



DRONES IN MONITORING ILLEGAL MINING IN INDIA

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ABSTRACT

The mining industry has been a significant primary industry that fuels the growth in the economies of all developing nations. Illegal mining has been a persistent challenge in India, which differs from region and the type of mineral it contains. Himachal Pradesh is one of the states that have witnessed a 44% rise in challans and almost a 40% higher fine collection for illegal mining in the first fiscal year of 2024. Meanwhile, Kerala recorded 425 cases of illegal sand mining, and coal mining violations remain a concern in Assam, Meghalaya, Karnataka, and Goa. Unregulated mining negatively affects host nations by causing social and environmental destruction and leading to economic losses. The use of monitoring systems can help combat illegal practices by either providing valuable information or ensuring widespread availability of information. Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, have emerged as a versatile tool with numerous applications in different fields such as surveillance, business, agriculture, photography, etc. It is the cost-effective, secure, reliable, precise data collection, consistent monitoring capabilities, etc. prove its advantageous nature. This research paper explores and aims to assess the application of drone technology, such as tracking and identifying unauthorised mining operations. This study incorporates a methodology for research, which is a qualitative research framework.

Keywords: Mining, Drone, UAVs, Illegal Mining, Impact, Surveillance, India.

I. INTRODUCTION

Mining serves as a cornerstone for the economic development of many countries, particularly in developing economies where it acts as a primary industry. The excavation and processing of mineral resources contribute to revenue generation, fostering infrastructure development, and creating job opportunities. Nevertheless, this industry faces a two-fold challenge: although its

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economic gains are incontestable, the environmental, social, and regulatory hurdles remain momentous. India exemplifies this duality as it equilibrates the economic vantage of mining with the permeating issue of illegal operations¹.

Illegal mining in India has been a relentless issue, with its impact varying across states and minerals. In Himachal Pradesh, fines and legal actions against illegal mining saw a sharp increase of over 40% in 2024. Similarly, states like Kerala registered 425 cases of illegal sand mining, and Assam and Meghalaya persist in conflict with unregulated coal extraction. These activities not only exhaust valuable natural resources but also aggravate environmental degradation, disrupt local ecosystems, and create fiscal losses for the government through unpaid royalties and taxes².

The environmental and social implications of illegal mining are austere. Deforestation, soil erosion, and water pollution are some of the most apparent influences, coupled with the displacement of local communities and the disruption of livelihoods. Additionally, these activities undermine India's environmental laws, such as the Environment Protection Act, 1986, and the Forest Conservation Act, 1980, which aspires to regulate mining activities responsibly³.

To confront these challenges, the integration of contemporary surveillance technologies has procured grip. Drones, also known as unmanned aerial vehicles (UAVs), are emerging as versatile tools across industries, including agriculture, urban planning, and law enforcement. In the context of illegal mining, drones proffer cost-effective and efficient solutions for monitoring, data collection, and real-time enforcement. Their capacity to access remote locations and provide high-resolution imagery makes them invaluable in determining and mitigating unlawful activities⁴.

¹ Ms Mary Abraham, 'India's Mining Sector: Towards a Sustainable and Equitable Future' (*Teri: The Energy and Resources Institute*) <<https://www.teriin.org/article/indias-mining-sector-towards-sustainable-and-equitable-future>> accessed 20 March 2025

² Albin-Lackey C, 'Out of Control' [2012] Human Rights Watch <<https://www.hrw.org/report/2012/06/14/out-control/mining-regulatory-failure-and-human-rights-india>> accessed 20 March 2025

³ *Ibid.*

⁴ Makam G, 'Navigating the Skies: Assessing the Regulatory Landscape and Future Implications of Drone Law in India' [2023] SSRN Electronic Journal <<https://www.ssrn.com/abstract=4480534>> accessed 20 March 2025

II. HISTORICAL DEVELOPMENT

The integration of drones into India's mining sector has evolved significantly over the past decade, driven by technological advancements and regulatory support. Drones, or Unmanned Aerial Vehicles (UAVs), were initially employed for military and research purposes in India.

Until 2015, the report projected the entire market enlargement, that is, it did not isolate military and civilian utilization except to the degree of earmarking percentages for military, consumer, and civil cumulative employment. However, 2015–2016 seems to have been an inflection point in the growth of civilian use of drones, as the organization has built on its experience of the past twelve years to prepare isolated reports for military and civilian use. The 2016 report on civilian usage estimates that non-military UAS production will increase from \$2.6 billion globally in 2016 to \$10.9 billion in 2025, a 15.4 percent compound annual growth rate. Construction is projected to lead the market for commercial use of drones, followed by agriculture. During this period, the mining industry started recognizing the potential of drones for enhancing safety, efficiency, and monitoring capabilities⁵. In a note released late in 2016, the Ministry of Mines called upon the state Government of India to explore the role that drones can play in governing the mining industry⁶.

