NAVIGATING ENVIRONMENTAL CHALLENGES IN AVIATION LAW: LEGAL FRAMEWORKS FOR WASTE MANAGEMENT AND ECOLOGICAL SUSTAINABILITY

Ms. Vanshika Chourasia, Ph.D Scholar, Faculty of Law, University of Delhi.

Ms. Pragati Gupta, Ph.D Scholar, Faculty of Law, University of Delhi

ABSTRACT

The tremendous progress of the aviation sector, as one of the major international economic contributors, has placed enormous environmental questions on our heads. In this article, an attempt has been made to analyze critically how the meting out of laws in waste management and ecology sustain justice to an ecologically sound aviation industry, with special reference to Indian enactments. There are many wastes generated from various activities in the aviation sector, such as hazardous maintenance wastes, inflight refuse, and pollutants generated by airports; waste management within the aviation industry warrants strong legislative measures for all forms of waste. The industry mainly contributes to GHG emissions and noise pollution. Therefore, environmental protection vocations cannot wait. At the global level, the regulatory framework related to environmental standards consists of the Chicago Convention's Annex 16, the Basel Convention, and ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). At the domestic level, India imposes a slew of environmental laws like the Environment (Protection) Act, 1986, and sectoral codes under the Aircraft Act, 1934. However, the enforcement remains tainted by fragmentation arising from institutional overlap, infrastructural limitations, and lack of high-end technical integration. Several case studies, including solar-powered operations at Cochin International Airport, demonstrate best practices in greening. It highlights loopholes in enforcement, the absence of environmental jurisprudence regarding aviation, and the pressing requirement for regulatory coherence. Some policy suggestions include strengthening the DGCA's environmental oversight, providing incentives for sustainable aviation fuels, encouraging public-private partnerships, and harmonizing domestic standards with international environmental regulations. This study emphasizes the urgent need for an integrated legal approach toward sustainability in the aviation sector. It must include dynamic legal reform, investment in emergent green technologies, and international cooperation for dealing with environmental risks. Meanwhile, as India gradually emerges as an aviation hub, it is imperative to

adopt a complete ecological scheme for sustainability of environmental and economic development in the sector.

I. Introduction:

The aviation industry is one of the key sectors on which the global economy stands, ranging from international trade to tourism and to business connectivity. The speed with which global air traffic is increasing has truly made the aviation sector one of the new foundations of the modern world. Sadly, such progress is yet hardly devoid of serious environmental challenges. Waste management and ecological sustainability have been noted as the most serious challenges, which continue to face the industry as it grows its environmental footprint.

The management of aviation waste includes handling the tons of waste produced by airlines, airports, or other related facilities[1]. It encompasses in-flight waste, such as those arising from the wastages created during the maintenance of the aircraft and includes hazardous chemicals and oils, as well as wastes resulting from decommissioned aircraft, which can be made of complicated materials that are difficult to recycle. Proper disposal and recycling of all these materials are crucial in reducing or preventing the environmental damages they cause. In this regard, aviation law has great importance because it provides the legal framework requiring airlines, airports, and aviation-related entities to engage in proper and sustainable waste management practices with compliance to environmental standards.

However, waste management is merely part of the environmental concerns that face the aviation industry. The latter draws enormous contributions to the pollution of air and noise, which indeed ends up having considerable implications not only in the ecology but in human health as well. Airborne emissions will nurture global warming and climate change, whereas aircraft noise creates disorder to ecosystems and communities where the flight operates. Laws, rules, and regulations concerning the aviation sector should hence address these two issues, in addition to innovations towards better designs in aircraft, more efficient fuels, and noise-reducing technologies.

The piece of information thus studied could involve what the legal frameworks governing waste management in aviation and environmental sustainability would entail with specific reference

[1] Geels FW, 'The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms' (2011) 1(1) Environmental Innovation and Societal Transitions 24 https://doi.org/10.1016/j.eist.2011.02.002

to Indian laws and international treaties. It focuses on the major international agreements such as the Chicago Convention[2] and the Paris Agreement as well as India's domestic laws like the Environment (Protection) Act and the Aircraft Act concerning the advancement of the legal landscape to deal with the twin pressures of environmental sustainability while encouraging growth in the industry[3]. It also discusses the challenges faced by India and other countries in enforcing these laws and implementation, revealing the gap between the intent of policy and practical reality. Through this view, this article aims to point out the critical necessity of putting strong reforms in the law with technological advancement and international cooperation to pave the way for a sustainable future for the aviation sector.

II. Types and Complexity of Aviation-Related Waste

Environmental pollution continues to add color to the problems with the management of aviation waste due to increased air traffic and expansion of airports[4]. Waste materials generated in the aviation sector are very diverse and complex, thus requiring specific handling and disposal mechanisms[5]. The precise range of aviation-related waste covers a myriad of materials, which can, without much effort, be broadly classified into the following categories:

1. In-Flight Waste

In-flight waste occurs during passenger and crew activities on board. Types of in-flight wastes consist of:

- Food packaging (plastic trays, wrappers, aluminum foils, and beverage containers)
- Single-use plastics such as cutlery and cups and stirrers
- Organic waste: food and beverage leftovers

[2] R Geiß, 'Civil Aircraft as Weapons of Large-Scale Destruction: Countermeasures, Article 3BIS of the Chicago Convention, and the Newly Adopted German "Luftsicherheitsgesetz"' (2005) 27(1) Michigan Journal of International Law 227 https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1185&context=mjil.
[3] C Cosgrove, 'Green Initiatives for Sustainable Airport Services' (2018) 12(4) Journal of Airport Management 350 https://doi.org/10.69554/kcqq4272.
[4] P Mehta, 'Aviation Waste Management: An Insight' (2015) 6(1) International Journal on Environmental Sciences 179 http://www.indianjournals.com/ijor.aspx?target=ijor:ijes&volume=6&issue=1&article=020.
[5] E Maleviti, Fundamentals of Sustainable Aviation (Taylor & Francis 2023)

- Sanitary waste from toilets[6]

It is a very difficult category to treat because of the mixture of biodegradable and non-biodegradable waste and international restrictions on the disposal of international catering waste mostly due to concerns related to biosecurity and disease control[7].

