GSI in the East of Ekarjuna Block in Wardha Valley Coalfield which proves the existence of “**Plunging Anticlinal**” geological Subsurface Structure. Also, some light has been thrown on the regional understanding of the geological behaviour of coal bearing Barakar Formation, erratic behaviour of the Motur Formation thickness, based on the available drilled boreholes data and exposed surfaces in UG and OC mines.

## Regional Geology

The Wardha Valley coalfield has been explored extensively by various agencies like GSI, DGM (MS), MECL and CMPDIL etc. and following

stratigraphic succession shown in Table:1, is established in this coalfield.

## Surface Exposure of Geological Formations in Wardha Valley

The Gondwana sediments boundary towards the east is delineated by the exposures of Archaean. The intervening area is occupied by coal-bearing sediments and is mostly divided by the faults running along the strike. In the southern and western parts, the Gondwana sediments boundary is delineated by Vindhyan Formation. The central part of the coalfield is occupied conspicuously by the Talchir. The Deccan Trap covers the Gondwana sediments towards the west and north.

Lameta is available in patches towards the north. A major part of the coalfield is covered by the Kamthi Formation and Black cotton soil. The coal bearing Barakar Formation is exposed only in the western part of the coalfield and in isolated patches within the extent of coalfield. The Gondwana sediments appear to continue in south-south-eastwards into the Godavari Valley sediments.

## Regional Structure

The regional structure of the Wardha Valley Coalfield is a broad anticline plunging towards NW. Both the western and eastern limbs of this anticline have been proved to be coal bearing. The Gondwana sedimentation in Wardha Valley Coalfield had taken

place in NW-SE trending rift basins separated by Vindhyan. The following Fig.1 of Geological Map of Wardha Valley Coalfield (source: GSI) clearly shows the geological distributions of the different Formations within the Coalfield.

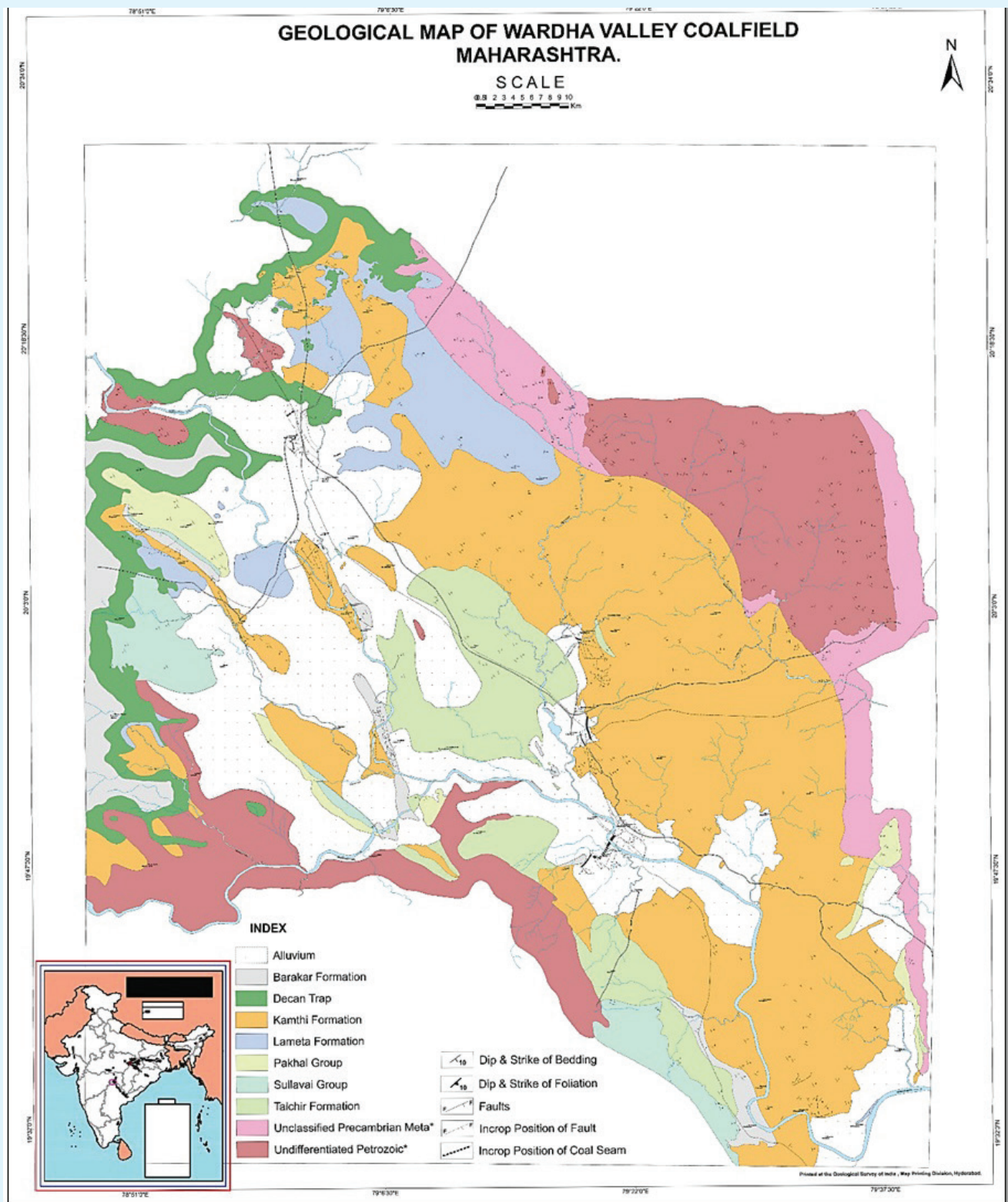


## Stratigraphic Succession of Wardha Valley Coal Field.

Table:1.

Age	Formation	Lithology
<b>Recent/ Sub Recent</b>	Detrital Mantle	Black cotton soil / sandy soil (Thickness: 0 m – 35 m)
<b>Upper Cretaceous-Eocene</b>	Deccan Trap	Basalts (Thickness: up to 100 m)
~~~~~~Unconformity~~~~~		
<b>Cretaceous</b>	Lameta	Cherty limestones, chert, brown, yellowish to pale white, silicified sandstones, claystone. (Thickness: 2 m – 50 m)
~~~~~~Unconformity~~~~~		
<b>Upper Permian to Lower Triassic</b>	Kamthi	Red, brown, and variegated clays, ferruginous medium to coarse grained sandstone and shale bands. (Thickness: 7 m – (+) 100 m)
~~~~~~Unconformity~~~~~		
<b>Middle Permian</b>	Motur	Medium to fine grained variegated sandstones, variegated clays, and shales. (Thickness: up to (+) 400 m)
<b>Lower Permian</b>	Barakar	Predominantly light grey to whitish, medium to coarse grained sandstones with minor grey shale, sandy shale, alternate bands of shale and sandstone and one thick (10 – 25 m) coal seam. (Thickness: 100 m – 400 m)
<b>Upper Carboniferous to Lower Permian</b>	Talchir	Greenish to grey coloured sandstones, siltstone, and shale. (Thickness: up to 200 m (?))
~~~~~~Unconformity~~~~~		
<b>Pre-Cambrian</b>	Sullavai sandstones	White to light brown quartzitic sandstones and conglomerates
	Pakhal Limestones	Grey, bluish, or pinkish limestones and cherts.
~~~~~~Unconformity~~~~~		
<b>Achaean</b>	Metamorphic	Quartzites, granites, gneisses, and schists etc.

Note: The thickness mentioned is drilled thickness and does not necessarily reflect the total thickness of the Formation column.



**Fig.1 Geological Map of Wardha Valley Coalfield.**

## Classification of Rift Basins

So far, five such coal bearing rift basins have been identified based on available regional and detailed exploration data. These Rift Basins may be classified based on dip and strike of Barakar

deposition and isolation with each other as: 1. Main Rift Basin, 2. Madheri Rift Basin, 3. Rajura Rift Basin, 4. Ghonsa Rift Basin & 5. Marki-Mangli Rift Basin.

## Geology of Study Area

The area of East of Ekarjuna Block is located between Latitude N - 20° 10' 56.746" and 20° 13' 18.529" and Longitude E-79° 01' 35.199" and 79° 05' 5.197" and is covered by Survey of India Toposheet No. - 55 P/4 (R.F. 1: 50,000). Geologically it is in the north western part of Main

Rift Basin of Wardha Valley Coalfield. It lies north of Konda-Hardola, North western boundary of NW extension of West of Takli Jena Bellora Block. The following stratigraphic succession is established in East of Ekarjuna Block based on 111 drilled boreholes within the block boundary.

### Stratigraphic Succession of East of Ekarjuna Block.

Table:2.

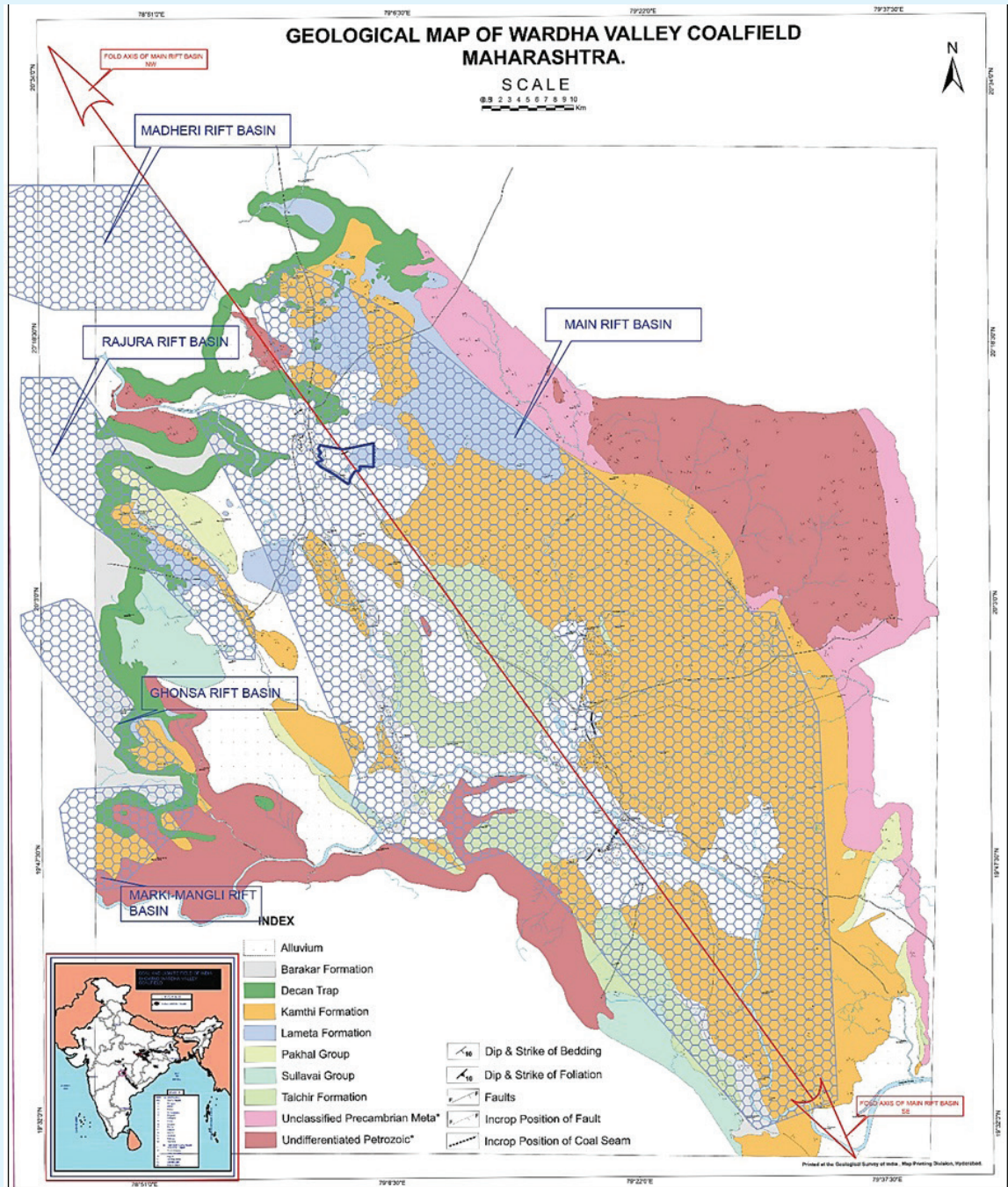
Age	Formation	Lithology
Recent / Sub-Recent	Soil/ Weathered Mantle	Black cotton soil/sandy soil. (Thickness: 0 – 31 m)
Late Cretaceous	Intertrappean	Sandstone, white clay beds interlayered with calcite. (Thickness: 5 – 20 m)
Upper Cretaceous to Eocene	Deccan trap	Basalt (Thickness: 2 – 32 m)
~~~~~~ Unconformity ~~~~~~		
Cretaceous	Lameta	Cherty limestone, chert, brown, yellowish to pale white silicified sandstones, claystone. (Thickness: 1 – 3 m)
~~~~~~ Unconformity ~~~~~~		
Upper Permian to Lower Triassic	Kamthi	Yellow to brown fine to coarse grained sandstones, shale, and variegated clays. (Thickness: 1 – 46 m)
~~~~~~ Unconformity ~~~~~~		
Middle Permian	Motur	Green to greenish grey fine to coarse grained sandstone, variegated clay, and claystone. (Thickness: 50 – 400 m)
Lower Permian	Barakar	Grey to white fine to coarse grained sandstones, thin clay bands, shale, intercalation of shale and sandstone, sandy- shale, shaly- sandstone, carb. shale, shaly coal, and coal. (Thickness: 40 – 225 m)

Note: The thickness mentioned is drilled thickness and does not necessarily reflect the total thickness of the Formation column.