Drones were for the first time utilized to map and survey a mining land site, rendering high-resolution imagery and 3D modeling capabilities⁷. They offered cost-efficient alternatives to conventional ground-based survey methods. For instance, mining industries began investing in drones to supervise the advancement of excavation activities, recognise structural modifications in mines, and evaluate the environmental consequences. This not only decreased operational costs but also built and improved worker safety by minimizing the necessity for human existence in hazardous spheres. The Indian government's proactive approach has played a crucial role in desegregation drones into the mining sector. The introduction of the Production Linked Incentive (PLI) scheme in 2021 marked a momentous hike for drone technology. Allocations such as ₹57 crores in the 2024 budget for drone constituents underscored India's

⁵ Padmanabhan A, 'CIVILIAN DRONES AND INDIA'S REGULATORY RESPONSE' Carnegie India <CarnegieIndia.org>

⁶ Benton D, 'Drones in the Sky of Diamonds: Drones Can Combat Illegal Mining in India' (17 May 2020) <<https://miningdigital.com/technology/drones-sky-diamonds-drones-can-combat-illegal-mining-india>> accessed 20 March 2025

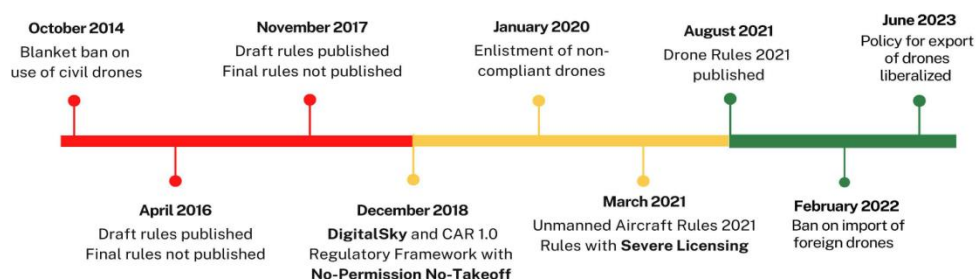
⁷ *Ibid.*

purpose to scale up its potential in this orbit. These initiatives encouraged industries, including mining, to adopt UAVs for several applications⁸.

Over time, improvements in drone technology, such as advanced 3D scanning, sensor integration, and real-time data transmission, further increased their utility in mining. Contemporary drones now alleviate careful mapping of open-cast and subsurface mines, discover illegal mining activities, and aid in creating accurate digital terrain models. In addition, the desegregation of 5G technology is anticipated to revolutionize drone operations by enabling broadloom communication and data analysis⁹.

The Indian mining industry proceeds to research the latent of drones for machine-controlled proctoring and prolonged practices. The usage of UAVs in felonious mining detection and environmental restitution highlights their critical role in addressing the sector's traditional challenges. With accelerated government and private sector investment, drones are balanced to become an indispensable tool in India's mining operations¹⁰.

Indian Drone Regulations - History



Picture: Ministry of Civil Aviation (Civil Aviation Regulatory Landscape of Indian Drone Ecosystem)

The Ministry of Mines formed the Mining Surveillance System (MSS) in 2016, a satellite-based monitoring system whose purpose is to “establish a regime of responsive mineral

⁸ Bodhisattwa Sanghapriya, ‘Innovation and Technology Advancements: Shaping the Future of Drones in India’ (*the_machinist*, 30 April 2024) <<https://www.themachinist.in/insights/4203068/innovation-technology-advancements-shaping-future-drones-india>> accessed 20 March 2025

⁹ *Ibid.*

¹⁰ Padmanabhan A, ‘CIVILIAN DRONES AND INDIA’S REGULATORY RESPONSE’ Carnegie India <CarnegieIndia.org>

administration, through public participation, by curbing instances of illegal mining activity through automatic remote sensing detection technology”¹¹.

III. UNDERSTANDING ILLEGAL MINING IN INDIA

Definition of illegal mining:

‘Illegal mining’ is defined under Rule 2(1)(c) of the Minerals (Other than Atomic and Hydro Carbons Energy Minerals) Concession Rules, 2016 as:

Rule 2(1)(c): “Illegal mining” means any reconnaissance or prospecting, or mining operation undertaken by any person or a company in any area without holding a mineral concession as required under sub-section (1) of section 4.

