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Pollution and Environmental Pressures from Intensive Dairy Farming

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Intensive and peri-urban dairy farming supports India's milk economy, but it can create substantial environmental pressures when manure, wastewater, emissions and resource use are poorly managed. This article reviews major environmental pressures associated with dairy operations: nutrient-rich effluent; methane, ammonia and nitrous oxide emissions; high-BOD/COD wastewater; pathogens and veterinary-drug residues; water use; downstream plastic-packaging waste; and indoor air pollution from dung burning. Drawing on Indian and international evidence and examples from the Netherlands, Delhi NCR, Haryana and the organized dairy industry, it examines regulatory approaches, mitigation options and the emerging role of initiatives such as GOBARdhan. It argues that dairy intensification should be accompanied by organized manure and effluent management, covered storage, appropriate biogas systems, evidence-based feeding strategies, water-use efficiency and stronger management of packaging waste across the value chain.

Introduction

Dairy farming underpins India's rural economy and nutritional security, and the country is the world's largest milk producer, supported by both organized, high-density dairies and traditional smallholder farms. As dairy units become larger and more concentrated, particularly in peri-urban areas, inadequate waste infrastructure can increase local environmental pressures. Intensive dairy operations generate dung, urine, wash water and effluent from sheds and milking areas; downstream chilling and processing facilities generate additional wastewater. Dairy wastewater can have a substantially higher organic load than domestic sewage, depending on milk losses, cleaning practices and dilution. If discharged untreated, it can degrade water and soil quality, create odour and increase health risks for animals, workers and nearby communities. Dairy-sector environmental pressures arise from several linked sources: enteric emissions, manure and slurry management, wastewater from washing animals and equipment, and the broader water-use and packaging footprint of the dairy supply chain. A complete assessment should therefore distinguish farm-level pollution from resource use and downstream value-chain impacts.

Types of Pollutants from Dairy Farming

Dairy farms generate air-, water- and soil-related pollutants, while the wider dairy value chain also creates resource-use and packaging pressures. Important sources include:

- Dung and urine
- Enteric methane produced during digestion, independent of manure
- Wash water from sheds, animals and milking equipment
- Silage effluent and feed residues
- Veterinary pharmaceuticals, including antibiotics and antiparasitic drugs

- Water use for drinking, cleaning and fodder production (a resource pressure rather than a pollutant)
- Packaging used in milk collection, processing and distribution (a downstream waste issue)

A) Nutrient Pollutants (Nitrogen and Phosphorus)

Dairy effluent can contain elevated nitrogen and phosphorus derived from manure, urine, milk residues and some cleaning agents (Kolev Slavov, 2017). Excess nutrient loading can accelerate eutrophication, leading to algal growth and oxygen depletion as organic matter decomposes, with adverse effects on aquatic life. Nitrate-contaminated drinking water is a concern because high nitrate exposure can cause methaemoglobinaemia in infants and nitrate toxicity in livestock (Lohia, 2025).

B) Gaseous Pollutants (Air Pollution and Greenhouse Gases)

Dairy cattle and buffaloes emit substantial methane through enteric fermentation. The relative contribution of enteric fermentation, feed production and manure management varies by production system; enteric fermentation is commonly a major source (Llonch et al., 2017). A life-cycle assessment of Haryana's buffalo-based dairy sector reported an average carbon footprint of 2.24 kg CO2-equivalent per kg of fat- and protein-corrected milk, with enteric fermentation as the largest contributor (Kumar et al., 2024). Earlier Indian estimates indicate that buffaloes contribute about 40 percent of livestock enteric methane emissions (Balhara et al., 2017). The principal gaseous emissions include methane (CH4) from enteric fermentation and anaerobic manure decomposition, a potent greenhouse gas (FAO, 2023); ammonia (NH3) released mainly from urea hydrolysis in urine and manure, which contributes to nitrogen deposition, ecosystem acidification, secondary particulate matter and respiratory irritation (Aneja et al., 2008); and nitrous oxide (N2O) produced during nitrification and denitrification in manure and fertilized soils, with a high global-warming potential and stratospheric ozone-depleting effect (Marszałek et al., 2018). Fossil carbon dioxide (CO2) is associated with energy and feed supply, whereas biogenic CO2 from animal respiration is generally not counted as a net anthropogenic emission in standard greenhouse-gas inventories.