## Study Area

Current paper deals with the structure of Barakar in East of Ekarjuna Block which lies on the fold axis in the NW of Main Rift Basin, and the structure of main rift basin is that of a broad plunging anticline, the axis of which is NW-SE plunging northerly. The western limb dips westerly, whereas, the eastern limb dips easterly. (Please refer

Fig.2). The eastern limit of this anticlinal structure is constituted by North (NW) of Belgaon block towards north and Wirur-Chincholi block towards south. Consequently, the Barakar Formation occurring below Kamthi Formation capping, dips towards west in the western limb and due east in the eastern limb.



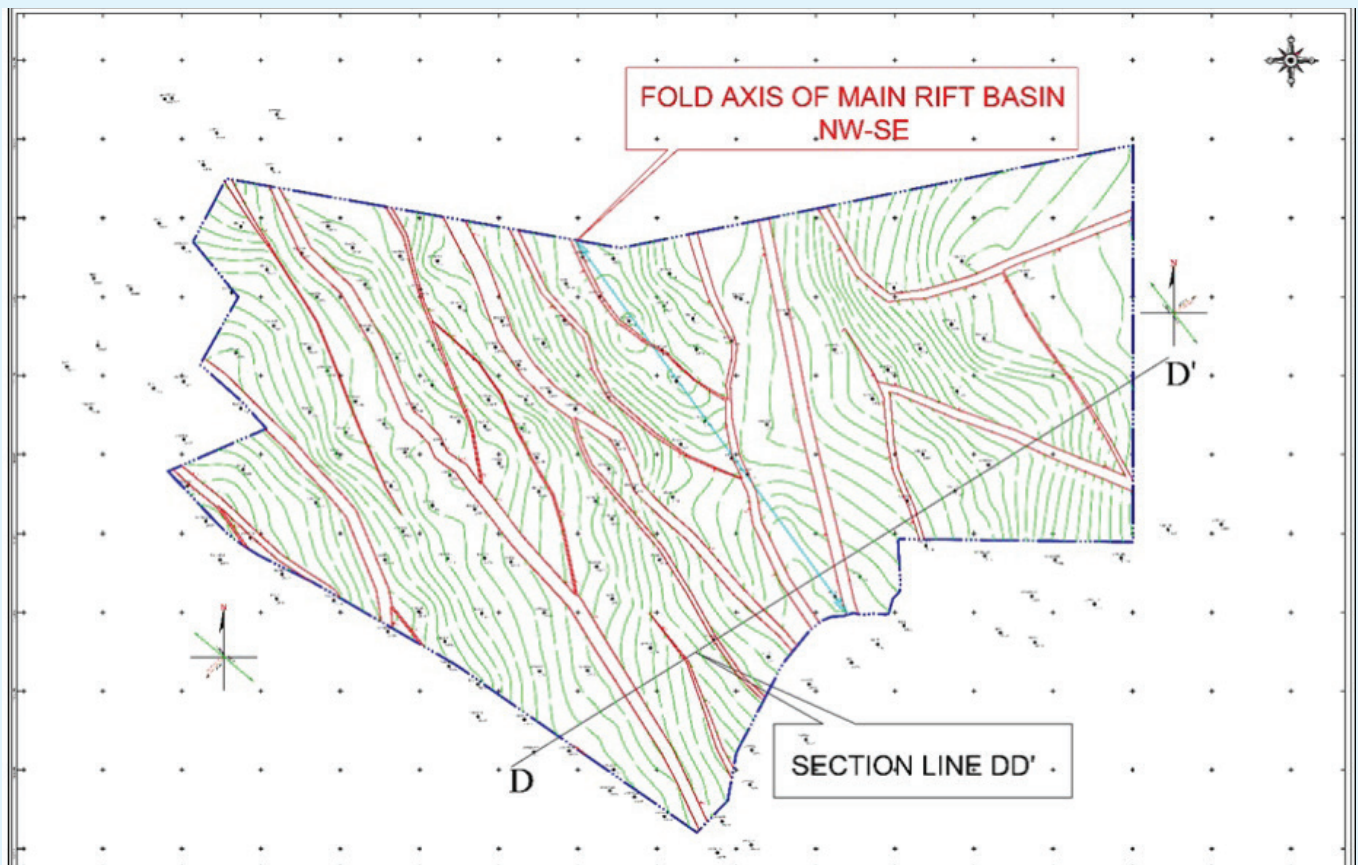
**Fig.2 Showing major Rift Basins and Fold axis orientation of main rift basin**

These limbs have been further affected by numerous NNW-SSE trending strike faults. Eastern limb appears to be less dissected by the faults than the western one.

The East of Ekarjuna block assessed in the present paper forms part of eastern & western limb of the plunging anticline in the north western part of main rift basin of Wardha Valley Coalfield. In East of Ekarjuna area the beds dip towards NE in North-Eastern portion and SW in South-Western portion hence diverging from the central part forming an anticline with its axis NW-SE. The anticlinal structure further faulted by normal gravity faults giving rise to horst & graben structure and forming the deepest part at anticline axis and is clearly

deciphered in cross section plan along DD' shown in fig.3b also same can be understand through 3D view obtained from the MINEX model of the block and shown in fig.3c. The subsurface structure has been interpreted based on logging of drilled boreholes data. The Faults are fixed based on reduction of thickness in parting and coal seam. The presence of slickenside and high angle fractures in recovered lithologs also aid in fixing the fault position.

This pattern of dip reversal is also at par with the adjacent explored blocks lying in South of the block viz. Konda-Hardola & NW Extension of West of Takli Jena Bellora Block where the strata dips in South-Westerly whereas in the Takli-Jena Bellora (N) & (S) the strata dip North-Easterly.



**Fig.3a East of Ekarjuna Block with DD' section line**

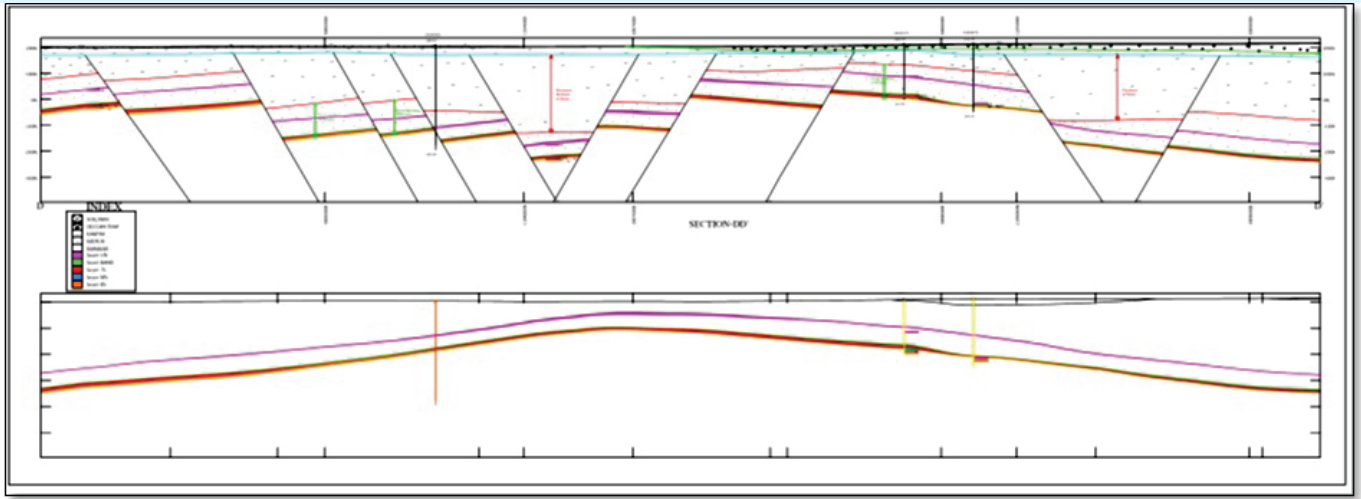
### Strike & Dip

The direction of dip in the North-Eastern portion of the block is N53°E and in South-Western portion is S39°W. The gradient in the North-Eastern & Eastern portion of the block varies from 1 in 5

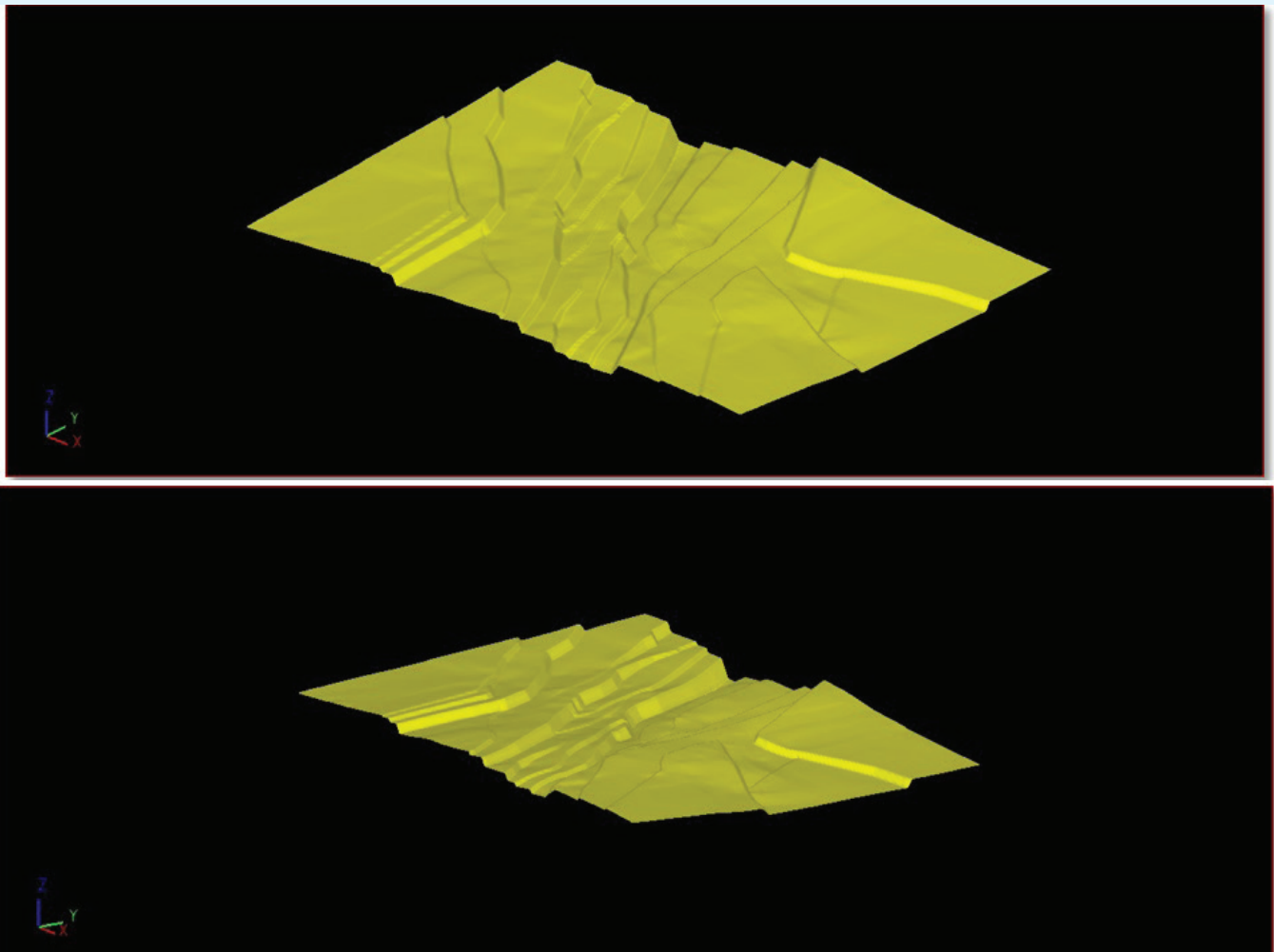
to 1 in 11, whereas the gradient in the South-Western & Western portion of the block varies from 1 in 4 to 1 in 9. The general trend of the strike direction is NW-SE. The change of attitude of beds

particularly towards proximity of the fault planes may be ascribed to dragging of beds also noticed in workings of OC & UG mines. The figure 3b shows the reverse dipping of the strata and hence forming

the Anticlinal Structure, obtained by MINEX modelling by un-faulting the strata, and the first diagram shows the interpreted structure based on drilled boreholes.