Explanation – For the purpose of this clause, -

- (a) violation of any rules, other than the rules made under section 23C, within the mining lease area by a holder of a mining lease shall not include illegal mining; and
- (b) Any area granted under a mineral concession shall be considered as an area held with lawful authority by the holder of such mineral concession, while determining the extent of illegal mining¹².

Overview of Illegal Mining

It has been evident that there had been various illegal mining like sand, coal, precious metals, etc. The illegal mining of treasured metals relates to prospecting and excavation of metals with high economic worth (mainly gold, silver, platinum, palladium, and iridium), conducted without suitable land rights, exploration and mining licenses, or mineral transit and other permits. Illegal mining can be coupled to encroaching on active or out or commissioned mining sites, and it can apply to mining in fortified regions. Illegal mining is progressively referred to as mining activities carried out by organized criminal groups, spearheaded by illicit mining syndicates, and is often related with other criminal activities such as trafficking in firearms and detonatives, money laundering, constrained labour, human trafficking, funding of terrorism,

¹¹ Benton D, ‘Drones in the Sky of Diamonds: Drones Can Combat Illegal Mining in India’ (17 May 2020) <<https://miningdigital.com/technology/drones-sky-diamonds-drones-can-combat-illegal-mining-india>> accessed 21 March 2025

¹² Minerals (Other than Atomic and Hydro Carbons Energy Minerals) Concession Rules, 2016

corruption, the usage of violence, felony and threat, often fueling armed battles and/or resulting in dense harm to the environment, usually in domains not under flooded control by the state¹³.

Illegal mining should not be compared to casual mining, nor to artisanal or handcrafted and small-scale mining (ASM), in which minerals are excavated as a craft, excluding the use of advanced machinery or technology, and usually in rather insecure conditions; this is often regulated or conducted in an unpleasant manner on the margins of state control. Especially for ASM, central authorities usually assign powers to local governments to grant licenses and regularize the sector. This high grade of decentralization often exposes further places for corruption to transpire at a local level. The deficiency of cooperation between the central and local authorities often results in overlap or divergence in legislative provisions on ASM. The countless, and reportedly ill-defined, legal provisions enacted to regularize the mining sector and the subsequent trouble in navigating them, united with the resulting heavy bureaucratic processes attached to requesting and granting permits, can result in artisanal and small-scale miners operating outside the law. Illegal mining can also occur in these casual and small-scale artisanal mining settings, in specific when organized criminal groups dominate the mining businesses. When unlawful ASM sites are found and destroyed, a deficiency of possible economic alternatives often instigates artisanal and small-scale miners to resort to illegal mining again, demanding a reply that takes into consideration sustainable alternative livelihoods¹⁴.

Consequences Of Illicit and Unscientific Mineral Extraction¹⁵

Illegal and unscientific mining poses serious threats which including environmental harm or degradation, loss of biodiversity, health risk, social issues, and economic setbacks.

i. Environmental Degradation:

- a. Large-scale deforestation:** Clearing forests for illegal mining causes harm to nature. The result of this is a severe impact on plants, animals, and other species.

¹³ Munita T, 'Response Framework on Illegal Mining and the Illicit Trafficking in Precious Metals'

¹⁴ Munita T, 'Response Framework on Illegal Mining and the Illicit Trafficking in Precious Metals'

¹⁵ Muntaha S and Singh D, 'Exploring Legal Frameworks for Regulating and Combating Illegal & Unscientific Mining Practices: A Comparative Analysis of Jurisdictions and Their Efficacy in Environmental Protection and Resource Conservation'

The removal of trees alters natural food chains, water cycles, weather patterns, etc., all of which contribute to environmental degradation.

- b. Water pollution:** Mining releases hazardous substances into surrounding waters or rivers. Heavy metals and toxic chemicals contaminate the waters or rivers, affecting aquatic habitats. Also, the people using this water may suffer severe health risks.
- c. Soil erosion:** Unregulated and careless mining activities weaken the soil structure. This leads to a reduction in the fertility of the soil, affecting agriculture.

ii. Impact on Biodiversity:

- a. Destruction of habitat:** Excavation activities wipe out ecosystems as they affect flora and fauna. This reduces the chances of survival of the species. Many wildlife relocate while others perish.
- b. Disrupt ecosystem:** Due to careless mining ecological imbalance is caused. The interconnected web of life faces disturbances leading to the decline of various species.