2. Maintenance Waste

Hazardous and non-hazardous wastes are generated through maintenance of machines. In aviation maintenance, a variety of wastes are generated, primarily hazardous, non-biodegradable, and being under stringent control legislation[8]. These waste materials arise as byproducts during routine maintenance repair and overhaul (MRO) of aircraft and engine servicing, which, if carried out improperly, can adversely affect human health and the environment.

1. Used engine oil, oils and lubricants, hydraulic fluids: The greatest constituents of waste streams in aircraft maintenance are used engine oils and hydraulic fluids. These fluids contain basically heavy metals, very often in combination with particulates and chemical additives, and become hazardous to the environment.Improper discharge into the soil leads to contamination of water that affects the entire ecosystem and tends to disturb the groundwater quality. Their disposal is governed under The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, by which proper storage and labeling must be done and treatment through authorized facilities.

2. Paints, Thinners, Solvents, And Cleaning Agents: Aircraft painting and cleaning procedures introduce volatile organic compounds (VOCs) and other chemicals that lounge in the air with detrimental vapors and contribute to air and surface pollution. Thinners, degreasers, and chemical strippers often harbor toxic-flammable substances, and their handling should therefore be vigilant. Their improper disposal would cause incidences of sludge formation in the soil, or, in some cases, local

[6] X Li, C Poon, S Lee, S Chung and F Luk, 'Waste Reduction and Recycling Strategies for the In-Flight Services in the Airline Industry' (2002) 37(2) Resources Conservation and Recycling 87 https://doi.org/10.1016/s0921-3449(02)00074-5.
[7] World Health Organization, Guide to Hygiene and Sanitation in Aviation (WHO 2009)
[8] JA Marceau, 'Corrosion Control Practices on Commercial Aircraft' (1987) SAE Technical Paper Series https://doi.org/10.4271/870747

waterways could become toxic. These chemicals qualify as hazardous waste under Indian legislation, for which compliance with MSDS (Material Safety Data Sheet) requirements and hazardous disposal is mandatory.

3. Mechanical repairs and overhauls that give by-products include metal shavings, filters, and old parts. There are byproducts generated in the process of mechanical repairs and overhauls: metal shavings, used fuel and oil filters, and various mechanically defective components. Some metals may be recyclable, while others may be oiled with hazardous materials such as chromium or cadmium, which are considered cancer-causing agents and highly polluting[9]. The filters usually have residual oils or fluids trapped within them, which if not cleaned and treated are considered hazardous waste[10]. And dispositional such as in associated condition with no kind of segregation or treatment will just make more landfills saturated and polluted.

4. Contaminated Rags and Protective Gear: Maintenance workers often utilize absorbent rags and single-use gloves, disposable masks, personal protective equipment (PPE) and coveralls that come into contact with toxic liquids. In practice, most of them get thrown into non-hazardous waste bins instead of proper collections for hazardous waste. This leads to potential hazards from denatured goods or from incineration or treatment by only authorized handlers, leaving the most threats possible to the numerous types of sources and modes of toxic exposure, soil contamination, injury, etc.

Such emissions typically comprise volatile organic compounds (VOCs), heavy metals, and other toxic chemicals that will require proper storage, transportation, and disposal mechanisms to comply with hazardous waste regulation such as under the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 in India.

[9] Y Zhang, S Fan, T Liu, MM Omar and B Li, 'Perspectives into Intensification for Aviation Oil Production from Microwave Pyrolysis of Organic Wastes' (2022) 176 Chemical Engineering and Processing - Process Intensification 108939 https://doi.org/10.1016/j.cep.2022.108939.
[10] US Environmental Protection Agency, Standard Operating Safety Guides (1984).

3. Construction and Decommissioning Waste

The construction of airport infrastructure and the decommissioning of aircraft yield large volumes of environmentally sensitive waste[11], such as:

- Non-biodegradable composite materials, used in aircraft structures for weight efficiency
- Heavy metals and electronic components, such as circuit boards and wiring
- Rubber waste, including tyres and seals
- Fiberglass and carbon fiber-reinforced polymers, which are difficult to recycle

End-of-life aircraft present a significant environmental hazard due to the difficulty in separating and recycling composite materials and electronic parts.

4. Ground Operations Waste

Airports themselves are sources of extensive waste streams, including:

- Cargo packaging materials, such as cardboard, bubble wrap, wooden crates, and pallets
- Administrative waste from airport offices, including paper, plastics, and e-waste[12]
- Fuel and chemical storage contaminants, including leakage from underground tanks and spill residues
- Vehicle emissions and maintenance waste from ground support equipment (GSE)

Such waste not only impacts the local soil and water systems but also contributes to the larger carbon and waste footprint of the aviation sector.

[11] Environmentally Harmful Subsidies (OECD 2005) https://doi.org/10.1787/9789264012059-en.
[12] M El-Fadel, AN Findikakis and JO Leckie, 'Environmental Impacts of Solid Waste Landfilling' (1997) 50(1) Journal of Environmental Management 1 https://doi.org/10.1006/jema.1995.0131.