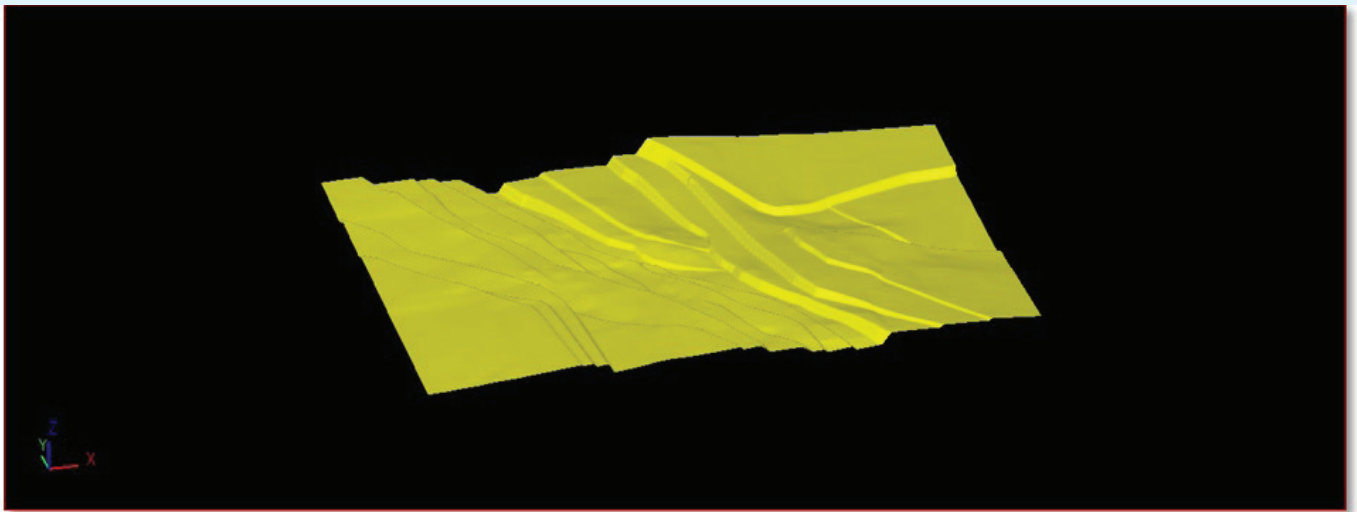


**Fig. 3b the cross-sectional plan along DD'.**



**Fig.3c 3-D view Obtained from MINEX**





**Fig.3c 3-D view obtained from MINEX (continued from previous page)**

## Tectonic Setup

Since, the thickness of Motur Formation varies from east to west as shown in cross sectional plan DD,' it is indicative of the prevailing extensional regime during the Gondwana Sediments deposition and fault controlled synsedimentary subsidence. It is inferred that the basement of the Gondwana Sediments deposited in the Main Rift Basin were an anticline plunging to the NW. During the initiation of sedimentation of the Gondwana Sediments, extensional regime caused the anticlinal structure of basement to be traversed by gravity fault forming the horst & graben structure and these horst & graben forms the site of Gondwana Sediments deposition. In course of time the depth of these basins increases due to prevailing extensional regime and hence

giving rise to syndepositional faulting.

The area under discussion have been identified with five seam viz. Upper band (UB), Band, Top Section (TS), Middle Section (MS), Bottom Section (BS) and at some places Composite Seam (TS+MS+BS). It is observed that the thickness from the Motur-Barakar contact to Upper band and thickness of Coal Seam Packet i.e., UB to BS is constant throughout the area. However, the thickness of Motur Formation varies abruptly within the fault zones. This can be inferred from the cross-section plan DD.' The sub surface structure of East of Ekarjuna Block, and cross section along DD,' clearly indicates towards the existence of anticlinal folded

## Conclusion

structure of basal strata of the basin, which has been faulted due to extensional regime prevailed and consecutively sedimentation of Talchir, Barakar and Motur have taken place in these basins and it can be inferred from there thickness variation especially of the Motur that these basins had undergone fault

controlled synsedimentary subsidence.

This classification of the Wardha Valley CF into 5 rift basins and its better structural understanding enhance the possibility of new horizons of coal existence.

## Acknowledgements

We, acknowledge the executives and drilling crew of Anandwan Camp for taking up the exploration activity in the East of Ekarjuna Block. We, also appreciate Sri Somnath Ray, HoD (Geology) for

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# A study on Inventory of Flora and Fauna (Baseline Group-II) of Amalgamated Yekona I & II Coal Mines Area, Western Coalfield Limited, Chandrapur, Maharashtra, India: An Overview

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## Abstract

The main aim of the study was to assess the floristic and faunistic composition of the study area and to prepare an inventory and base line data on floral and faunal composition, assemblage and probable impact of mine project on flora and fauna. A total of 44 floral species belonging to 17 families were observed in Core zone and 62 floral species belonging to 28 families were observed in buffer zone. A total of 110 faunal species belonging to 62 families were observed in core zone and 272 faunal species belonging to 125 families were observed in buffer zone. In the study a total number of 21 species of mammals, 17 species of birds, 18 species of reptiles, 8 species of amphibians, 30 species of insects, 11 species of butterflies, 3 species of Mollusca and 2 species of crustaceans were observed in the core zone. In the buffer zone 31 species of mammals, 135 species of birds, 26 species of reptiles, 11 species of amphibians, 33 species of insects, 11 species of butterflies, 7 species of Mollusca and 4 species of crustaceans were observed. Conservation of Biodiversity has become the most important requirement of the present-day world, because survival of the man depends upon the biodiversity. Present account is, thus, an evaluation of the status of the biodiversity of the mining lease area, and propose offset measures to any negative impact on biodiversity.

**Key words:** Core zone, Buffer zone, Western Coalfield, Yekona I & II, Chandrapur.

## Introduction

India has abundance of coal resources and is the 3rd largest coal producing country after China and USA. It spreads over eight States in India (Jharkhand, West Bengal, Orissa, Chhattisgarh, M.P, U.P, Maharashtra and Assam) and operates in 473 Mines

(Under Ground: 283, Open Cast: 155, Mixed: 35). (Mahalik and Satapathy, 2016. Maharashtra with its 4.2 % share, is a major consumer of coal, fueled by its vast industrial base. The Chandrapur coalfield and Wardha River Coalfield carter to the state's

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need and contribute to its industrial need. The coal of India not only fulfil the demand of own nation but also the demand of other nation. This provides foreign exchange earnings. India is the world third largest energy consumer due to its population. India's energy consumption is growing by 4.6 % per annum. Coal plays vital role in meeting country's energy demand. From the total nation's electricity generating capacity coal accounts 53%. Therefore, the mining activities are increasing drastically to satisfy the demand. To make mining possible several forests are cleared and this leads to deforestation which causes loss of flora and fauna (Chabukdhara and Singh, 2016). India is rich in important mineral resources and over the year of extraction of these have resulted in ecosystem degradation (Swier and Singh, 2004). Unscientific mining of minerals poses a serious threat to the environment, resulting in reduction of forest cover, erosion of soil at a greater scale, pollution of air, water and land and reduction in biodiversity (UNESCO, 1985). Mining operations, which involve minerals extraction from the earth's crust tends to, make a notable impact on the environment, landscape and biological communities of the earth (Bell et al. 2001). Open cast mining of coal deposits involves removal of overlying soil and rock debris. This debris is heaped in the form of dumps and is called mine spoil. These dumps change the natural land topography and affect the drainage system of the mining area (Chaulya et al. 2000). Lack of vegetation cover on such dumps often leads to acute problem of soil erosion and environmental pollution (Singh et al. 1996). Therefore, development of vegetation on the dumps is essential for the conservation of biodiversity and stable environment in the coalfield area (Singh et al. 2002). Besides, specific use of native and indigenous species for revegetation of mine spoil has also been suggested (Banerjee et al. 1996; Jha & Singh 1993). Hence, the objective of study was to provide base line data on the floral and faunal composition, assemblage and probable impact of mine project on flora and fauna. Before the present study was done, no such study to prepare floral and

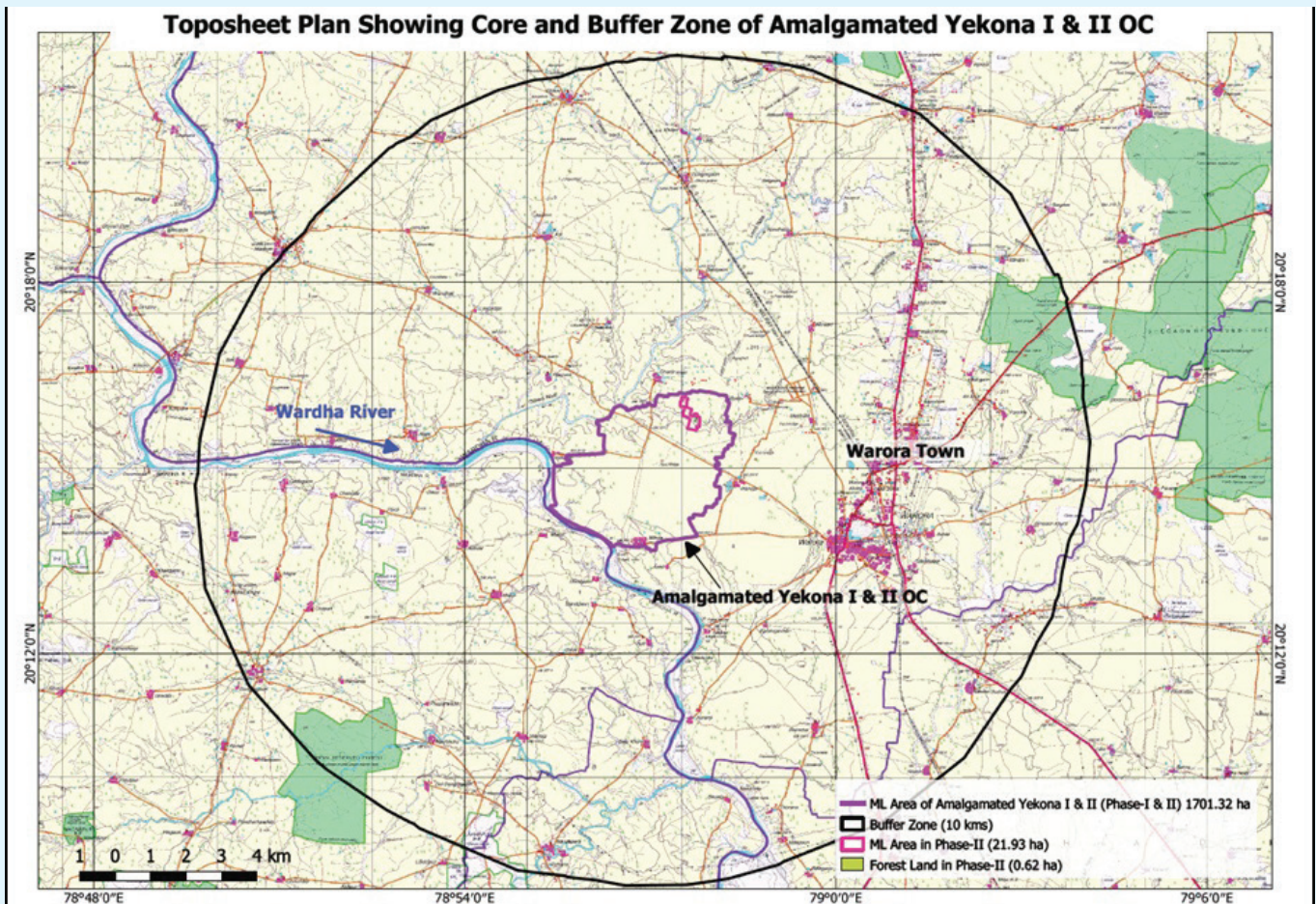
faunal inventories of Yekona I & II coal mine area was undertaken. The present work is supposed to be the first consolidated flora and fauna inventory of the area.