iii. Health Risks:

- a. Hazardous Atmospheric Conditions:** During the mining process, dust and fine particles are released into the air, which causes breathing difficulties and further lung diseases.
- b. Tainted Water:** Mining pollutes water bodies with harmful substances, affecting the safety of drinking water for both people and wildlife.

iv. Impacts on society:

- a. Involuntary Resettlement:** Illegal mining usually compels local communities to leave their homes without appropriate recompense or resettlement plans.
- b. Struggles and Unlawful practices:** Mining operations that are performed outside the legal scheme can lead to social agitation, dispute, and the proliferation of unlawful activities such as human trafficking and drug trade.

v. Financial Consequences:

- a. Drop in Revenue:** Governments experience latent revenue decline due to the deficiency of regulation and taxation on illicit mining operations, impacting public services and infrastructure improvement.
- b. Rapid Exhaustion of Natural Resources:** Illegal and unscientific mining can deplete natural resources faster than they can be replenished, leading to long-term economic challenges for affected regions.

IV. OVERVIEW OF DRONE TECHNOLOGY

Drones are Unmanned Aerial Vehicles (UAVs) or Remotely Piloted Aerial Systems (RPAS) that are controlled either by a pilot on the ground or with the help of technology.

Drones propose tremendous advantages to almost every sectors of the economy like – agriculture, mining, infrastructure, surveillance, emergency response, transportation, geo-spatial mapping, defence and law enforcement etc. Drones can be momentous creators of employment and economic growth due to their extent, versatility, and simplicity in usage, especially in India's remote and inaccessible areas.

Because of its traditional strengths in innovation, information technology, frugal engineering, and huge domestic demand, India has to be a worldwide drone hub by 2030¹⁶.

What is the concept of drones?

India has its own Rules for Drones under the Drones Rules, 2021.

Rule 3. Definitions:¹⁷

(i) "Drone" means an unmanned aircraft system.

(zb) "Unmanned aircraft system" means an aircraft that can operate autonomously or can be operated remotely without a pilot on board.

¹⁶ 'Press Information Bureau The Drone Rules 2021'

¹⁷ 'Ministry of Civil Aviation, Drone Rules, 2021'

Rule 5. Classification of unmanned aircraft systems¹⁸.

The unmanned aircraft system shall, based on the maximum all-up weight including payload, be classified as follows:—

- a) Nano unmanned aircraft system: weighing less than or equal to 250 grams;
- b) Micro unmanned aircraft system: weighing more than 250 grams, but less than or equal to 2 kilograms;
- c) Small unmanned aircraft system: weighing more than 2 kilograms, but less than or equal to 25 kilograms;
- d) Medium unmanned aircraft system: weighing more than 25 kilograms, but less than or equal to 150 kilograms; and
- e) Large unmanned aircraft system: weighing more than 150 kilograms.

Drone Variants

- a. **Fixed-wing drones:** These are unmanned aerial vehicles that possess fixed wings, which are immobile and incapable of movement.
- b. **Rotary wing drones:** Drones equipped with revolving blades or propeller-based mechanisms are commonly referred to as rotary wing drones.

Applications of Drones in India:

- Drone drone-based surveillance system was introduced for Railway Security.
- Survey of India to use drones for mapping of inhabited rural locations under the “SVAMITVA” scheme.
- India deployed drones to deliver COVID-19 vaccines. The ICMR-led pilot project is being rolled out in Manipur, Nagaland, and the Andaman and Nicobar Islands.

¹⁸ *Ibid.*

- Drone is utilized for surveillance of COVID-19 hotspots and containment zones to ensure rigorous compliance with lockdown guidelines. The system has been demonstrated to the Chandigarh Police in a containment zone.
- Ministry of Civil Aviation (MoCA) and Directorate General of Civil Aviation (DGCA) have granted conditional exemption to the Board of Control for Cricket in India (BCCI) for the deployment of drones for live aerial cinematography of the India Cricket Season in 2021¹⁹.
- Drones equipped with multispectral cameras can be utilized to monitor crop health, optimize irrigation, and apply pesticides, improving precision agriculture.
- The usage of Drones for law enforcement, border monitoring, and disaster response is due to their capability to access remote or dangerous locations.
- Drones provide real-time monitoring of mining sites.

Key features for mining surveillance

UAVs create 3D maps for planning GPS and detect hazards with thermal imaging, RGB-D, and spectral cameras, LiDARs, gas instruments, etc²⁰.