C) Organic Pollutants and Effluent Load (BOD and COD)

Wastewater from milking parlours, shed cleaning and dairy processing can have a high organic load. Reported chemical oxygen demand (COD) and biochemical oxygen demand (BOD) values vary widely with the type of operation and degree of dilution (Kolev Slavov, 2017). Some reported raw-wastewater values are far above the general standards cited for discharge to inland surface waters under the Environment (Protection) Rules, 1986 (CPCB, 2024). Water use and wastewater generation also vary considerably between farm and processing operations. Untreated high-strength discharge can rapidly reduce dissolved oxygen in receiving waters and harm aquatic ecosystems.

D) Odorous Compounds

Dairy sheds and manure-storage areas can generate odour from ammonia, volatile fatty acids and hydrogen sulphide released during decomposition. Poorly managed storage and drainage can create persistent odour nuisance for nearby communities, especially where peri-urban dairy clusters are located close to residential areas.

E) Pathogens, Antibiotic Residues and Heavy Metals

Dung and effluent can carry pathogens such as E. coli and Salmonella as well as residues of veterinary drugs. A study of dairy farmers in eastern Haryana documented the use of antibiotics and other veterinary treatments, including dry-cow therapy and deworming practices (Kumar and Gupta, 2018). Poor manure and wastewater management may contribute to the environmental dissemination of antimicrobial-resistant bacteria and resistance genes. Detergents and sanitizers can add salts and other chemicals to farm effluent.

F) Water Footprint and Water Consumption

Water is used throughout dairy production, from fodder irrigation and animal drinking to shed cleaning, milk chilling and processing. The National Dairy Development Board reports a water footprint of about 1,062 litres per kg of milk for animals fed a balanced ration, around

14 percent lower than the 1,236 litres per kg reported for more grain-intensive feeding patterns (NDDB, 2024). Processing-water demand varies widely by plant design and cleaning practices (Boguniewicz-Żabłocka et al., 2019). In water-stressed regions, dense dairy clusters may add pressure to local groundwater resources. Greater use of suitable crop residues and agricultural by-products can reduce reliance on water-intensive feed ingredients.

G) Packaging and Downstream Plastic Waste

Low-density polyethylene (LDPE) pouches are widely used for liquid-milk distribution in India (Prakash et al., 2025). The resulting volume of single-use pouches creates a substantial downstream plastic-waste stream, but the national quantities cited in secondary media sources should be treated cautiously until verified against official or peer-reviewed data. Pouches that escape formal collection can persist in the environment and fragment into smaller plastic particles in soil and water.

H) Indoor Air Pollution from Traditional Use of Dung as Fuel

A further dimension is the traditional use of dried dung cakes as household cooking fuel. NFHS-5 reported that 43.2 percent of rural households used clean cooking fuel, indicating that solid-fuel use remained widespread, although this indicator does not separately quantify dung-cake use (MoHFW, 2023). Personal-exposure monitoring in rural kitchens found high emissions of PM10, PM2.5, volatile organic compounds, carbon monoxide, nitrogen dioxide and benzene from cow-dung combustion (Gautam et al., 2013). Where locally feasible, diverting dung to well-managed biogas systems can reduce direct dung burning while recovering energy and nutrients.

Pathways of Pollutant Release and Resource Pressure

- Soil pathways: direct land application of dung and slurry, surface runoff, and nutrient accumulation beyond crop uptake capacity.
- Water pathways: surface runoff, leaching to groundwater, and direct discharge of untreated wastewater into drains or surface waters, particularly where peri-urban waste infrastructure is inadequate.
- Air pathways: volatilization of ammonia, emission of methane from animals and manure, and release of odour and particulate matter from sheds and storage areas.
- Resource-pressure pathways: groundwater abstraction for drinking, cleaning and fodder irrigation, potentially contributing to water stress in already water-scarce dairy regions.