Global Guidelines and Regulations

There are a number of international instruments which deal with waste management in aviation:

- The standards Annex 16 of the Chicago Convention of ICAO contain, amongst other things, provisions for environmental protection which include waste management.
- The Basel Convention, with regard to issues covering the transboundary movement and disposal of hazardous wastes, has implications for the international waste that aircraft generate[13].
- IATA's Environmental Assessment (IEnvA) is an optional environmental management system that aids airlines in their pursuit of sustainability.

There has been an upsurge in efforts being made to adopt waste management techniques by airports and airlines all over the globe[14]. These techniques include; composting, material segregation, and incineration of hazardous waste. Importance is in particular for airports in the forefront of implementing circular economic strategies to recycle or repurpose the majority of their waste, Schiphol Airport in Amsterdam and Changi Airport in Singapore.

III. Environmental Impact of the Aviation Industry

The aviation industry is a major antagonist to environmental health through the creation of atmospheric, hydrological, and soil pollution, as well as noise pollution[15].

Air Pollution and Climate Change

Around 2-3% of total global carbon emissions are due to aircraft emissions, although there is a direct effect of nitrogen oxides (NO_x) on the depletion of ozone. Conventional aviation fuels

[13] N Gunningham, RA Kagan and D Thornton, 'Social License and Environmental Protection: Why Businesses Go Beyond Compliance' (2004) 29(2) Law & Social Inquiry 307 https://doi.org/10.1111/j.1747-4469.2004.tb00338.x.
[14] A Kumar, A A and H Gupta, 'Evaluating Green Performance of the Airports Using Hybrid BWM and VIKOR Methodology' (2019) 76 Tourism Management 103941 https://doi.org/10.1016/j.tourman.2019.06.016.
[15] Lee JJ, Lukachko SP, Waitz IA, and Schafer A, 'Historical and Future Trends in Aircraft Performance, Cost, and Emissions' (2001) 26(1) Annual Review of Energy and the Environment 167 https://doi.org/10.1146/annurev.energy.26.1.167

release massive greenhouse gases that contribute to global warming[16]. Sustainable Aviation Fuel (SAF), bio-based, is a possible alternative that might help reduce aviation's carbon footprint. Unfortunately, due to the high production cost and restricting infrastructures, renewable alternatives are less frequently used than conventional alternatives.

Water and Soil Pollution

The aviation pollutants resulting from fuel spills, hydraulic fluid leaks, and chemicals from maintenance of aircrafts further contaminate freshwater and soil, hence degrading the environment. Poor waste disposal methods at airports have perpetuated the additional environmental injuries to local communities and wildlife.

Noise Pollution

The very essence of an aircraft also suggests that it represents the devilry of noise in terms of public health by engendering stress, sleeplessness, and cardiovascular diseases. The International Civil Aviation Organisation (ICAO) deals with mitigation measures that follow the Balanced Approach to Noise Management and include operational restrictions, new aircraft specifications, and noise insulation programs.

IV. Indian Aviation Laws on Waste Management

India has brought a legislative framework of general environmental laws with regulations on aviation aspects regarding the waste management in the present context[17]. These laws aim to ensure that the aviation sector operates toward the goals of sustainable development while catering to the specific challenges of waste produced by aircraft operations and maintenance as well as airport infrastructure.

1. The Environment (Protection) Act, 1986

This umbrella law will act as the foundation for and serve as the utmost importance in the environmental regulatory regime of India. Brought into existence in the wake of the Bhopal Gas Tragedy, the Act has given the powers to the Central Government Contain and control all

[16] Wolfe PJ, Yim SH, Lee G, Ashok A, Barrett SR, and Waitz IA, 'Near-Airport Distribution of the Environmental Costs of Aviation' (2014) 34 Transport Policy 102 https://doi.org/10.1016/j.tranpol.2014.02.023
[17] G Noor, Aviation Law: Recent Developments in Aviation Laws (BFC Publications 2024).

steps for protecting and improving the quality of the environment and in the prevention and control of environmental pollution[18].

Under the Act, the government can:

- Set standards for the emissions and discharges from different sources like airports and maintenance facilities of aircraft.
- Regulate hazardous substances handling.
- Give directives to any industry, including aviation regarding the adoption of pollution control measures.

Thus, in connection with aviation, the Act permits the framing of industry specific rules and notification like those on solid waste, hazardous waste, chemical safety and noise pollution, directly applicable to airport operations and aircraft maintenance.

2. The Aircraft Act, 1934 and the Aircraft Rules, 1937

More number or less, without a ditch someone has to consider these Acts for the management of waste, although being very specific to the concerned subjects of safety in aviation. The Directorate General of Civil Aviation (DGCA) is empowered by such law to certify and inspect all aircraft and aviation facilities. Maintenance protocols include storage and disposal of waste oils, hydraulic fluids, and expired parts. Aircraft servicing procedures that may generate toxic or non-recyclable waste[19]. Adherence to safety standards, which increasingly incorporate environmental considerations. The last has now started incorporating metrics on sustainability in safety audits, thus pushing adherence to environmental norms even without specific aviation-environmental law.