V. DRONES IN MONITORING ILLEGAL MINING

Capabilities of Drones in Mining Surveillance

UAVs and rotorcraft in particular are perfect for these applications due to their capability to move omnidirectionally in 3D, execute rapid and agile maneuvering with altitudinous precision, and entrance in constrained zones deserted for ground robots. Moreover, UAV capabilities are revealed by their ability to be equipped with a broad range of sensorial devices that both allows autonomy and data-access to specific inspection parameters²¹.

Drones can speedily cover massive, remote mining locations, providing high-resolution imaging and precise data. They are peculiarly effective in terrains, patrolling immense sites

¹⁹ 'Press Information Bureau The Drone Rules 2021'

²⁰ Lindqvist B and others, 'Deployment of Autonomous Uavs in Underground Mines: Field Evaluations and Use-Case Demonstrations' (2023) <<https://www.ssrn.com/abstract=4374895>> accessed 21 March 2025

²¹ Lindqvist B and others, 'Deployment of Autonomous Uavs in Underground Mines: Field Evaluations and Use-Case Demonstrations' (2023) <<https://www.ssrn.com/abstract=4374895>> accessed 21 March 2025

where manual or non-automated monitoring is challenging. Drone technology caters high-resolution data with higher precision in comparison to old traditional means, leading to more informed decisions and improved operational results²². Drones that are equipped with thermal and RGB-D can notice or detect unauthorized movements, including trucks used for traversing illegally the mined substances²³.

VI. LEGAL AND ETHICAL ASPECTS

Drone Regulations in India²⁴

1. In **2014**, the Directorate General of Civil Aviation (DGCA) introduced the **initial set of guidelines** for civil UAV operations. These guidelines primarily addressed key areas like permits, registration, and operational restrictions, laying the groundwork for more comprehensive regulations in the future.
2. In December **2018**, the DGCA launched the **Civil Aviation Requirements (CAR)**, outlining the rules for operating Remotely Piloted Aircraft Systems (RPAS) in India. The CAR categorizes drones into five types based on their maximum take-off weight: Nano, Micro, Small, Medium, and Large. According to these regulations, all drones, except those in the Nano category, must be registered with the DGCA and obtain a Unique Identification Number (UIN) before they can be operated.
3. To address the evolving demands of the industry, the Indian government introduced the **Drone Rules in 2021**, replacing the CAR 2018. These updated rules clarified the regulatory process by reducing the number of required forms and easing some operational limitations. Additionally, the Drone Rules 2021 introduced a digital platform called Digital Sky, designed to facilitate the registration and monitoring of drone operations, making it easier for operators to comply with regulations.

²² 'How Drones Are Transforming Indian Mining Industry: A Comprehensive Analysis.' (*Indrones*) <https://indrones.com/blogs/Drones_Revolutionizing_Indian_Mining_Industry.html> accessed 21 March 2025

²³ Policy VC for L, 'Eye in the Sky'- India's Drone Operations and Privacy Concerns' (*Vidhi Centre for Legal Policy*, 31 July 2021) <<https://vidhilegalpolicy.in/blog/eye-in-the-sky-indias-drone-operations-and-privacy-concerns/>> accessed 22 March 2025

²⁴ Dibakar Dam, 'The Legal Landscape of Drone Technology in India: Navigating Privacy, Security, and Commercial Use.' (*The Amikus Qriae*, 31 October 2024) <<https://theamikusqriae.com/the-legal-landscape-of-drone-technology-in-india-navigating-privacy-security-and-commercial-use/>> accessed 22 March 2025

Key Features of Drone Rules of 2021:²⁵

1. **Drone Classification:** Under the current regulatory system, drones in India are categorized into five classes based on their maximum take-off weight (MTOW): nano (up to 250 grams), micro (251 grams to 2 kilograms), small (2.1 kilograms to 25 kilograms), medium (25.1 kilograms to 150 kilograms), and large (over 150 kilograms). Each category has specific operational requirements, including the need for registration, pilot certification, and special permissions for activities such as flying in restricted airspace or conducting Beyond Visual Line of Sight (BVLOS) operations.

This categorization system makes sure that the regulatory requirements are proportionate to the latent hazards connected with the size and capability of the drones. For instance, nano drones, due to their minimal weight it face fewer limitations compared to bigger drones, which require more rigorous oversight to ensure safety and compliance. The model aims to equilibrate innovation and safety, facilitating the development of the drone industry while safeguarding public and national interests.