## Materials and Method

### Study area

The study area is the Northern extension of western limit of Wardha Valley Coalfield and located adjacent to Yekona village which falls in Warora Tahsil of Chandrapur District of Maharashtra State. Nagpur and Chandrapur townships are located at a distance of 110 kms and 52 kms from the block respectively. The area is bounded by latitudes 20°13'42"N to 21°15'45"N and longitudes 78°55'00"E to 78°58'30"E and is covered by Survey of India Topo Sheet No. 55L/15 & 55L/16. The entire area of the mine is covered by agriculture land with black cotton soil and exhibits a gently undulating topography with general slope towards north. The altitude of the area ranges from 187 m to 203.72 m from Mean Sea Level. Yekona - I & II block exhibits a gently undulating topography with the general slope towards North. The drainage in the area is controlled by the Wardha River which is flowing southerly and also demarcates the western limit of the mine. One seasonal nala flowing towards west passes north of the block and meets Wardha River. H.F.L. of Wardha River in the block area is about 198 m. The climate of the area is subtropical monsoon type characterized by hot summer and mild winter. The bulk of the rainfall is due to SW monsoon. Monsoon advances in the month of June. Maximum rainfall occurs during July and August months. The average temperature in Warora is 27.4 °C. Precipitation here averages 1233 mm. The forest of the study area can be classified into Tropical Dry Deciduous Forest in accordance with "Survey of Forest Types of India" as per (Champion and Seth 1968). The survey was done in the month of February, 2024.





**Figure 1. Map of study area**

## Field Sampling

**Floral species:** A simple stratified random sampling technique was adopted for carrying out floral survey in the Core (Mine lease) and Buffer zone (10 km radius from mine lease) of the study area. Quadrates of uniform size 10 X 10 m were laid to enumerate and measure trees and 5 X 5 m for shrub species. Sub plots of 1X1 m were laid to enumerate herbs and grass species. The total number

of quadrats laid was 20. 5 quadrates in Core zone and 15 quadrates in Buffer zone. The quantitative community characteristic such as frequency, density, dominance and Importance value index (IVI) was calculated (Mishra, 1968; Curtis, 1959). The species found in quadrates were identified with the help of flora of Maharashtra State (Singh and Karthikeyan, 2000).

## Data analysis

The relative value of density, frequency and dominance was calculated. They were summed up to get importance value index. Then the importance value index of each (Cottam and Curtis, 1956)

The following formulae were used for calculation:

$$\text{Frequency} = \frac{\text{Sampling units in which species occur}}{\text{Total sampling unit studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of single}}{\text{Total number of quadrates taken}}$$

$$\text{Basal area} = \pi r^2 \quad (\text{where } r = \text{radius, } \pi = 3.14)$$

After calculating frequency, density and basal area of the identified species, the relative frequency, relative density and relative dominance were calculated by using following formulae:

$$\text{Relative Frequency} = \frac{\text{Frequency of a single species}}{\text{Total frequency of all the species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Density of a single species}}{\text{Total density of all the species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of single species}}{\text{Total basal area of all the species}} \times 100$$

Finally, the values of relative frequency, relative density and relative dominance were added to get the Importance Value Index (IVI).

$$\text{IVI} = \text{Relative frequency} + \text{Relative density} + \text{Relative dominance}$$

**Faunal species:** Data collection on animal groups of core and buffer zone were done by direct and indirect observation technique. In direct observation technique Road transect and Line transect method was used. In indirect observations, Sign survey method was used to collect animal signs such as Pug marks/ hoof mark / footprint / pellets / dung / scats/ scrapes/scratches, rake marks on trees, call, kill, body remains, etc. The quadrates of 10 x 10 m laid for plants were used. The quadrates were searched thoroughly for signs of animals and recording the species along with the number of each (Heyer et al., 1994). For monitoring mammals intensive survey has been done by transect method (walking) in all major habitats by direct and indirect evidence. Birds were sampled by using line transect method, point count method, and opportunistic bird sightings. By using bird vocal sounds and photographs, the species were identified with the help of field guides (Grimmett et al. 1999; Kazmierczak & Singh 2001; Ali 2001). Survey of reptiles was done by Visual Encounter Survey method (VES): This method is useful for studying the species richness and abundance in a survey path

(Crump and Scott 1994). VES are standard method for inventory of terrestrial herpetofauna (Campbell and Christman 1982; Corn and Bury 1990). For surveying and monitoring amphibians, searches (under the logs and stones, digging through litter and soil, searching short bushes and tree hollows, and under fallen barks and water-catchments was done. By using vocal sound and photographs, the amphibian species were identified. The direct count method (visual survey) was used for surveying the fish species. The villagers angling in different places were approached for fish specimens' collection and identification. Opportunistic recording of butterflies and insects encountered during the field visits were also done). In addition, Secondary information on flora and fauna their distribution (past and present status) was collected from Range Office. Interaction with the local people and even some households were done for information on the presence of various animal species within each locality. Apart from this fauna information was also verified with EIA/EMP, standard publications/ research papers, data from Zoological Survey of India, national and international published literature.

**Limitations:** A complete list of flora and fauna require multiple surveys, at different times, and over a period of years, to enable observation of all species present. Some flora species, such as annuals, are only available for collection at certain times of the year, and others are only identifiable at certain times (such as when they are flowering). Additionally, climatic and stochastic events (such

as fire) may affect the presence of plant species. Species that have a very low abundance in the area are more difficult to locate, due to above factors. Therefore, there is the possibility that some species with low abundance in the area may be overlooked. The fauna reported are species that can be easily seen, heard or have distinctive signs, such as tracks. Many cryptic and nocturnal species may not have been identified during a survey.

## Results

A total of 44 floral species belonging to 17 families were observed in Core zone area and 62 floral species belonging to 28 families were observed in buffer zone. The highest species number was represented by family Fabaceae followed by Poaceae and Lamiaceae in Core zone. The dominant species was Anacardiaceae in core zone and Poaceae in buffer zone. The dominant tree species in core zone was *Prosopis juliflora*, followed by *Pithecellobium dulce* and *Vachillea nilotica*. The dominant climber species in core zone was *Cocculus hirshutus* followed by *Pergularia daemia*. The dominant Shrubs, herbs and grasses in core zone were *Chromolaena odorata*, *Xanthium strumarium* and *Cyperus rotundus* respectively. The dominant tree species in buffer zone was *Ficus religiosa* followed by *Vachillea nilotica* and *Ficus benghalensis*. The dominant climber species was

*Cassytha filiformis*. The dominant Shrubs, herbs and grasses in buffer zone were *Chromolaena odorata*, *Hyptis suaveolens* and *Cyanodon dactylon* respectively. A total of 110 faunal species belonging to 62 families were observed in core zone and 272 faunal species belonging to 125 families were observed in buffer zone. In the study a total number of 21 species of mammals, 17 species of birds, 18 species of reptiles, 8 species of amphibians, 30 species of insects, 11 species of butterflies, 3 species of Mollusca and 2 species of crustaceans were observed in the core zone. In the buffer zone 31 species of mammals, 135 species of birds, 26 species of reptiles, 11 species of amphibians, 33 species of insects, 11 species of butterflies, 7 species of Mollusca and 4 species of crustaceans were observed in the buffer zone.

**Table 1. IVI (Important Value Index) of flora species observed in core zone.**

S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
1	<i>Abutilon indicum</i>	Atibala	Malvaceae	Herb	4.839	7.527	5.195	17.560
2	<i>Acacia ferruginea</i>	Acacia	Fabaceae	Tree	5.560	2.940	8.120	16.620
3	<i>Aristida setacea</i>	Wild broom grass	Poaceae	Grass	1.613	2.151	4.453	8.216
4	<i>Azadirachta indica</i>	Neem	Meliaceae	Tree	5.560	2.940	1.070	9.570
5	<i>Bombax ceiba</i>	Seemal	Malvaceae	Tree	5.560	2.940	5.430	13.930
6	<i>Bothriochloa pertusa</i>	Indian blue grass	Poaceae	Grass	1.613	2.151	4.453	8.216
7	<i>Butea monosperma</i>	Polash	Fabaceae	Tree	5.560	2.940	4.290	12.790
8	<i>Calotropis procera</i>	Awk	Apocynaceae	Climber	3.226	2.151	2.226	7.603
9	<i>Cassia siamea</i>	Chakundi	Fabaceae	Tree	22.220	14.710	0.270	37.200
10	<i>Chromolaena odorata</i>	Siam weed	Asteraceae	Shrub	4.839	8.602	5.937	19.378
11	<i>Coccinea grandis</i>	Ivy guard	Cucurbitaceae	Climber	1.613	1.075	2.226	4.915
12	<i>Cocculus hirsutus</i>	Binding vine	Menispermaceae	Climber	3.226	2.151	2.226	7.603
13	<i>Cullen corylifolium</i>	Bahuchi	Fabaceae	Herb	1.613	2.151	4.453	8.216
14	<i>Cyanodon dactylon</i>	Dhoop grass	Poaceae	Grass	6.452	4.301	2.226	12.979
15	<i>Cyperus rotundus</i>	Nut grass	Cyperaceae	Grass	3.226	3.226	3.340	9.791
16	<i>Dactyloctenium aegyptiacum</i>	Finger grass	Poaceae	Grass	3.226	3.226	3.340	9.791
17	<i>Dalbergia sissoo</i>	Seesham	Fabaceae	Tree	5.560	14.710	0.000	20.260
18	<i>Echinochloa colona</i>	Dung grass	Poaceae	Grass	4.839	7.527	5.195	17.560
19	<i>Eragrostis japonica</i>	Love grass	Poaceae	Grass	4.839	4.301	2.968	12.108
20	<i>Heteropogon contortus</i>	Spear grass	Poaceae	Grass	6.452	5.376	2.783	14.611
21	<i>Hibiscus</i>	Wild Hibiscus	Malvaceae	Herb	3.226	3.226	3.340	9.791
22	<i>Hyptis suaveolens</i>	Van tulsi	Lamiaceae	Herb	6.452	4.301	2.226	12.979
23	<i>Ipomoea obscura</i>	Obscure morning glory	Convolvulaceae	Climber	3.226	2.151	2.226	7.603
24	<i>Lantana camera</i>	Wild sage	Lamiaceae	Shrub	1.613	3.226	6.679	11.518
25	<i>Mangifera indica</i>	Aam	Anacardiaceae	Tree	5.560	2.940	64.480	72.980
26	<i>Moringa oleifera</i>	Drumstick	Moringaceae	Tree	5.560	2.940	2.420	10.910
27	<i>Ocimum americanum</i>	American basil	Lamiaceae	Herb	3.226	3.226	3.340	9.791
28	<i>Ocimum tenuiflorum</i>	Sweet basil	Lamiaceae	Herb	4.839	3.226	2.226	10.291



S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
29	<i>Parthenium hysterophorus</i>	Congress ghas	Compositae	Herb	4.839	3.226	2.226	10.291
30	<i>Pergularia daemia</i>	Trellis vine	Apocynaceae	Climber	1.613	1.075	2.226	4.915
31	<i>Pithecellobium dulce</i>	Jungli jelebe	Fabaceae	Tree	5.560	2.940	5.430	13.930
32	<i>Pongamia pinnata</i>	Karanjva	Fabaceae	Tree	5.560	2.940	0.000	8.500
33	<i>Prosopis juliflora</i>	Mesquite	Fabaceae	Tree	5.560	5.880	0.620	12.050
34	<i>Senna tora</i>	Panward	Leguminosae	Herb	6.452	8.602	4.453	19.506
35	<i>Solanum virginianum</i>	Kateli	Solanaceae	Herb	1.613	1.075	2.226	4.915
36	<i>Tectona grandis</i>	Sagwan	Lamiaceae	Tree	5.560	2.940	2.430	10.920
37	<i>Terminalia arjuna</i>	Arjun	Combretaceae	Tree	5.560	17.650	0.000	23.200
38	<i>Terminalia bellirica</i>	Bahera	Combretaceae	Tree	5.560	14.710	0.000	20.260
39	<i>Tinospora cordifolia</i>	Geloy	Menispermaceae	Climber	3.226	2.151	2.226	7.603
40	<i>Tridax procumbens</i>	Coat button	Compositae	Herb	3.226	2.151	2.226	7.603
41	<i>Triumphetta rotundifolia</i>	Tupkati	Malvaceae	Herb	1.613	2.151	4.453	8.216
42	<i>Vachillea nilotica</i>	Babul	Fabaceae	Tree	5.560	5.880	5.430	16.870
43	<i>Wattakakka volubilis</i>	Green wax climber	Apocynaceae	Climber	1.613	1.075	2.226	4.915
44	<i>Xanthium strumarium</i>	Cockle bur	Compositae	Herb	1.613	3.226	6.679	11.518