3. Solid Waste Management Rules, 2016

Under these rules, airports are categorized as institutional[20] generators of solid waste, thereby

[18] Global Waste Management Outlook (United Nations 2016) https://doi.org/10.18356/765baec0-en
[19] MA Hasan, AA Mamun, SM Rahman, K Malik, MIUA Amran, AN Khondaker, O Reshi, SP Tiwari and FS Alismail, 'Climate Change Mitigation Pathways for the Aviation Sector' (2021) 13(7) Sustainability 3656 https://doi.org/10.3390/su13073656.
[20] ADL Inc and RC Fraser, Civil Aviation Development: A Policy and Operations Analysis (1980).

placing them under the jurisdiction of the municipal solid waste management regime. Key obligations include:

- Segregation of waste at source into biodegradable, non-biodegradable, and domestic hazardous waste.
- Prohibition on the use of non-recyclable plastic and encouragement of compostable materials.
- Mandatory tie-ups with authorized recyclers and composting units.
- Ensuring that airport food courts, lounges, and vendors comply with packaging and waste disposal norms.

The application of these rules to airports ensures that terminals and support services operate within the urban waste management framework, bringing aviation waste within broader municipal waste governance systems.

4. The Hazardous Waste and Other Wastes Rules, 2016

These rules are very essential for the management of waste for aviation, since the bulk of the waste arising in the maintenance, repair, and overhaul activities of aircraft are of hazardous types. Among the provisions specific to the aviation sector are:

- Registration requirement for the Aircraft Maintenance and Repair Organizations (AMROs) handling hazardous waste.
- Guidelines for the labeling, packaging, storage, and transportation of used oils, chemical solvents, paints, and batteries.
- Regulations regarding the import/export of aviation components containing hazardous materials.
- Manifest system and record keeping requirement set up for hazardous waste producers to track and hold accountable.

Also, each airport and each MRO is required to comply with the emergency preparedness

plans, especially in cases of accidental spills or leaks of hazardous substances.

V. Implementation Challenges in India

Challenges in Enforcement[21] and Practical Implementation of Aviation Waste Laws in India

The Indian legal regime provides a comprehensive framework to shield the environment and check waste generation and emissions. Yet, enforcement problems faced in translating the regulatory intent into practical reality within the sector of aviation are huge hurdles before India. This is due to a delicate interplay of various constraints: institutional, infrastructural, economic, and lastly, awareness.

1. Lack of Enforcement Capacity

The regulatory agencies, namely, the Directorate General of Civil Aviation (DGCA), the Central Pollution Control Board (CPCB), and the State Pollution Control Boards (SPCBs), are poorly resourced and overburdened to carry on consistent monitoring and enforcement activities. Thus, it has contributed to:

- Rare and inconsistent inspections of aviation waste practices.
- Limited imposition of penalties or sanctions for non-compliance on the part of airlines, maintenance operators, or airports.
- No sector-specific environmental audit framework provided under the DGCA regulations.
- Not much use has been made of real-time monitoring devices that are fitted with sensors, digitally reporting, or tracking waste with the aid of AI.
- Thus, there is absence of accountability for waste handling, particularly for hazardous wastes like hydraulic fluids, used oils, and chemical solvents in many airports and

[21] MA Hasan, AA Mamun, SM Rahman, K Malik, MIUA Amran, AN Khondaker, O Reshi, SP Tiwari and FS Alismail, 'Climate Change Mitigation Pathways for the Aviation Sector' (2021) 13(7) Sustainability 3656 https://doi.org/10.3390/su13073656.

their maintenance facilities.

2. Insufficient Infrastructure in Airports

Basic infrastructure for waste segregation, composting, recycling, or safe storage of hazardous substances are lacking in many of the Tier-II and Tier-III cities. For example, some of the infrastructural shortcomings include:

No dedicated recycling unit on-site in airports.

- Poor containment systems for chemical and fuel spills.
- There are no collaborations and tie-ups with authorized waste handlers and recyclers.
- On-site hazardous waste treatment and temporary storage have not been provided, resulting either in disposal by unauthorized means or illegal dumping.

These deficiencies blatantly affect compliance with Solid Waste Management Rules, 2016, and Hazardous Waste Rules, 2016, and engender immediate threats of environmental degradation into and around airport zones.

3. Limited Awareness and Training Among Personnel

There is an urgent need for improved environmental literacy among airline and airport personnel, so:

- Ground handling staff has never been taught segregation.
- Maintenance staff was never trained to handle hazardous waste.
- Housekeeping and catering are often inappropriately disposing of organic waste along with plastic waste.
- Managers of airlines may not be aware of some legal obligations pertaining to environmental compliance.

This lack of awareness affects the implementation of waste management-related policies, resulting in poor enforcement of even basic practices such as the avoidance of single-use

plastics or the use of compostable food packaging.

4. Low Private Sector Participation and Technological Innovation

Within the domain of airport infrastructure, programs for public-private partnerships (PPP) continue to multiply, while private sector involvement in green flying technologies remains scarce. A few particularities are:

- Airport operators are making limited investments into sustainable[22] waste-processing systems.
- Withdrawal of any economic motivation or persuasion towards research on biocompatible materials for an aircraft or recyclable components for aviation-the homes of all the research.
- Poor physicochemical integration between aviation companies and startups or innovators in greentech for conceptualizing any environmentally friendly solutions.

Private sectors, as a rule, get narrowly driven by operational profitability with little attention to environmental compliance, as there are no regulatory headaches that would invoke performance-based environmental indicators.

VI. Judicial Activism and Emerging Legal Trends

Dedicated case law specifically relating to aviation waste is limited in India; however, increasing interventions by the courts into the environmental aspects of airport development and expansion have visibly been on the rise.