2. **Airspace Segmentation:** The Ministry of Civil Aviation provides an interactive airspace map with three zones for drone operations: The Ministry of Civil Aviation offers an interactive airspace map that divides drone operations into three zones:
 - i. **Yellow Zone:** Airspace is restricted and requires permission from air traffic control. This includes areas above 400 feet in green zones and above 200 feet within 8-12 kilometers of an airport.
 - ii. **Green Zone:** Airspace is unrestricted up to 400 feet, except in the 8-12 kilometer radius around an airport, where the limit is 200 feet.
 - iii. **Red Zone:** This is a highly restricted airspace, where drone operations are only allowed with permission from the Central Government. These zones help drone operators determine where they can fly their drones safely and legally.
3. **Mandatory Permission for Takeoff:** The NPNT requirement, introduced under the Drone Rules, 2021, is a crucial safety measure that mandates drones must receive prior

²⁵ Dibakar Dam, 'The Legal Landscape of Drone Technology in India: Navigating Privacy, Security, and Commercial Use.' (*The Amikus Qriae*, 31 October 2024) <<https://theamikusqriae.com/the-legal-landscape-of-drone-technology-in-india-navigating-privacy-security-and-commercial-use/>> accessed 22 March 2025

approval via the Digital Sky platform before taking off. This centralized digital system manages drone registrations, flight permissions, and real-time tracking, ensuring that all drone activities are recorded and monitored. By requiring pre-flight authorization, NPNT ensures compliance with the designated airspace zones (Green, Yellow, Red) and other regulations. If the necessary permissions are not obtained, the drone's software will prevent it from taking off, enhancing airspace safety by stopping unauthorized and potentially dangerous operations.

4. **Certification and Training Program:** On the Digital Sky platform, the applicants must submit Form D-1, including the requisite fee, to acquire a Type Certificate for an unmanned aircraft system (UAS) in India. Within 60 days, the Quality Council of India (QCI) or an authorized testing entity reviews the application and submits a test report to the Director General. Then, within 15 days, the Director General issues the Type Certificate based on this report. Certain immunities apply, like for nano UAS and model remotely piloted aircraft systems. For operating drones, individuals must hold a Remote Pilot Certificate (RPC), which conditions being between 18 and 65 years old, having passed the 10th grade, and completing specified training. The validity of RPC is for 10 years if listed on the Digital Sky platform. The consequence of non-compliance with these rules is penalties up to ₹1 lakh, as per Rule 50 of the Drone Rules, 2021.

Government Initiatives of Drones in India²⁶

- i. Drone Rules 2021 liberalized drone policy.
- ii. Airspace map released for drone operations.
- iii. 20% financial incentive under the Production Linked Incentive (PLI) Scheme.
- iv. Unmanned Traffic Management (UTM) policy framework introduced.
- v. Pilot projects in agriculture, healthcare, and defence conducted.
- vi. SOP for pesticide and nutrient spraying launched by the Ministry of Agriculture.

²⁶ Piyush Srivastava, 'Civil Aviation Regulatory Landscape of Indian Drone Ecosystem' <<https://legalaffairs.gov.in/>>

- vii. Ministry of Agriculture announces subsidy for Kisan Drones.
- viii. 100 Kisan drones launched by the PM to promote drone use.
- ix. A 1000-drone light show held at Rashtrapati Bhavan.
- x. Drone Shakti Mission announced by the Finance Minister.
- xi. Import ban on drones and kits to boost domestic manufacturing.
- xii. Policy for drone exports simplified and liberalized.
- xiii. PM announces loans and training for 15,000 women SHGs to operate and repair drones.

VII. INSIGHTS ON ADDRESSING ILLEGAL MINING IN INDIA

The mines ministry is pushing for the use of drones in a bid to curb illegal mining in the country and has asked states and Public Sector Undertakings (PSUs) to consider using unmanned Aerial Vehicles (UAVs).

In **October 2024**, the Department of Mining and Geology initiated a drone survey to make sure that mining activities are carried on in compliance with regulations. It also aims to prevent illegal mining. Minister of Industries, Law, and Coir P. Rajeeve inaugurated Kerala Mineral Drone LiDAR Survey Project and Drone LiDAR Survey Portal at a ceremony held at Perumkadavila Delta Quarry in Thiruvananthapuram district²⁷.

In **January 2024**, the Government of Rajasthan launched a major campaign against illegal mining activities by conducting surveys through drones, wherever required, to put a curb on the sources of such activities²⁸.