**Table 2. IVI (Important Value Index) of flora species observed in buffer zone**

S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
1	<i>Abutilon indicum</i>	Atibala	Malvaceae	Herb	3.846	2.484	1.67	7.999
2	<i>Abutilon pannosum</i>	Atibala	Malvaceae	Herb	3.846	3.106	2.09	9.037
3	<i>Acacia ferruginea</i>	Safed khair	Fabaceae	Tree	0.40	2.78	1.51	4.68
4	<i>Acacia leucophylla</i>	Safed babul	Fabaceae	Tree	0.17	2.78	3.04	5.98
5	<i>Achyranthus aspera</i>	Chir chita	Amaranthaceae	Herb	1.923	1.242	1.67	4.833
6	<i>Albizia procera</i>	Safed siris	Fabaceae	Tree	1.89	2.78	1.51	6.17
7	<i>Alternanthera tenella</i>	Amaranth weed	Amaranthaceae	Herb	1.923	2.484	3.34	7.744
8	<i>Apluda mutica</i>	Congo grass	Poaceae	Grass	2.885	3.727	3.34	9.947

S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
9	<i>Aristida setacea</i>	Wild broom grass	Poaceae	Grass	1.923	2.484	3.34	7.744
10	<i>Azadirachta indica</i>	Neem	Meliaceae	Tree	0.40	5.59	3.04	9.03
11	<i>Balanites aegyptica</i>	Desert date	Zygophyllaceae	Tree	1.99	5.59	4.57	12.15
12	<i>Bothriochloa pertusa</i>	Indian blue grass	Poaceae	Grass	1.923	1.242	1.67	4.833
13	<i>Butea monosperma</i>	Palash	Fabaceae	Tree	0.11	2.78	3.04	5.93
14	<i>Butea superba</i>	Budel, latapalas	Papillionaceae	Shrub	1.923	1.863	2.5	6.289
15	<i>Capparis sepiaria</i>	Wild caper bush	Capparaceae	Shrub	0.962	1.242	3.34	5.54
16	<i>Cassytha filiformis</i>	Akasa valli	Lauraceae	Climber	2.885	3.727	3.34	9.947
17	<i>Chromolaena odorata</i>	Siam weed	Asteraceae	Shrub	2.885	2.484	2.22	7.593
18	<i>Coccinea grandis</i>	Ivy guard	Cucurbitaceae	Climber	0.962	0.621	1.67	3.251
19	<i>Cocculus hirshutus</i>	Binding vine	Menispermaceae	Climber	0.962	0.621	1.67	3.251
20	<i>Cordia myxa</i>	Lasura	Boraginaceae	Tree	4.03	2.78	1.51	8.31
21	<i>Cullen corylifoia</i>	Bahuchi	Leguminosae	Herb	0.962	0.621	1.67	3.251
22	<i>Cyanodon dactylon</i>	Dhoop grass	Poaceae	Grass	4.808	6.211	3.34	14.35
23	<i>Cyperus rotundus</i>	Nut grass	Cyperaceae	Grass	4.808	4.969	2.67	12.45
24	<i>Dactylactenium aegyptiacum</i>	Finger grass	Poaceae	Grass	2.885	2.484	2.22	7.593
25	<i>Echinochloa colona</i>	Dung grass	Poaceae	Grass	1.923	2.484	3.34	7.744
26	<i>Eragrostis japonica</i>	Love grass	Poaceae	Grass	2.885	3.727	3.34	9.947
27	<i>Eucalyptus terreticornis</i>	Blue gum	Myrtaceae	Tree	1.35	2.78	1.51	5.63
28	<i>Ficus benghalensis</i>	Bargath	Moraceae	Tree	16.13	2.78	1.51	20.41
29	<i>Ficus hispida</i>	Devil fig	Moraceae	Tree	0.55	2.78	1.51	4.83
30	<i>Ficus religiosa</i>	Peepal	Moraceae	Tree	20.65	2.78	1.51	24.93
31	<i>Gossypium herbaceum</i>	Cotton fileld	Malvaceae	Herb	4.808	4.969	2.67	12.45



S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
32	<i>Heteropogon contortus</i>	Spear grass	Poaceae	Grass	1.923	3.106	4.17	9.199
33	<i>Hibiscus panduriformis</i>	Wild bindi	Malvaceae	Herb	0.962	1.242	3.34	5.54
34	<i>Hyptis suaveolens</i>	Van tulasi	Lamiaceae	Herb	3.846	4.969	3.34	12.15
35	<i>Indigofera linnaei</i>	Wild indigo	Leguminosae	Herb	1.923	2.484	3.34	7.744
36	<i>Jatropha curcas</i>	Jatropha	Euphorbiaceae	Shrub	1.923	1.242	1.67	4.833
37	<i>Lantana camera</i>	Wild sage	Lamiaceae	Shrub	0.962	1.242	3.34	5.54
38	<i>Leucaena leucocephala</i>	Subabul	Fabaceae	Tree	0.18	2.78	1.51	4.46
39	<i>Limonia acidissima</i>	Wood apple	Rutaceae	Tree	1.75	2.78	1.51	6.03
40	<i>Madhuca longifolia</i>	Mahua	Sapotaceae	Tree	38.96	5.47	4.57	49
41	<i>Monoon longifolia</i>	Tall Asoca	Annonaceae	Tree	0.74	2.78	3.04	6.55
42	<i>Moringa concanensis</i>	Wild drum stick	Rubiaceae	Tree	1.12	2.78	1.51	5.4
43	<i>Operculina turpethum</i>	Turpiti root	Convolvulaceae	Climber	0.962	1.242	3.34	5.54
44	<i>Parthenium hysterophorus</i>	Congress ghas	Compositae	Herb	3.846	3.727	2.5	10.07
45	<i>Phyllanthus maderaspatana</i>	Madras bhui-amla	Euphorbiaceae	Herb	1.923	1.863	2.5	6.289
46	<i>Pithecellobium dulce</i>	Jungle jilebe	Moringaceae	Tree	0.04	5.59	3.04	8.67
47	<i>Prosopis juliflora</i>	Mesquite	Fabaceae	Tree	0.63	13.88	41.1	55.6
48	<i>Saccharum spontaneum</i>	Kans grass	Poaceae	Grass	5.769	4.969	2.22	12.96
49	<i>Senna tora</i>	Panwar	Leguminosae	Herb	2.885	1.863	1.67	6.416
50	<i>Sida acuta</i>	Bala	Malvaceae	Herb	5.769	4.969	2.22	12.96
51	<i>Sida cordata</i>	Long stalked sida	Malvaceae	Herb	1.923	1.863	2.5	6.289
52	<i>Tamarindus indicus</i>	Imili	Fabaceae	Tree	6.98	2.78	1.51	11.26
53	<i>Tectona grandis</i>	Teak	Lamiaceae	Tree	1.02	2.78	5.94	9.74
54	<i>Tephrosia purpurea</i>	Sharpunka	Leguminosae	Herb	1.923	1.242	1.67	4.833
55	<i>Teramnus labialis</i>	Blue wiss	Leguminosae	Climber	0.962	0.621	1.67	3.251
56	<i>Thysanolaena maxima</i>	Broom grass	Poaceae	Grass	1.923	1.242	1.67	4.833
57	<i>Tinospora cordifolia</i>	Geloy	Menispermaceae	Climber	0.962	0.621	1.67	3.251

S. No	Scientific name	Common name	Family	Habit	Relative Frequency	Relative Density	Relative Dominance	IVI
58	<i>Trichodesma zeylanica</i>	Camel bush	Boraginaceae	Herb	1.923	2.484	3.34	7.744
59	<i>Typha angustifolia</i>	Narrowleaf cattail	Typhaceae	Grass	5.769	6.211	2.78	14.76
60	<i>Vachillea nilotica</i>	Babul	Fabaceae	Tree	0.24	13.88	7.53	21.65
61	<i>Vitex negundo</i>	Nirgundi	Lamiaceae	Tree	0.04	2.78	1.51	4.33
62	<i>Zizyphus mauritiana</i>	Ber	Rhamnaceae	Tree	0.63	5.55	3.04	9.26

**Table 3. Checklist of faunal species observed in core zone**

Sl. No.	Scientific Name	Common/ English Name	Family	Animal species
1	<i>Acheta domesticus</i>	House cricket	Gryllidae	Insects
2	<i>Amphiesma stolatum</i>	Buff Striped keelback	Colubridae	Reptiles
3	<i>Anopheles sp.</i>	Species of Mosquito	Culicidae	Insects
4	<i>Apis cerana indica</i>	Indian honeybee	Apidae	Insects
5	<i>Argiope pulchella</i>	Species of Spider	Araneidae	Insects
6	<i>Aspidomorpha westwoodii</i>	Orange tortoise beetle	Chrysomelidae	Insects
7	<i>Atretium schistosum</i>	Olive keelback snake	Colubridae	Reptiles
8	<i>Bandicota bengalensis</i>	Bandicoot Rat	Muridae	Mammals
9	<i>Blattella asahinai</i>	Indian cockroach	Ectobiidae	Insects
10	<i>Bombus terrestris</i>	Bumble bee	Apidae	Insects
11	<i>Bos taurus</i>	Domestic cow	Bovidae	Mammals
12	<i>Boselaphus tragocamelus</i>	Nilgai	Bovidae	Mammals
13	<i>Bubalus bubalis</i>	Domestic buffalo	Bovidae	Mammals
14	<i>Bufo melanostictus</i>	Common Indian Toad	Bufoidea	Amphibians
15	<i>Bungarus caeruleus</i>	Indian Krait	Elapidae	Reptiles
16	<i>Calotes versicolor</i>	Indian Garden Lizard	Agamidae	Reptiles
17	<i>Camponotus compressus</i>	Indian black Ant	Formicidae	Insects
18	<i>Canis aureus indicus</i>	Indian Jackal	Canidae	Mammals
19	<i>Canis lupus</i>	Domestic dog	Canidae	Mammals
20	<i>Capra hircus</i>	Domestic goat	Bovidae	Mammals
21	<i>Catharsius birmanensis</i>	Cow dung beetle	Scarabaeidae	Insects
22	<i>Catopsilia pomona</i>	Common Emigrant	Pieridae	Butterflies
23	<i>Chilades lajus</i>	Lime blue	Lycaenidae	Butterflies
24	<i>Cimex lectularius</i>	Bedbug	Cimicidae	Insects
25	<i>Coccinella spp.</i>	Lady bug beetle	Coccinellidae	Insects
26	<i>Coelognathus helena</i>	Common Trinket	Colubridae	Reptiles
27	<i>Copsychus saularis saularis</i>	Indian magpie robin	Pycnonotidae	Birds
28	<i>Coracias benghalensis</i>	Northern roller	Coraciidae	Birds
29	<i>Corvus macrorhachos culminates</i>	Indian jungle crow	Corvidae	Birds