Public Interest Litigation (PIL) Actions and Constitutional Mandates

In PILs filed under Articles 21 (Right to Life) and 48A (Directive Principles for Protection of Environment) of the Constitution, environmental lawyers and NGOs state improper waste management and unregulated airport expansion violate citizens' rights to a clean and healthy

[22] D Chiaramonti, 'Sustainable Aviation Fuels: The Challenge of Decarbonization' (2019) 158 Energy Procedia 1202 https://doi.org/10.1016/j.egypro.2019.01.308.

environment[23].

Some landmark events include:

- Judicial scrutiny of airport expansion projects that were able to make a mockery of an Environmental Impact Assessment (EIA) for most projects in ecologically sensitive places[24].

  Stay orders issued or conditional approvals granted by the High Courts and by the National Green Tribunal (NGT) on issues of encroachments in wetlands, lack of waste treatment plants, and incorrect disposal of construction debris.

- The NGT has ensured compliance with the protocols for waste disposal and imposed environmental compensation against defaulting airport authorities.

While no one case may be seen as a leading case dealing exclusively with aviation waste, this growing invocation of Article 21 environmental jurisprudence would sufficiently point towards a receptive judicial environment wherein accountability for the aviation sector is cast.

Waste Management in the Aviation Industry

Aviation waste includes many varieties, such as waste from in-flight operations, maintenance of the aircraft, and the waste generated from decommissioning an aircraft. In-flight waste consists of single-use plastic, food packaging, and organic waste, often to be tossed in a landfill. Maintenance of the aircraft brings about wastes in the form of potentially hazardous materials, including hydraulic fluids, waste oils, and chemical residues[25]. Not to mention, decommissioning of aircraft introduces long-term environmental threats of disposal from non-recyclable composites, metals, and electronic components. ICAO[26] and IATA[27] set down the necessary regulations that require airlines and airports to adopt sustainable waste

[23] ADL Inc and RC Fraser, Civil Aviation Development: A Policy and Operations Analysis (1980).
[24] C Abraham, Environmental Jurisprudence in India (1999) https://doi.org/10.1163/9789004635432.
[25] Hui P, Waste Management in Aviation Industry (1999) https://doi.org/10.5353/th_b3125422
[26] International Civil Aviation Organization, Environmental Protection https://www.icao.int/environmental-protection/Pages/default.aspx
[27] International Air Transport Association, Aviation and Sustainability https://www.iata.org/en/pressroom/2023/05/aviation-and-sustainability/

management practices. An emphasis on this area is laid down, i.e. the Basel Convention on hazardous waste and the Waste Directive of the European Union. Airports across the globe are implementing waste segregation, recycling, and biodegradable materials to reduce the impact on landfills.

Indian Aviation Laws on Waste Management

There are many law provisions in India to regulate the disposal of aviation-related wastes. The government is empowered to regulate the disposal of wastes and pollution in the aviation sector under the Environment (Protection) Act, 1986.

- The Aircraft Act, 1934, and Aircraft Rules, 1937 provide for operational safety and environmental compliance[28].
- The Solid Waste Management Rules, 2016 mandate that wastes need to be segregated and disposed of at all airports.
- The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 govern hazardous waste disposal from aircraft maintenance.

So why are there problems with implementation? There is a serious shortcoming with enforcement issues, and these have resulted in inadequacies with waste disposal and lack of recycling infrastructure. Stepping these compliance mechanisms up and applying newer waste management technology, all are cardinal for the aviation industry in India to keep pace with international trends.

VII. International Legal Frameworks for Environmental Regulation in Aviation

The following international conventions and ordinances comprehensively deal with the environmental impact of aviation:

- **Chicago Convention, 1944:** It provides standards and regulations for every possible aspect of aviation, including general noise and emission regulations under Annex 16.

[28] BF Havel and GS Sanchez, The Principles and Practice of International Aviation Law (2014) https://doi.org/10.1017/cbo9781139104210.

- **Kyoto Protocol, 1997, and Paris Agreement, 2015:** These treaties impose obligations on states to incorporate reduction of CO2 emissions caused by aviation into national policy.[29]

- **CORSIA 2016:** International scheme coordinated through International Civil Aviation Organization wherein it is defined that all international airlines would have to offset carbon emitted after investment in sustainable projects[3031].

- **Basel Convention, 1989:** It deals with all possible transboundary hazardous waste as introduced concerning aviation, meaning that it encourages sound disposal.

Such frameworks work on the premise of anchoring into the specific legislative systems the sustainable approaches while making the commitment to comply with acknowledged 31 international environmental standards.

Indian Initiatives for Sustainable Aviation

However, the draft for National Green Aviation Policy 2019 intends to focus on ensuring the sustainability of airport operations and air travel[32]:

- **Promotion of Sustainable Aviation:** Fuel attempts to lower carbon emissions through alternate fuel source(s).

- **Green Airports:** Airports such as Cochin International Airport run on solar energy and serve as good examples of sustainability across the globe.

- **Zero Waste Airport Programs:** Several Indian airports are working towards the reduction and management of waste through various measures like recycling and

[29] MA Mehling, H van Asselt, K Das, S Droege and C Verkuijl, 'Designing Border Carbon Adjustments for Enhanced Climate Action' (2019) 113(3) American Journal of International Law 433 https://doi.org/10.1017/ajil.2019.22.
[30] International Civil Aviation Organization (ICAO), Carbon Offsetting and Reduction Scheme for International Aviation (2016) https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx
[31] Weber EP and Khademian AM, 'From Agitation to Collaboration: Clearing the Air through Negotiation' (1997) 57(5) Public Administration Review 396 https://doi.org/10.2307/3109986
[32] Hari TK, Yaakob Z, and Binitha NN, 'Aviation Biofuel from Renewable Resources: Routes, Opportunities and Challenges' (2014) 42 Renewable and Sustainable Energy Reviews 1234 https://doi.org/10.1016/j.rser.2014.10.095

composting[33].