In **December 2023**, a bid to curb revenue leakages and heighten non-tax revenue collection, the state government is set to lay down drone surveys as a standard operating procedure (SOP) to monitor and forbid illegal mining of minor minerals. The initiative, already launched in 10

²⁷ 'Drone Survey to Prevent Illegal Mining Activities' *The Times of India* (24 October 2024) <<https://timesofindia.indiatimes.com/city/thiruvananthapuram/kerala-launches-revolutionary-drone-survey-to-combat-illegal-mining/articleshow/114556464.cms>> accessed 22 March 2025

²⁸Bureau TH, 'Rajasthan Launches Major Drive against Illegal Mining with Drone Survey' *The Hindu* (27 January 2024) <<https://www.thehindu.com/news/national/other-states/rajasthan-launches-major-drive-against-illegal-mining-with-drone-survey/article67783443.ece>> accessed 22 March 2025

districts through the Karnataka State Remote Sensing Application Center (KSRAC), is part of a pilot programme²⁹.

In **August 2019**, CM asked the mines and geology department authorities to employ even drone cameras and a satellite system to ensure effective control and appropriate vigilance on sand mining in several rivers across the state. After reviewing a presentation on the state's new sand policy-2019, he also asked officials to take effective steps to end the monopoly of big players in sand mining across the state³⁰.

In **May 2018**, in order to maintain a check on illegal sand mining activity occurring on 60 kilometers of “sensitive” Sabarmati riverbed in the districts of Ahmedabad, Gandhinagar, and Sabarkantha, the Gujarat chief minister set in motion a drone surveillance project. This is the first instance that the state government is utilizing drones with “night-vision” to check illegal mining³¹.

VIII. CHALLENGES AND FUTURE PROSPECTS

Operational and Technological Challenges

- a. **Coarse Environment:** One of the chief issues in supervising is sensor degradation in coarse environments. The potash mine mission has the highest dust levels to the point of visual information being next to useless for navigation, and LiDAR (Light Detection and Ranging) systems endeavor as well, with dust particles contaminating SLAM data. It is necessary to use the Ouster OS1 LiDAR (Light Detection and Ranging) sensor specifically due to its ability to infiltrate such dust to an ample magnitude and enable the demonstrated mission.
- b. **Dust Corrupting data:** A relentless difficulty throughout the test is online tenancy mapping for route designing, both due to the effects of dust corrupting the data, but also in the constricting test regions, there were many moments of poor density of

²⁹ ‘3D Drone Surveys to Combat Illegal Mining, Plug Leakages’ *The Times of India* (19 December 2023) <<https://timesofindia.indiatimes.com/city/bengaluru/3d-drone-surveys-combat-illegal-mining/articleshow/106107387.cms>> accessed 22 March 2025

³⁰ ‘Bihar CM Nitish Kumar: Use Drone to Keep Watch on Sand Mining’ *The Times of India* (3 August 2019) <<https://timesofindia.indiatimes.com/city/patna/cm-use-drone-to-keep-watch-on-sand-mining/articleshow/70503680.cms>> accessed 22 March 2025

³¹ ‘Drones with Night-Vision Launched for Surveillance against Illegal Mining on Sabarmati River-Bed’ (*The Indian Express*, 22 May 2018) <<https://indianexpress.com/article/india/drones-with-night-vision-launched-for-surveillance-against-illegal-mining-on-sabarmati-river-bed-5185768/>> accessed 23 March 2025

maps, even using the state-of-the-art rule. In addition, in the large-scale environment, the designated voxel size in such maps has to be small enough to exactly represent the surroundings, while small voxels also lead to computational issues in grid-search path planners.

The most important confining cause is the battery life and flight time of 3D-LiDAR (Light Detection and Ranging) equipped UAVs due to the significant proportional weight of 3D LiDAR (Light Detection and Ranging) systems. Mining regions are large in size, and scrutiny or surveying missions demand to traverse large areas, which is highly challenging with current battery and drone design technologies³².

- c. **Battery Capacity And Charging:** The Drone is ordinarily equipped with system to proctor battery level and calculates the time period as long as the leftover capacity permits for flight, as well as the propinquity to the nearest base station. In the event of low battery, drone returns to the base station to substitute the battery.
- d. **Drone Swarm Control:** The Drone swarm control problem has long been connected with drone patrolling due to its variable sensors and gadgets that individual drones may possess in order to render expert sensing practicalities. Drones in a patrolling operation can act like a swarm when their dominance integrates a coordination characteristic.
- e. **Drone Security:** Despite every advantage of Drones, they are not exempt from security exposures. Drones have vulnerabilities to exploit the Drone system, misuse it, and execute numerous kinds of attacks.
- f. **Object Detection:** Automation in identifying people needs algorithms that are more advanced. It needs machine learning techniques for visual object identification, which is able to process images exceedingly fast and accomplish altitudinous detection rates.
- g. **Return To Home Functions:** Drones exercise the Return to Home (RTH) feature to go back to the previously recorded home point and ground. In a definite kind of drones, there are three types of RTH: Low Battery RTH, Failsafe RTH, and Smart