Summary of Major Pollutants

Table 1 summarizes the principal farm-level pollutant categories (sections A to E), their sources, potential impacts and common mitigation measures. Water use, packaging waste and household dung burning are related environmental pressures but should be distinguished from pollutants discharged directly by the farm.

Table 1. Summary of major pollutants and impacts associated with intensive dairy farms, their sources and recommended mitigation measures.

Pollutant Category	Major Sources	Key Pollutants	Environmental / Health Impact	Key Mitigation Measures
Nutrient pollutants	Dung, urine, milk residues in wash water	Nitrogen, phosphorus	Eutrophication of water bodies, nitrate contamination of groundwater, methaemoglobinaemia risk in infants	Phosphorus matched land application, nutrient budgeting
Gaseous pollutants	Enteric fermentation, manure storage, feed production, energy use	Methane (CH4), ammonia (NH3), nitrous oxide (N2O), carbon dioxide (CO2)	Climate forcing; nitrogen deposition; ecosystem acidification and eutrophication; secondary particulate matter formation; stratospheric ozone depletion (N2O)	Improved feed quality and evidence-based methane mitigation, covered slurry storage, biogas capture

Organic pollutants (effluent)	Milking parlour and shed wash water, utensil cleaning	High BOD and COD load, fats, oils and grease	Dissolved oxygen depletion in receiving water bodies, fish and aquatic life loss	Dissolved air flotation pre-treatment, anaerobic plus biological ETP
Odorous compounds	Anaerobic decomposition of manure and slurry	Hydrogen sulphide, volatile fatty acids, ammonia	Nuisance and reduced quality of life for nearby communities	Regular manure removal, covered storage, adequate shed ventilation
Pathogens and veterinary-drug residues	Dung, effluent, veterinary treatment	E. coli, Salmonella, veterinary-drug residues	Zoonotic disease risk, spread of antimicrobial resistance in soil and water	Proper waste segregation, composting, responsible antibiotic use

Environmental Impacts of Pollutants from Intensive Dairy Farming

A. Water Pollution

Untreated dairy effluent can promote eutrophication because of its nitrogen, phosphorus and organic-matter content. Reports from Delhi NCR describe numerous dairy operations receiving pollution notices for untreated waste discharge, illustrating the pressure that poorly serviced peri-urban dairy clusters can place on drainage systems (Chalmers, 2021). Nitrate leaching is also a concern where manure or effluent is applied in excess of crop nutrient requirements.

B. Soil Degradation

Over-application of dung and slurry beyond crop nutrient requirements can cause phosphorus accumulation, salt build-up and changes in soil chemistry. Under chronic excess loading, these changes can impair soil quality and increase nutrient losses to water (Cardenas et al., 2025).

C. Air Pollution and Climate Impact

Ammonia emissions contribute to local and regional air pollution and, after atmospheric transformation and deposition, to ecosystem acidification and eutrophication. Methane and nitrous oxide from enteric fermentation, manure management and fertilized soils are important greenhouse gases. FAO estimates that cattle, including dairy and beef animals, account for about 3.8 gigatonnes of CO_2-equivalent emissions annually, approximately 62 percent of livestock-sector emissions (FAO, 2023).

D. Human and Animal Health Impacts

Contaminated water can transmit enteric pathogens to humans and animals. Ammonia and particulate matter can irritate the respiratory tract and may contribute to occupational and community exposure near poorly ventilated or poorly managed facilities. Nitrate-contaminated drinking water is a well-documented risk for methaemoglobinaemia in infants, while improperly managed manure can disseminate antibiotic-resistant bacteria, antibiotic residues and resistance genes (Chee-Sanford et al., 2009).