VIII. Key Challenges in Regulation and Implementation

Despite a growing awareness of the environmental impacts of aviation, the regulatory landscape in both India and globally continues to face formidable challenges. While legal instruments exist on paper, the gap between legislation and implementation is evident. The following are the primary hurdles obstructing effective environmental governance in aviation:

1. Regulatory Enforcement Gaps

One of the most persistent challenges in aviation environmental law is the weak enforcement of existing regulations. Despite having a robust legal foundation through statutes like the Environment (Protection) Act, 1986, and specific waste management rules, there remains a significant deficit in oversight and accountability. Which is due to various factors:

- Institutional overlap and confusion: The regulatory responsibilities are allocated to various agencies such as the DGCA[34], MoEFCC, AAI, and Pollution Control Boards that lead to jurisdictional confusion.

- Lack of Discrete Environmental Wing: The critical aviation body does not have an environmental enforcement wing having the technical capability to monitor aviation-specific wastes or emissions.

- Much opacity and unreliability in reporting: The airlines and airport operators are not uniformly required to report on waste generation and treatment or carbon emissions, adversely affecting regulation through such non-Conformance.

- Limited punitive actions: Penalty provisions which are rampant provide insufficient deterrence against environmentally degrading behavior.

[33] BI Scott, The Law of Unmanned Aircraft Systems (Kluwer Law International BV 2022).
[34] AT McKenzie, I Katsyv, W Song, M Wang and B Zhang, 'DGCA: A Comprehensive R Package for Differential Gene Correlation Analysis' (2016) 10(1) BMC Systems Biology https://doi.org/10.1186/s12918-016-0349-1.

2. High Cost of Eco-Friendly Technologies

The adoption of green technology[35] in aviation is no economically prohibitive in itself; however, in emerging markets like India, whose cost-sensitivity is high, it is prohibitively expensive. The key barriers are:

Sustainable Aviation Fuels (SAF) are loaded in high prices compared with standard jet fuels; there are no subsidy or incentive structures to nurture their use.

- Waste treatment and recycling infrastructure such as compactors for in-flight waste or hazardous waste incinerators on-site entail heavy capital investments and operational costs.

- **Retrofitting existing airport facilities** to comply with green building norms, install solar power, or achieve carbon neutrality also imposes financial burdens, particularly on smaller or regional airports.

It is therefore, that forcing green to private operators in their operations does not encourage them to leap into the change unless it is by law, funded by the state or has favorable tax incentives.

3. Quality of Infrastructures and Logistics Lacking

Environmental Compliance in Aviation is majorly best depends on over-ready logistics and infrastructures; still most in many areas of the Indian aviation ecosystem are crude[36]:

- Facilities for waste segregation and recycling are mostly missing or dysfunctional at airports, which results in indiscriminate disposal of waste materials.

- Limited hazardous waste collection points lead to disposal of oils, chemicals without battery safety protocols-because there are fewer handling points available-and batteries then-which get disposed-of randomly.

[35] D Krass, T Nedorezov and A Ovchinnikov, 'Environmental Taxes and the Choice of Green Technology' (2013) 22(5) Production and Operations Management 1035 https://doi.org/10.1111/poms.12023.
[36] BI Scott, The Law of Unmanned Aircraft Systems (Kluwer Law International BV 2022).

- Transport-drainage-disposal chain does not operate efficiently enough that wastes travel long distances for treatment where they incur unnecessary environmental costs, as well as carbon footprints.

- Smaller airports, particularly in Tier-II and III cities, even lack certified recyclers or biomedical/hazardous waste handlers, and this problem further widens non-compliance[37].

Not only this, but without such robust infrastructure, good policies are also difficult to implement at the operational level.

4. International Regulatory Fragmentation and Lack of Harmonization

Being a truly international industry, aviation is unfortunately not supported by environmental regulations universally harmonized, leaving behind loopholes and gaps that distract from the real aim of minimizing aviation's environmental footprint[38]. These are some of the specific concerns:

- **Conflicting standards:** Although ICAO's Annex 16 to the Chicago Convention provides global guidance on noise and emissions, specific countries usually go on adopting different standards that would generalize fragmentation in regulation.

- **Voluntary mechanisms**: Initiatives like CORSIA[39] (Carbon Offsetting and Reduction Scheme for International Aviation) are voluntary in nature and do not impose legally binding commitments on all nations, resulting in patchy implementation.

- **Differing enforcement timelines and capabilities**: Developed countries may impose stricter environmental norms, whereas developing nations may delay enforcement due

[37] K Liu, Q Tan, J Yu and M Wang, 'A Global Perspective on E-Waste Recycling' (2023) 2(1) Circular Economy 100028 https://doi.org/10.1016/j.cec.2023.100028.
[38] JE Penner, DH Lister, EJ Griggs, DJ Dokken and M McFarland, Aviation and the Global Atmosphere (IPCC 384)
http://www.agriculturedefensecoalition.org/sites/default/files/pdfs/25L_1999_IPCC_Aviation_The_Global_Atmosph ere_Jets.pdf.
[39] DET Awesso, 'The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)' in Cambridge University Press eBooks (Cambridge University Press 2022) 137–157 https://doi.org/10.1017/9781108919166.010.

to capacity constraints, creating uneven playing fields in international aviation.

- **Transboundary waste management- A challenge:** The Basel Convention[40] is the governing treaty for the international movement of hazardous waste; however, procedural complexities and lack of coordination of customs authorities along with bureaucratic bottlenecks often block due compliance in the handling of waste from the aviation industry[41].