³²Lindqvist B and others, 'Deployment of Autonomous Uavs in Underground Mines: Field Evaluations and Use-Case Demonstrations' (2023) <<https://www.ssrn.com/abstract=4374895>> accessed 23 March 2025

RTH. The RTH will actuate when the user starts Smart RTH, the drone battery runs low, or the signal between the remote controller and the drone is missed, except that the drone has registered the home point correctly and the GPS signal is strong. In addition, RTH will be activated in another abnormal condition, like a video transmission loss³³.

IX. RECOMMENDATIONS AND IMPLEMENTATION

As Drones are regulated by the Directorate General of Civil Aviation (DGCA), there are gaps in the enforcement of regulations in relation to drones usage in remote mining locations, which is often misused for illegitimate activities.

Many mining operations in India fall out without appropriate licenses. Drones can aid in supervising these land sites but may confront challenges in distinguishing between lawfully-begotten and illicit activities, as well as in navigating the lack of a distinct rule of thumb on drone surveillance for illegal mining.

- i.** India should travel toward greater mechanization and real-time processing of airspace authorization.
- ii.** Comprehensive training programs and certification processes should be enforced to ensure compliance and public trust.
- iii.** The government could propose payments to local industrials and startups, strengthening the domestic ecosystem³⁴.
- iv.** Developing distinct and encompassing regulations is fundamental.
- v.** As drones transform and adapt freshly features, regulatory composition must be flexible to adapt. This postulates an uninterrupted monitoring of technological advancement and the capability to revise regulations as required.

³³ Abas HA and Nasir N, 'Drone Patrolling Applications, Challenges, and Its Future: A Review' (2024) <<https://www.ssrn.com/abstract=4682937>> accessed 23 March 2025

³⁴ Routhu R, 'Navigating The Skies: Challenges And Regulatory Landscape Of Drone Technology In India' (2024) 2

- vi. Educating drone operators about their legal duties or obligations within the regulatory framework is crucial. This may include far-flung public outreach campaigns, available online resources, and well-organized training programs.
- vii. Leveraging technology can significantly bolster enforcement potential. This may allow for implementing geo-fencing technology to forbid drone access in restricted areas, deploying remote identification systems to quickly recognize drones in action, and utilizing software tools to monitor and analyze drone flight data efficiently.
- viii. Enforcing penalties for non-compliance is crucial. However, these penalties must be proportionate to the gravity of the offense committed in order to maintain fairness. Measures like fines and license revocations are effective deterrents, their application should be judicious in nature³⁵.

X. PUBLIC-PRIVATE PARTNERSHIPS

There is a need the policymakers should prioritize collaborative engagement with various kinds of stakeholders to efficiently address the complex challenges that are associated with drones. This comprises not only government organisations but also manufacturing players, academic establishments, and the common people. By uniting these different perspectives, policymakers can develop well-rounded regulations by considering a wide range of interests and concerns. This kind of cooperative approach fosters an environment of trust among stakeholders, which is very important for the effective and successful implementation of drone regulations³⁶.

XI. CONCLUSION

Drone technology is rapidly advancing in the mining sector each day. The utilization of drones for surveillance is expanding and gaining considerable interest. However, there is a need for more research that will focus on drone patrolling applications. This study demonstrates the value of exercising drone surveillance instead of customary surveillance applications, since they put forward many benefits over conventional surveillance, such as reduced costs,

³⁵ Kushagra Mehrotra, 'DRONE REGULATIONS Indian Scenario' SSRN Electronic Journal

³⁶ *Ibid*

enhanced safety than putting humans in hazardous circumstances, and the ability to accomplish tasks at a brisker pace with precision than conventional modes.

States are finding answers and building frameworks to combat forbidden sand mining. Specifically, in the state of Haryana, the Haryana government has developed a Standard Operating Procedure (SOP) to curtail illicit mining practices in the state. The SOP comprises initiatives such as installing CCTV cameras, launching unmanned aerial vehicles to supervise mining sites, and implementing a system to trace vehicles that are hauling mining goods. The government aspires that these steps will help curb the unlawful mining activities that have been uncontrolled in the state.