Sl. No.	Scientific Name	Common/ English Name	Family	Animal species
30	<i>Corvus splendens splendens</i>	Indian house crow	Corvidae	Birds
31	<i>Danaus chrysippus</i>	Plain tiger	Nymphalidae	Butterflies
32	<i>Dendrelaphis tristis</i>	Common Bronze back	Colubridae	Reptiles
33	<i>Dendrocitta vagabunda vagabunda</i>	Rufous treepie	Corvidae	Birds
34	<i>Dicrurus adsimilis macrocercus</i>	South Indian black drongo or king crow	Dicruridae	Birds
35	<i>Dinopium benghalensis benghalensis</i>	Lesser golden backed woodpecker	Picidae	Birds
36	<i>Eutropis carinata</i>	Common Indian Skink	Scincidae	Reptiles
37	<i>Fejervarya pierrei</i>	Paddy field frog	Dicroglossidae	Amphibians
38	<i>Felis catus</i>	Domestic cat	Felidae	Mammals
39	<i>Felis chaus</i>	Jungle Cat	Felidae	Mammals
40	<i>Fowlea piscator</i>	Checkered Keelback	Colubridae	Reptiles
41	<i>Funambulus palmarum</i>	Indian Palm squirrel	Leporidae	Mammals
42	<i>Golunda ellioti ellioti</i>	Indian Bush Rat	Muridae	Mammals
43	<i>Grypotyphlops acutus</i>	Blind Snake	Typhlopidae	Reptiles
44	<i>Harmonia axyridis</i>	Asian lady beetle	Coccinellidae	Insects
45	<i>Harpaphe haydeniana</i>	Yellow-spotted millipede	Xystodesmidae	Insects
46	<i>Hemidactylus brookii</i>	Spotted House Gecko	Gekkonidae	Reptiles
47	<i>Hemidactylus frenatus</i>	Indian House Gecko	Gekkonidae	Reptiles
48	<i>Herpestes edwardsi</i>	Indian Grey Mongoose	Herpestidae	Mammals
49	<i>Heterometrus bengalensis</i>	Indian black Scorpion	Scorpionidae	Insects
50	<i>Hottentotta tamulus</i>	Indian red Scorpion	Buthidae	Insects
51	<i>Hystrix indica</i>	Common Indian Porcupine	Hystricidae	Mammals
52	<i>Idopoma dissimilis</i>	Paddy field snail	Ampullariidae	Mollusk
53	<i>Lepus nigricollis</i>	Indian hare	Leporidae	Mammals
54	<i>Lithobius forficatus</i>	Stone centipede	Lithobiidae	Insects
55	<i>Lycodon aulicus</i>	Indian wolf snake	Colubridae	Reptiles
56	<i>Lygosoma punctatus</i>	Common Snake-eyed Skink	Scincidae	Reptiles
57	<i>Macaca mulatta</i>	Rhesus macaque	Cercopithecidae	Mammals
58	<i>Macrobrachium rosenbergii</i>	Freshwater mud Prawn	Palaemonidae	Crustaceans
59	<i>Macrochlymus indica</i>	Indian snail	Ariophantidae	Mollusk
60	<i>Melanochelys trijuga trijuga</i>	Indian Pond Terrapin	Bataguridae	Reptiles
61	<i>Merops orientalis orientalis</i>	Indian small green bee-eater	Meropidae	Birds
62	<i>Microhyla ornata</i>	Ornate Microhylid	Microhylidae	Amphibians
63	<i>Microhyla spp.</i>	Narrow mouth Frog	Microhylidae	Amphibians
64	<i>Microtermes obesi</i>	Termite	Termitidae	Insects
65	<i>Mus booduga booduga</i>	Indian field mouse	Muridae	Mammals
66	<i>Nectarinia asiatica asiatica</i>	Indian purple sunbird	Nectarinidae	Birds
67	<i>Neopithecops zalmora</i>	Common Quaker	Lycaenidae	Butterflies
68	<i>Oecophylla smaragdina</i>	Green tree ants	Formicidae	Insects
69	<i>Oligodon arnensis</i>	Common kukri Snake	Colubridae	Reptiles

Sl. No.	Scientific Name	Common/ English Name	Family	Animal species
70	<i>Oriolus oriolus kundoo</i>	Indian golden oriole	Orididae	Birds
71	<i>Oriolus xanthornus maderaspatanus</i>	South Indian black headed oriole	Orididae	Birds
72	<i>Ovis aries</i>	Domestic sheep	Bovidae	Mammals
73	<i>Pantala flavescens</i>	Dragonfly	Libellulidae	Insects
74	<i>Papilio demoleus</i>	Lime butterfly	Papilionidae	Butterflies
75	<i>Papilio helenus</i>	Red Helen	Papilionidae	Butterflies
76	<i>Papilio polymnestor</i>	Blue Mormon	Papilionidae	Butterflies
77	<i>Papilio polytes</i>	Common mormon	Papilionidae	Butterflies
78	<i>Paragomphus lineatus</i>	Common hook tail dragonfly	Gomphidae	Insects
79	<i>Parathelphus convexa</i>	Paddy field Crab	Gecarcinucidae	Crustaceans
80	<i>Passer domesticus indicus</i>	Indian house sparrow	Ploceidae	Birds
81	<i>Pteropus giganteus</i>	Indian fruit bat	Pteropodidae	Mammals
82	<i>Phalanta phalanta</i>	Common leopard	Nymphalidae	Butterflies
83	<i>Pila globosa</i>	Apple snail	Ampullariidae	Mollusk
84	<i>Platypleura hampsoni</i>	Indian cicada	Ampullariidae	Insects
85	<i>Plocues philippinus</i>	Indian baya	Ploceidae	Birds
86	<i>Poekilocerus pictus</i>	Indian grasshopper	Pyrgomorphidae	Insects
87	<i>Ptyas mucosus</i>	Common Rat Snake	Colubridae	Reptiles
88	<i>Python molurus</i>	Indian Rock Python	Boidae	Reptiles
89	<i>Rana crassa</i>	Jerdon's Bull Frog	Ranidae	Amphibians
90	<i>Rana erythraea</i>	Leaping Frog	Ranidae	Amphibians
91	<i>Rana limnocharis</i>	Cricket Frog	Ranidae	Amphibians
92	<i>Rana tigrina</i>	Indian Bull Frog	Ranidae	Amphibians
93	<i>Rattus rattus gangutrianus</i>	Common Indian rat	Muridae	Mammals
94	<i>Saxicoloides fulicata erythrura</i>	Indian robin	Pycnonotidae	Birds
95	<i>Scolopendra morsitans</i>	Red headed centipede	Scolopendridae	Insects
96	<i>Semnopithecus entellus</i>	Hanuman langur	Cercopithecidae	Mammals
97	<i>Solenopsis geminata</i>	Indian red Ants	Formicidae	Insects
98	<i>Spalgis epius</i>	Apefly	Lycaenidae	Butterflies
99	<i>Sphenomorphus maculatus</i>	Spotted forest skink	Scincidae	Reptiles
100	<i>Spirostreptus Sp.</i>	Giant Millipede	Spirostreptidae	Insects
101	<i>Sturnus malabaricus</i>	Grey headed maina	Sturnidae	Birds
102	<i>Sturnus pagodarum</i>	Black headed myna	Sturnidae	Birds
103	<i>Sus scrofa cristatus</i>	Indian wild boar	Suidae	Mammals
104	<i>Tirumala limniace</i>	Blue Tiger	Nymphalidae	Butterflies
105	<i>Trombidium Spp.</i>	Red velvet mite	Trombidiidae	Insects
106	<i>Upupa epops ceylonensis</i>	Ceylon hoopee	Upuciidae	Birds
107	<i>Vespa orientalis</i>	Oriental hornet	Vespidae	Insects
108	<i>Vespula vulgaris</i>	Common wasp	Vespidae	Insects
109	<i>Xanthippus corallipes</i>	Brown spotted grasshopper	Acrididae	Insects
110	<i>Xylocopa latipes</i>	Tropical carpenter bee	Apidae	Insects



**Table 4. Checklist of faunal species observed in buffer zone**

Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
1	<i>Accipiter badius</i>	Shikra	Accipitridae	Birds
2	<i>Acheta domesticus</i>	House cricket	Gryllidae	Insects
3	<i>Acridotheres ginginianus</i>	Bank Mayna	Sturnidae	Birds
4	<i>Acridotheres tristis</i>	Common Myna	Sturnidae	Birds
5	<i>Acrocephalus dumetorum</i>	Blyth's Reed Warbler	Acrocephalidae	Birds
6	<i>Actitis hypoleucos</i>	Common Sandpiper	Scolopacidae	Birds
7	<i>Aegithina tiphia</i>	Common Iora	Aegithinidae	Birds
8	<i>Alcedo atthis</i>	Common Kingfisher	Alcedinidae	Birds
9	<i>Amaurornis phoenicurus</i>	White-breasted Water hen	Rallidae	Birds
10	<i>Amphiesma stolatum</i>	Buff Striped keelback	Colubridae	Reptiles
11	<i>Anabas testudineus</i>	Koi	Anabantidae	Fishes
12	<i>Anas acuta</i>	Northern pintail	Anatidae	Birds
13	<i>Anastomus oscitans</i>	Asian Openbill Stork	Ciconiidae	Birds
14	<i>Anopheles sp.</i>	Species of Mosquito	Culicidae	Insects
15	<i>Anthus rufulus</i>	Paddy-field Pipit	Motacillidae	Birds
16	<i>Antilope cervicapra</i>	Blackbuck	Bovidae	Mammals
17	<i>Apis cerana indica</i>	Indian honeybee	Apidae	Insects
18	<i>Apus affinis</i>	House Swift	Apodidae	Birds
19	<i>Ardea alba</i>	Great egret	Ardeidae	Birds
20	<i>Ardea cinerea</i>	Grey Heron	Ardeidae	Birds
21	<i>Ardeola grayii</i>	Indian Pond Heron	Ardeidae	Birds
22	<i>Ardeotis nigriceps</i>	Great Indian bustard	Otididae	Birds
23	<i>Argiope pulchella</i>	Species of Spider	Araneidae	Insects
24	<i>Aspidimorpha westwoodii</i>	Orange tortoise beetle	Chrysomelidae	Insects
25	<i>Athene brama</i>	Spotted Owlet	Strigidae	Birds
26	<i>Atretium schistosum</i>	Olive keelback snake	Colubridae	Reptiles
27	<i>Axis axis</i>	Spotted deer/ Chital	Cervidae	Mammals
28	<i>Bandicota bengalensis</i>	Bandicoot Rat	Muridae	Mammals
29	<i>Barytelphusa guerini</i>	Fresh water crab	Barytelphusa	Crustaceans
30	<i>Blattella asahinai</i>	Indian cockroach	Ectobiidae	Insects
31	<i>Bombus terrestris</i>	Bumble bee	Apidae	Insects
32	<i>Bombyx mori</i>	Silk moth	Bombycidae	Insects
33	<i>Bos taurus indicus</i>	Domestic cow	Bovidae	Mammals
34	<i>Boselaphus tragocamelus</i>	Nilgai	Bovidae	Mammals
35	<i>Bubalus bubalis</i>	Domestic buffalo	Bovidae	Mammals
36	<i>Bubulcus ibis</i>	Cattle Egret	Ardeidae	Birds
37	<i>Bufo melanostictus</i>	Common Indian Toad	Bufo	Amphibians
38	<i>Bungarus caeruleus</i>	Indian Krait	Elapidae	Reptiles
39	<i>Cacomantis sonneratii</i>	Banded Bay Cuckoo	Cuculidae	Birds
40	<i>Calotes versicolor</i>	Indian Garden Lizard	Agamidae	Reptiles

Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
41	<i>Camponotus compressus</i>	Indian black Ant	Formicidae	Insects
42	<i>Canis aureus indicus</i>	Indian Jackal	Canidae	Mammals
43	<i>Canis lupus</i>	Domestic dog	Canidae	Mammals
44	<i>Capra hircus</i>	Domestic goat	Bovidae	Mammals
45	<i>Caprimulgus asiaticus</i>	Indian Nightjar	Caprimulgidae	Birds
46	<i>Catharsius birmanensis</i>	Cow dung beetle	Scarabaeidae	Insects
47	<i>Catla catla</i>	Catla	Cyprinidae	Fishes
48	<i>Catopsilia pomona</i>	Common Emigrant	Pieridae	Butterflies
49	<i>Centropus sinensis</i>	Greater coucal	Cuculidae	Birds
50	<i>Ceryle rudis</i>	Pied kingfisher	Alcedinidae	Birds
51	<i>Channa gachua</i>	Chang	Channidae	Fishes
52	<i>Channa punctatus</i>	Lata	Channidae	Fishes
53	<i>Channa striatus</i>	Sole	Channidae	Fishes
54	<i>Charadrius dubius</i>	Little Ringed Plover	Charadriidae	Birds
55	<i>Chilades lajus</i>	Lime blue	Lycaenidae	Butterflies
56	<i>Ciconia episcopus</i>	Woolly-Necked Stork	Ciconiidae	Birds
57	<i>Cimex lectularius</i>	Bedbug	Cimicidae	Insects
58	<i>Cinnyris asiaticus</i>	Purple Sunbird	Nectariniidae	Birds
59	<i>Circus aeruginosus</i>	Eurasian Marsh Harrier	Accipitridae	Birds
60	<i>Cirrhinus mrigala</i>	Mrigal	Cyprinidae	Fishes
61	<i>Clarias batrachus</i>	Magur	Clariidae	Fishes
62	<i>Coccinella spp.</i>	Lady bug beetle	Coccinellidae	Insects
63	<i>Coelognathus helena</i>	Common Trinket	Colubridae	Reptiles
64	<i>Columba livia</i>	Rock Pigeon	Columbidae	Birds
65	<i>Columba livia domestica</i>	Domestic Pigeon	Columbidae	Birds
66	<i>Copsychus malabaricus</i>	White-rumped shama	Muscicapidae	Birds
67	<i>Copsychus saularis</i>	Oriental Magpie Robin	Muscicapidae	Birds
68	<i>Coracias benghalensis</i>	Indian Roller	Coraciidae	Birds
69	<i>Coracina macei</i>	Large Cuckooshrike	Campephagidae	Birds
70	<i>Coracina melanoptera</i>	Black-headed Cuckoo Shrike	Campephagidae	Birds
71	<i>Corvus macrorhynchus</i>	Large-billed Crow	Corvidae	Birds
72	<i>Corvus splendens</i>	House Crow	Corvidae	Birds
73	<i>Coturnix coromandelica</i>	Blackbreasted or Rain Quail	Phasianidae	Birds
74	<i>Cuculus canorus</i>	Eurasian Cuckoo	Cuculidae	Birds
75	<i>Cyanoderma pyrrhops</i>	Black-chinned Babbler	Timaliidae	Birds
76	<i>Cynopterus marginatus</i>	Short-nosed fruit bat	Pteropodidae	Mammals
77	<i>Cyprinus carpio</i>	Common carp	Cyprinidae	Fishes
78	<i>Cypsiurus balasiensis</i>	Asian Palm Swift	Apodidae	Birds
79	<i>Danaus chrysippus</i>	Plain tiger	Nymphalidae	Butterflies
80	<i>Dendrelaphis tristis</i>	Common Bronze back	Colubridae	Reptiles
81	<i>Dendrocitta vagabunda</i>	Rufous Treepie	Corvidae	Birds
82	<i>Dendrocygna javanica</i>	Lesser Whistling Duck	Anatidae	Birds



Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
83	<i>Dicaeum agile</i>	Thick-billed flowerpecker	Dicaeidae	Birds
84	<i>Dicrurus caerulescens</i>	White-bellied Drongo	Dicruridae	Birds
85	<i>Dicrurus macrocercus</i>	Black Drongo	Dicruridae	Birds
86	<i>Dinopium benghalense</i>	Black rumped flameback	Picidae	Birds
87	<i>Dinopium javanense</i>	Common Flameback	Picidae	Birds
88	<i>Egretta garzetta</i>	Little Egret	Ardeidae	Birds
89	<i>Elanus axillaris</i>	Black Shoulder Kite	Accipitridae	Birds
90	<i>Eremopterix grisea</i>	Ashy-crowned Sparrow Lark	Alaudidae	Birds
91	<i>Eremopterix grisea</i>	Black-bellied Finch Lark	Alaudidae	Birds
92	<i>Eryx johnii johnii</i>	Red Sand Boa	Boidae	Reptiles
93	<i>Eudynamys scolopaceus</i>	Asian Koel	Cuculidae	Birds
94	<i>Eumyias thalassinus</i>	Verditer flycatcher	Muscicapidae	Birds
95	<i>Eutropis carinata</i>	Common Indian Skink	Scincidae	Reptiles
96	<i>Falco tinnunculus</i>	Common Kestrel	Falconidae	Birds
97	<i>Fejervarya pierrei</i>	Paddy field frog	Dicroglossidae	Amphibians
98	<i>Felis catus</i>	Domestic cat	Felidae	Mammals
99	<i>Felis chaus</i>	Jungle Cat	Felidae	Mammals
100	<i>Ficedula albicilla</i>	Taiga flycatcher	Muscicapidae	Birds
101	<i>Fowlea piscator</i>	Checkered Keelback	Colubridae	Reptiles
102	<i>Funambulus palmarum</i>	Indian Palm squirrel	Leporidae	Mammals
103	<i>Gallinula chloropus</i>	Common Moorhen	Rallidae	Birds
104	<i>Golunda ellioti ellioti</i>	Indian Bush Rat	Muridae	Mammals
105	<i>Gongylophis conicus</i>	Common Sand Boa	Boidae	Reptiles
106	<i>Gracupica contra</i>	Pied Starling	Sturnidae	Birds
107	<i>Grypotyphlops acutus</i>	Blind Snake	Typhlopidae	Reptiles
108	<i>Halcyon smyrnensis</i>	White-throated kingfisher	Alcedinidae	Birds
109	<i>Haliastur indus</i>	Brahminy Kite	Accipitridae	Birds
110	<i>Harmonia axyridis</i>	Asian lady beetle	Coccinellidae	Insects
111	<i>Harpaphe haydeniana</i>	Yellow-spotted millipede	Xystodesmidae	Insects
112	<i>Hemidactylus brookii</i>	Spotted House Gecko	Gekkonidae	Reptiles
113	<i>Hemidactylus frenatus</i>	Indian House Gecko	Gekkonidae	Reptiles
114	<i>Herpestes auropunctatus</i>	Small Indian Mongoose	Herpestidae	Mammals
115	<i>Herpestes edwardsi</i>	Indian Grey Mongoose	Herpestidae	Mammals
116	<i>Heterometrus bengalensis</i>	Indian black Scorpion	Scorpionidae	Insects
117	<i>Heteropneustes fossilis</i>	Singi	Heteropneustidae	Fishes
118	<i>Hierococyx varius</i>	Common Hawk Cuckoo	Cuculidae	Birds
119	<i>Himantopus himantopus</i>	Black Winged Stilt	Recurvirostridae	Birds
120	<i>Hirudinaria granulosa</i>	Leech	Cylicobdellidae	Insects
121	<i>Hirundo rustica</i>	Barn Swallow	Hirundinidae	Birds
122	<i>Hirundo smithii</i>	Wire-tailed Swallow	Hirundinidae	Birds
123	<i>Hottentotta tamulus</i>	Indian red Scorpion	Buthidae	Insects

Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
124	<i>Huttonella bicolor</i>	Screw snail	Achatinidae	Mollusc
125	<i>Hyaena hyaena</i>	Striped hyena	Vespertilionidae	Mammals
126	<i>Hydrophasianus chirurgus</i>	Pheasant tailed jacana	Jacanidae	Birds
127	<i>Hypophthalmichthys molitrix</i>	Silver carp	Cyprinidae	Fishes
128	<i>Hystrix indica</i>	Common Indian Porcupine	Hystricidae	Mammals
129	<i>Idopoma dissimilis</i>	Paddy field snail	Ampullariidae	Mollusc
130	<i>Kaloula pulchera</i>	Painted Frog	Microhylidae	Amphibians
131	<i>Labeo rohita</i>	Rohu	Cyprinidae	Fishes
132	<i>Lamellidens marginalis</i>	Situa/ clam	Unionidae	Mollusc
133	<i>Lanius cristatus</i>	Brown shrike	Laniidae	Birds
134	<i>Lanius schach</i>	Long tailed shrike	Laniidae	Birds
135	<i>Lanius vittatus</i>	Baby-backed Shrike	Laniidae	Birds
136	<i>Leopicus mahrattensis</i>	Yellow-crowned Woodpecker	Picidae	Birds
137	<i>Lepus nigricollis</i>	Indian hare	Leporidae	Mammals
138	<i>Lithobius forficatus</i>	Stone centipede	Lithobiidae	Insects
139	<i>Liza parsia</i>	Parse	Mugilidae	Fishes
140	<i>Lonchura malacca</i>	Black-headed Munia	Estrildidae	Birds
141	<i>Lonchura punctulata</i>	Scaly Breasted Munia	Estrildidae	Birds
142	<i>Lycodon aulicus</i>	Indian wolf snake	Colubridae	Reptiles
143	<i>Lygosoma punctatus</i>	Common Snake-eyed Skink	Scincidae	Reptiles
144	<i>Mabuya carinata</i>	Golden skink	Scincidae	Reptiles
145	<i>Macaca mulatta</i>	Rhesus macaque	Cercopithecidae	Mammals
146	<i>Macrobrachium malcolmsoni</i>	Freshwater Tiger Prawn	Palaemonidae	Crustaceans
147	<i>Macrobrachium rosenbergii</i>	Freshwater mud Prawn	Palaemonidae	Crustaceans
148	<i>Macrochlymus indica</i>	Indian snail	Ariophantidae	Mollusc
149	<i>Melanochelys trijuga trijuga</i>	Indian Pond Terrapin	Bataguridae	Reptiles
150	<i>Melanoperdix niger</i>	Black Partridge	Phasianidae	Birds
151	<i>Merops orientalis</i>	Green Bee-eater	Meropidae	Birds
152	<i>Merops philippinus</i>	Blue-tailed Bee-eater	Meropidae	Birds
153	<i>Mesophoyx intermedia</i>	Intermediate Egret	Ardeidae	Birds
154	<i>Metopidius indicus</i>	Bronze-winged Jacana	Jacanidae	Birds
155	<i>Microhyla ornata</i>	Ornate Microhylid	Microhylidae	Amphibians
156	<i>Microhyla spp.</i>	Narrow mouth Frog	Microhylidae	Amphibians
157	<i>Microtermes obesi</i>	Termite	Termitidae	Insects
158	<i>Milvus migrans</i>	Black Kite	Accipitridae	Birds
159	<i>Monticola solitarius</i>	Blue rock Thrush	Muscicapidae	Birds
160	<i>Motacilla alba</i>	White Wagtail	Motacillidae	Birds
161	<i>Motacilla flava</i>	Yellow Wagtail	Motacillidae	Birds
162	<i>Motacilla maderaspatensis</i>	White-browed Wagtail	Motacillidae	Birds
163	<i>Mus booduga booduga</i>	Indian field mouse	Muridae	Mammals