In the absence of a comprehensive and binding international regulatory framework that would impose uniform standards on all states with regard to environmental protection in aviation, countries are in practice still allowed to exercise discretion on the matter and this ultimately results in regulatory inefficiency and environmental endangerment[42].

IX. Policy Recommendations

1. Strengthening DGCA's Role in Environmental Governance

For effective environmental oversight within the aviation industry, DGCA requires a clearer and broader environmental mandate. Most of the efforts of DGCA are concentrated on safety, security, and airworthiness, being left with very little jurisdiction over matters concerning any environmental issue[43]. Amending the Aircraft Act, 1934, or maybe establishing an entirely new statute would directly delegate the environmental responsibilities onto the DGCA, which include development of emission targets, compliance monitoring to environmental standards, and clearance of green infrastructure projects. The establishment of a Division within DGCA focusing solely on environmental compliance would allow strengthening regulatory capabilities and improve coordination with other environmental agencies, like MoEFCC and CPCB.

[40] E Lauterpacht, CJ Greenwood, K Lee and AG Oppenheimer, International Law Reports: Consolidated Table of Treaties, Volumes 1–125 (Cambridge University Press 2004).
[41] Joan Martinez-Alier, Leah Temper, Daniela Del Bene and Arnim Scheidel, 'Is There a Global Environmental Justice Movement?' (2016) 43(3)The Journal of Peasant Studies 731 https://doi.org/10.1080/03066150.2016.1141198
[42] Craig Zwerling, Beverly Bryant and Paul Mohai, 'Race and the Incidence of Environmental Hazards: A Time for Discourse' (1994) 23(1) Contemporary Sociology: A Journal of Reviews 52 https://doi.org/10.2307/2074862
[43] International Civil Aviation Organization, Safety Oversight Manual: The Establishment and Management of a Regional Safety Oversight Organization (ICAO 2011)

2. Aviation-Specific Environmental Regulation

In India, there is an urgent need for a complete body of aviation-specific environmental regulations to cover the very specific waste streams, emissional profiles, and operational predicaments of this sector. Such regulations should cover:

- Categorization and treatment of aircraft maintenance and inflight waste
- Sustainable airport design and construction standards
- Noise pollution thresholds and operational restrictions
- Emissions standards clearly set out in accordance with international norms

This could be brought into law as a "Green Aviation Code" that stakeholders such as airport operators, airlines, environment experts, and civil society will help develop. This will, therefore, fill the current legal vacuum and instill more certain and enforceable environmental norms into the aviation ecosystem.

3. Incentivize Use of Sustainable Aviation Fuels [44](SAFs)

SAFs are a good hope for reducing the lifecycle greenhouse gas emissions from aviation, but the high costs of production and little distribution and storage infrastructure have not helped promote its adoption in India.

To give SAF acceptance a healthy push by interventions on the part of government, it could:

(a) offer fiscal incentives in the form of tax holidays, subsidies, and viability gap-funding;

(b) encourage public-private partnerships for setting up SAF production plants;

(c) impose blending mandates to allow gradual entry of SAFs into the regular distribution systems of fuel;[45]

[44] M Aslam, S Mishra and JA Anell, Sustainable Aviation Fuels: Recent Advances and Future Challenges (Springer Nature 2025).
[45] BF Havel and GS Sanchez, The Principles and Practice of International Aviation Law (Cambridge University Press 2014) https://doi.org/10.1017/cbo9781139104210.

(d) promote R&D with funding and cooperation with academic institutions

Integrating targets for SAF into India's national aviation policy and carbon reduction strategy shall help to tighten India's commitment under the Paris agreement and ICAO's CORSIA initiative.

4. <u>Technology is clearly the game-changer with respect to environmental efficiency</u>

Airports and airlines should be motivated to adopt:

- AI and IoT technologies for real-time monitoring of emissions, fuel consumption, and noise
- Smart waste management systems for segregation, recycling, and energy recovery
- Green building certifications for airport infrastructure(i.e. GRIHA and LEED)
- This includes wind energy for ground operations, solar energy, etc.

The government will also support this transition by capacity building, technology transfer, and funding in platforms such as the National Green Technology Mission. This will support this transition.

5. Alignment of Domestic Law with ICAO/CORSIA

India must align its domestic legal regime with the other eminent international instruments for the sake of international credibility and regulatory predictability. More specifically:

- There should be an integration of ICAO Annex 16, which deals with Volumes I & II on aircraft noise and emissions, into DGCA regulations
- A domestic carbon offset and reduction framework should be promulgated under CORSIA rules with periodic reports and compliance verifications[46]
- The guidelines for the ICAO State Action Plan should be adopted as a template for the

[46] D E T Awesso, 'The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)' in Cambridge University Press eBooks (2022) 137–157 https://doi.org/10.1017/9781108919166.010.

formulation of national policy

Such alignment would further encourage fine global cooperation and ease access to technology, while diminishing the compliance burden on airlines operating globally[47].

6. Enhancement of Global Cooperation and Regional Frameworks

Given the trans-boundary nature of environmental risk, India must actively engage in negotiations related to international aviation-environment and encourage regional cooperation in South Asia and the Indo-Pacific.[48] The shared platforms may be created to:

- Achieve harmonization of emission and noise standards
- Enable cross-border environmental audits and technology-sharing
- Coordinate carbon-offsetting schemes and air traffic optimization measures

With India at the lead in regional forums such as SAARC, BIMSTEC, and ASEAN+, cooperative frameworks can begin to be set up for reductions in sustainability problems shared by the AVIATION sector.

7. Coordination of Institutions and Engagement of Stakeholders

Approaching environmental governance in aviation as a multi-stakeholder responsive effort requires the establishment of an institutional architecture that links the following institutions:

- government bodies (DGCA, MoEFCC, AAI, and CPCB)
- airlines and airport operators
- civil society and environmental NGOs
- researchers and academic institutions.

A national Green Aviation Council can be convened to serve as an advisory and monitoring

[47] D Hodgkinson and R Johnston, Aviation Law and Drones: Unmanned Aircraft and the Future of Aviation (2018) https://openlibrary.org/books/OL28928370M/Aviation_Law_and_Drones.
[48] Development Zones in Asian Borderlands (2021) https://doi.org/10.2307/j.ctv1pncrbr.

body in charge of use, recommending reforms from time to time, and ensuring transparency. Further, stakeholder engagement mechanisms-such as public consultations and industry dialogues-would also foster compliance and innovation[49].

X. Future Reforms and Recommendations

In order to address such problems, the aviation law must be improved by:

- **Stricter Regulatory Compliance:** Governments are to intensify the penalties imposed for noncompliance but, at the same time, strengthen monitoring mechanisms..
- **Invest More in Green Technologies:** Airlines and airport authorities should devote a large part of their budgetary allocations to research and development in fuel alternatives and waste recycling solutions.[50]
- **International Cooperation:** Having said that, the main idea tends to prompt an enhanced collaboration among countries which, ultimately, would add toward uniform environmental regulations for the sector in consideration-aviation.
- **Public-Private Partnership:** Public private partnerships would speed up some sustainability projects if it would encourage collaboration across government agencies and private aviation entities.

XI. Conclusion

Known to be a symbol of modern advancement, the aviation industry becomes the central link for global connectivity, trade, and tourism. However, the imprint left by the industry on the environment—with obnoxious waste generation, considerable greenhouse gas emissions, noise attacks, and severe ecological damages is grossly under consideration. Thus, the art of aviation law is not limited merely to security and economic efficiency but to combining the oft-polar

[49] DET Awesso, 'The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)' in Cambridge University Press eBooks (Cambridge University Press 2022) 137–157 https://doi.org/10.1017/9781108919166.010.
[50] OECD Environmental Performance Reviews 2001 (OECD Environmental Performance Reviews, 2001) https://doi.org/10.1787/9789264192133-en.

extremes of development and environmental sustainability[51].

There has been tremendous progress in recent decades in recognition and escape from the environmental effects of aviation. Legal instruments at the international and domestic levels are now in place to address the various components of aviation waste and pollution management. The Chicago Convention (Annex 16), the Basel Convention, and CORSIA lay down the fabric of regulation at the global level. In India, the Environment (Protection) Act, 1986, and rules like the Solid Waste Management Rules, 2016, and Hazardous and Other Wastes Rules, 2016 make sure that sustainable practices are being followed in the aviation industry.[52]

Contrary to this, it can be said that laws are grossly insufficient. Enforcement has been sporadic, particularly due to the multiplicity of acts and functions being dispersed among regulatory bodies, unavailability of trained personnel, lack of infrastructure, and absence of dedicated environmental jurisprudence concerning the aviation sector. Also, high costs of the ecologically sound alternatives, lag in technology, and inconsistencies in regulations across jurisdictions are other hurdles impeding the course of sustainable aviation.

It is therefore imperative to adopt a systematic approach to close the above-mentioned gaps. Making the regulatory frameworks stronger by giving clear mandates and imposing stiff penalties, and improving the institutional capacities to inspect, monitor, and be transparent about data should take top priority. On the other hand, stimulating investments in sustainable aviation technologies, such as bio-based fuels, electric aircraft research, and waste recycling infrastructure, is also crucial for the push toward sustainability[53]. Governments should not only enact law in pursuit of innovation but also actively facilitate processes such as public-private partnerships that drive green transformation.

International cooperation can then be deepened further to push for harmonized environmental benchmarks across borders. Shared goals, concomitant reporting systems, and cooperative funding for clean aviation technologies are essential for ensuring global compliance that is both

[51] RR Sobotta, HE Campbell and BJ Owens, 'Aviation Noise and Environmental Justice: The Barrio Barrier' (2007) 47(1) Journal of Regional Science 125 https://doi.org/10.1111/j.1467-9787.2007.00503.x.
[52] C Lyle, 'Beyond the ICAO's CORSIA: Towards a More Climatically Effective Strategy for Mitigation of Civil-Aviation Emissions' (2018) 8 Climate Law 104. https://doi.org/10.1163/18786561-00801004
[53] CR Spitzer, 'The All-Electric Aircraft: A Systems View and Proposed NASA Research Programs' (1984) AES-20(3) IEEE Transactions on Aerospace and Electronic Systems 261 https://doi.org/10.1109/taes.1984.310509.

comprehensive and effective[54]. Since aviation does not recognize national borders, there will be the need for a super-jurisdictional regulatory model.

Future consideration and design in airports, aircraft, and ground operations would include sustainable practices that will enable future generations to minimize their environmental impacts on the bright future[55]. Case studies like the Cochin International Airport in India and many others across the globe have proven that the modern technologies adopted in airport operation have brought about better compliance with the environment both for domestic and international air travel.

[54] H Baum and S Auerbach, Strategic Management in the Aviation Industry (Taylor & Francis 2017).
[55] A Wittmer, T Bieger and R Müller, Aviation Systems: Management of the Integrated Aviation Value Chain (Springer 2011)