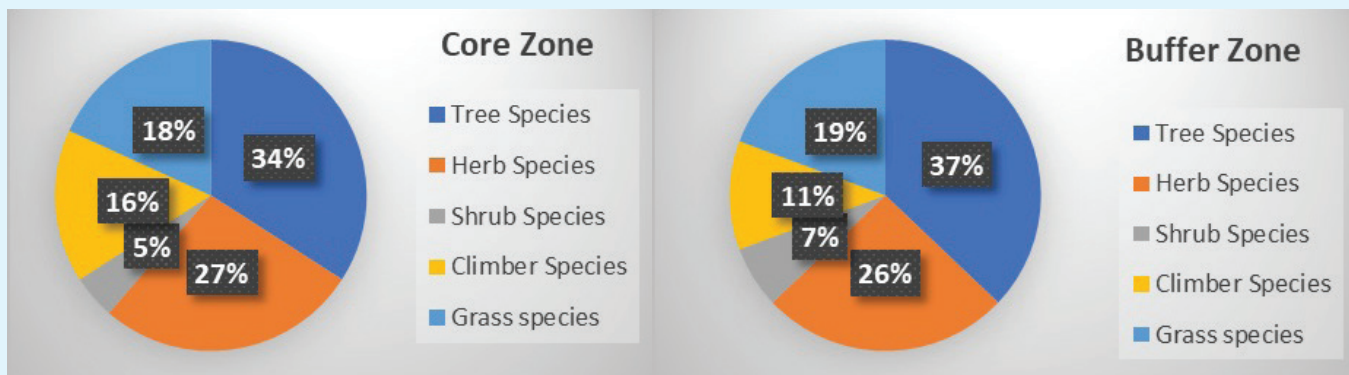
Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
164	<i>Mystas gulio</i>	Tangra	Bagridae	Fishes
165	<i>Naja naja</i>	Spectacled Cobra	Elapidae	Reptiles
166	<i>Neopithecops zalmora</i>	Common Quaker	Lycaenidae	Butterflies
167	<i>Nycticorax nycticorax</i>	Black crowned night heron	Ardeidae	Birds
168	<i>Oecophylla smaragdina</i>	Green tree ants	Formicidae	Insects
169	<i>Oligodon arnensis</i>	Common kukri Snake	Colubridae	Reptiles
170	<i>Oriolus larvatus</i>	Black headed oriole	Oriolidae	Birds
171	<i>Oriolus xanthornus</i>	Black hooded oriole	Oriolidae	Birds
172	<i>Orthotomus sutorius</i>	Tailor Bird	Cisticolidae	Birds
173	<i>Ortyornis pondicerianus</i>	Grey francolin	Phasianidae	Birds
174	<i>Ovis aries</i>	Domestic sheep	Bovidae	Mammals
175	<i>Pantala flavescens</i>	Dragonfly	Libellulidae	Insects
176	<i>Panthera pardus fusca</i>	Indian leopard	Felidae	Mammals
177	<i>Panthera tigris tigris</i>	Bengal tiger	Felidae	Mammals
178	<i>Papilio demoleus</i>	Lime butterfly	Papilionidae	Butterflies
179	<i>Papilio helenus</i>	Red Helen	Papilionidae	Butterflies
180	<i>Papilio polymnestor</i>	Blue Mormon	Papilionidae	Butterflies
181	<i>Papilio polytes</i>	Common mormon	Papilionidae	Butterflies
182	<i>Paradoxurus hermaphroditus</i>	Common Palm civet	Viverridae	Mammals
183	<i>Paragomphus lineatus</i>	Common hook tail dragonfly	Gomphidae	Insects
184	<i>Parathelphus convexa</i>	Paddy field Crab	Gecarcinucidae	Crustaceans
185	<i>Passer domesticus</i>	House sparrow	Passeridae	Birds
186	<i>Pavo cristatus</i>	Indian Peafowl	Phasianidae	Birds
187	<i>Pellorneum ruficeps</i>	Puff-throated Babbler	Pellorneidae	Birds
188	<i>Perdica asiatica</i>	Jungle Bush Quail	Phasianidae	Birds
189	<i>Pericrocotus cinnamomeus</i>	Little minivet	Campephagidae	Birds
190	<i>Pericrocotus speciosus</i>	Scarlet minivet	Campephagidae	Birds
191	<i>Pteropus giganteus</i>	Indian fruit bat	Pteropodidae	Mammals
192	<i>Phalacrocorax carbo</i>	Great Cormorant	Phalacrocoracidae	Birds
193	<i>Phalacrocorax niger</i>	Little Cormorant	Phalacrocoracidae	Birds
194	<i>Phalanta phalanta</i>	Common leopard	Nymphalidae	Butterflies
195	<i>Photinus pyralis</i>	Firefly	Lampyridae	Insects
196	<i>Picoides nanus</i>	Pigmy Woodpecker	Picidae	Birds
197	<i>Pila globosa</i>	Apple snail	Ampullariidae	Mollusc
198	<i>Platypleura hampsoni</i>	Indian cicada	Ampullariidae	Insects
199	<i>Ploceus benghalensis</i>	Black-breasted Weaver	Ploceidae	Birds
200	<i>Ploceus philippinus</i>	Baya Weaver	Ploceidae	Birds
201	<i>Podiceps cristatus</i>	Great Crested Grebe	Podicipedidae	Birds
202	<i>Poekilocerus pictus</i>	Indian grasshopper	Pyrgomorphidae	Insects
203	<i>Polypedates maculatus</i>	Tree Frog	Rhacophoridae	Amphibians
204	<i>Porphyrio poliocephalus</i>	Grey-headed swamphen	Rallidae	Birds

Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
205	<i>Prinia inornata</i>	Plain Prinia	Cisticolidae	Birds
206	<i>Prinia socialis</i>	Ashy Prinia	Cisticolidae	Birds
207	<i>Prinia hodgsonii</i>	Grey-breasted Prinia	Cisticolidae	Birds
208	<i>Psammophilus blanfordanus</i>	Rock agama	Agamidae	Reptiles
209	<i>Psammophilus dorsalis</i>	Peninsular Rock Agama	Agamidae	Reptiles
210	<i>Pseudibis papillosa</i>	Red-naped Ibis	Threskiornithidae	Birds
211	<i>Psilopogon asiaticus</i>	Blue-throated Barbet	Megalaimidae	Birds
212	<i>Psilopogon haemacephalus</i>	Coppersmith Barbet	Megalaimidae	Birds
213	<i>Psilopogon zeylanicus</i>	Brown-headed Barbet	Megalaimidae	Birds
214	<i>Psittacula cyanocephala</i>	Plum-headed parakeet	Psittaculidae	Birds
215	<i>Psittacula eupatria</i>	Alexandrine or Large Indian Parakeet	Psittaculidae	Birds
216	<i>Psittacula krameri</i>	Rose ring parakeet	Psittaculidae	Birds
217	<i>Ptyas mucosus</i>	Common Rat Snake	Colubridae	Reptiles
218	<i>Pycnonotus cafer</i>	Red-vented Bulbul	Pycnonotidae	Birds
219	<i>Pycnonotus jocosus</i>	Red whiskered bulbul	Pycnonotidae	Birds
220	<i>Python molurus</i>	Indian Rock Python	Boidae	Reptiles
221	<i>Rana crassa</i>	Jerdon's Bull Frog	Ranidae	Amphibians
222	<i>Rana cyanophlyctis</i>	Skipping Frog	Ranidae	Amphibians
223	<i>Rana erythraea</i>	Leaping Frog	Ranidae	Amphibians
224	<i>Rana limnocharis</i>	Cricket Frog	Ranidae	Amphibians
225	<i>Rana tigerina</i>	Indian Bull Frog	Ranidae	Amphibians
226	<i>Rattus rattus gangetrius</i>	Common Indian rat	Muridae	Mammals
227	<i>Rhipidura albicollis</i>	White-throated fantail	Rhipiduridae	Birds
228	<i>Rostratula benghalensis</i>	Common Snipe	Scolopacidae	Birds
229	<i>Saxicola caprata</i>	Pied Bush Chat	Muscicapidae	Birds
230	<i>Saxicoloides fulicata</i>	Indian Robin	Muscicapidae	Birds
231	<i>Scolopendra morsitans</i>	Red headed centipede	Scolopendridae	Insects
232	<i>Semnopithecus entellus</i>	Hanuman langur	Cercopithecidae	Mammals
233	<i>Solenopsis geminata</i>	Indian red Ants	Formicidae	Insects
234	<i>Spalgis epius</i>	Apefly	Lycaenidae	Butterflies
235	<i>Sphenomorphus maculatus</i>	Spotted forest skink	Scincidae	Reptiles
236	<i>Spilopelia chinensis</i>	Spotted Dove	Columbidae	Birds
237	<i>Spilopelia senegalensis</i>	Laughing Dove	Columbidae	Birds
238	<i>Spirostreptus</i> Sp.	Giant Millipede	Spirostreptidae	Insects
239	<i>Stactolaema olivacea</i>	Green Barbet	Megalaimidae	Birds
240	<i>Sterna aurantia</i>	River Tern	Laridae	Birds
241	<i>Sturnia malabarica</i>	Chestnut tailed starling	Sturnidae	Birds
242	<i>Sturnia pagodarum</i>	Brahmany Starling	Sturnidae	Birds
243	<i>Sturnus pagodarum</i>	Brahminy Myna	Sturnidae	Birds
244	<i>Subulina octona</i>	snails	Achatinidae	Mollusc

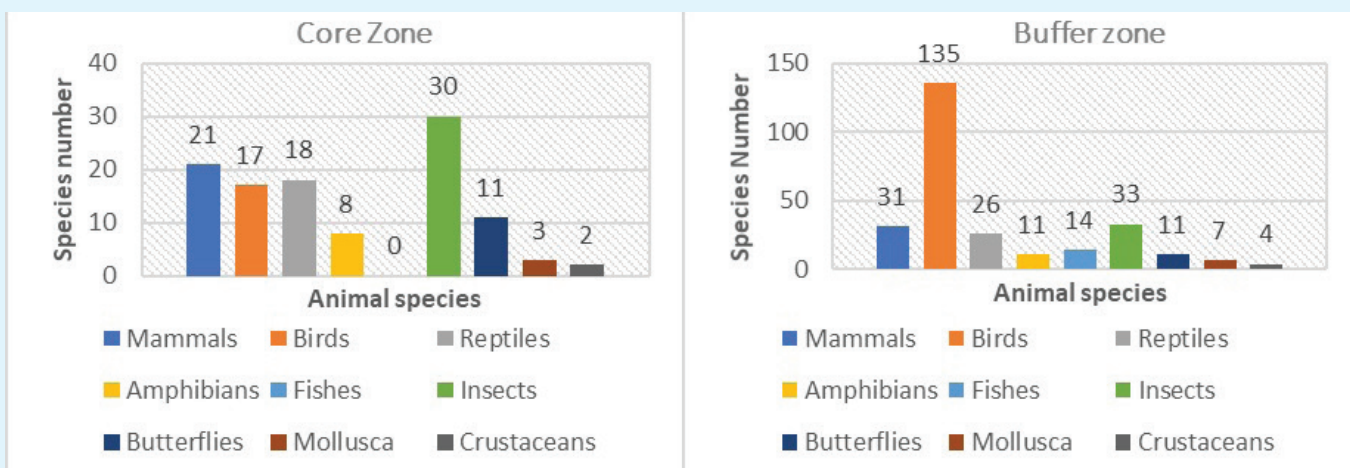


Sl. No.	Scientific Name	Common/ English Name	Family	Animal Species
245	<i>Sus scrofa cristatus</i>	Indian wild boar	Suidae	Mammals
246	<i>Tachybaptus ruficollis</i>	Little Grebe	Podicipedidae	Birds
247	<i>Tephrodornis pondicerianus</i>	Common woodshrike	Vangidae	Birds
248	<i>Threskiornis melanocephalus</i>	Black-headed Ibis	Threskiornithidae	Birds
249	<i>Tilapia mozambica</i>	Tilapia	Cichlidae	Fishes
250	<i>Tirumala limniace</i>	Blue Tiger	Nymphalidae	Butterflies
251	<i>Treron phoenicoptera</i>	Yellow footed green pigeon	Columbidae	Birds
252	<i>Tringa glareola</i>	Wood Sandpiper	Scolopacidae	Birds
253	<i>Trombidium Spp.</i>	Red velvet mite	Trombidiidae	Insects
254	<i>Turdoides affinis</i>	Yellow-billed Babbler	Leiothrichidae	Birds
255	<i>Turdoides striata</i>	Jungle Babbler	Leiothrichidae	Birds
256	<i>Turnix tanki</i>	Button Quail	Turnicidae	Birds
257	<i>Tyto alba</i>	Barn Owl	Tytonidae	Birds
258	<i>Upupa epops</i>	Common hoopoe	Upupidae	Birds
259	<i>Vanellus cinereus</i>	Grey-headed Lapwing	Charadriidae	Birds
260	<i>Vanellus indicus</i>	Red-wattled lapwing	Charadriidae	Birds
261	<i>Vanellus malabaricus</i>	Yellow-wattled Lapwing	Charadriidae	Birds
262	<i>Varanus bengalensis</i>	Bengal monitor	Varanidae	Reptiles
263	<i>Vespa orientalis</i>	Oriental hornet	Vespidae	Insects
264	<i>Vespula vulgaris</i>	Common wasp	Vespidae	Insects
265	<i>Vipera russelli</i>	Russel's Viper	Viperidae	Reptiles
266	<i>Viverricula indica</i>	Small Indian civet	Viverridae	Mammals
267	<i>Vulpes bengalensis</i>	Indian Fox	Canidae	Mammals
268	<i>Xanthippus corallipes</i>	Brown spotted grasshopper	Acrididae	Insects
269	<i>Xylocopa latipes</i>	Tropical carpenter bee	Apidae	Insects
270	<i>Zootecus insularis</i>	Screw snail	Achatinidae	Mollusc
271	<i>Zoothera citrina</i>	Orange-headed Thrush	Turdidae	Birds
272	<i>Zosterops palpebrosus</i>	Indian White-eye	Zosteropidae	Birds

**Figure 2. Flora observed in core and buffer zone of amalgamated Yekona I & II coal mines**



**Figure 3. Fauna observed in core and buffer zone of amalgamated Yekona I & II coal mines**



**Figure 4. Field exercise during the study period.**



**Figure 5. Photographs of some animals observed during the study period**



## Conclusion

The study reveals that there is a good concentration of flora and fauna, but their distribution is restricted to forest areas only. Dust particle is one of the probable impact arising from the opencast mine. It was noted that native species of plants were used to plant on OB dumps, along the roads and in areas surrounding the coal pits. The plantation done on the OB dumps helps in binding of the soil thus, preventing it from erosion by water during rain. The plants also help in prevention of dust generated by strong winds. Apart from these the plantation not

only provides a lush green cover but also provides shelter and food to the animals present in that area. Therefore, it is helping in the preservation and protection of the regional flora and fauna of the area. Conservation of Biodiversity has become the most important requirement of the present-day world, because survival of the man depends upon the biodiversity. Present account is, thus, an evaluation of the status of the biodiversity of the study area, and proposed offset measures to impacts on biodiversity.

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