E. Impacts on Water Resources

Beyond contamination, water demand across the dairy value chain—from fodder cultivation to animal care, cleaning and processing—can add pressure to aquifers in water-scarce regions. This is a resource-use impact and should be distinguished from pollution in the conventional sense.

F. Socio-Environmental Impacts

Communities near poorly managed dairy clusters may experience persistent odour, contaminated drains, vector nuisance and reduced local amenity. Stronger claims about property values, distributive impacts or environmental injustice require location-specific social and economic evidence.

Case Studies

I. Netherlands: Nitrogen Crisis and the Dutch Manure Crisis

Decades of intensive, land-scarce livestock farming have contributed to excessive nitrogen deposition in many Dutch Natura 2000 areas (RIVM, 2023). Under the EU Nitrates Directive, the general ceiling for livestock-manure nitrogen is 170 kg N/ha/year; the Netherlands' temporary derogation allowing higher application rates is being phased out. The resulting nutrient-management constraints, together with broader nitrogen policy, have increased pressure for structural changes in livestock production and have contributed to major farmer protests (Bonavate, 2025; IDDRI, 2024).

II. Delhi and the National Capital Region: Peri-Urban Dairy Colonies

Reports from Delhi NCR describe large numbers of dairy operations receiving pollution notices for untreated waste discharge into local drains. The example illustrates the risks of concentrating dairy animals without corresponding investment in drainage, manure handling and wastewater management; however, the scale of enforcement action should be verified from DPCC, CPCB, NGT or municipal records rather than a secondary media source (Chalmers, 2021).

III. Haryana: Life Cycle Carbon Footprint of Buffalo Milk

An ISO 14040/14044 life-cycle assessment of Haryana's buffalo-based dairy sector found enteric fermentation to be the dominant greenhouse-gas source per animal, ahead of feed and fodder production and manure management (Kumar et al., 2024). The result supports prioritizing interventions that reduce enteric methane while retaining manure-management measures needed for methane, ammonia, nutrient and water-quality control.

IV. Mother Dairy: A Degradable Alternative to the Milk Pouch

In June 2026, media reports described Mother Dairy's launch of a naturally degradable milk pouch for a cow-milk product in Delhi NCR (Mehra, 2026; Verma, 2026). Claims about being 'India's first,' degradation pathways, degradation time and recycling rates should be attributed explicitly to the company unless independently verified. The initiative nevertheless illustrates growing industry attention to downstream packaging waste.

Regulatory Framework and Mitigation

In India, dairy farms and associated wastewater discharges are subject to the Water (Prevention and Control of Pollution) Act, 1974, the Environment (Protection) Act and Rules, applicable state consent conditions, and CPCB guidance implemented through SPCBs/PCCs and local authorities. CPCB's revised Guidelines for Environmental Management of Dairy Farms and Gaushalas (2021) specifically address wastewater, dung, air quality and siting. General standards cited for discharge to inland surface waters include BOD of 30 mg/L, COD of 250 mg/L, total suspended solids of 100 mg/L and pH 5.5–9.0, but the applicable limit depends on discharge route and authorization (CPCB, 2021; CPCB, 2024). Treatment design should therefore be based on measured influent characteristics, required effluent quality and site-specific conditions rather than a single universal treatment train. A significant recent development is GOBARdhan, the National Circular Bioenergy Scheme, approved by the Union Cabinet on 6 August 2026 with a total outlay of ₹23,731 crore for FY 2026–27 to FY 2035–36. Led by the Ministry of Petroleum and Natural Gas, the scheme supports conversion of cattle dung, agricultural residues, press mud, municipal organic waste and other biomass into compressed biogas and organic manure. It aims to increase domestic CBG production nearly tenfold through assured demand, pricing support, capital assistance, pipeline connectivity, credit support and technology development (PIB, 2026).

Mitigation practices include the following

- Solid–liquid separation of manure, followed by composting, vermicomposting or biogas/CBG production where technically and economically appropriate (CPCB, 2021; PIB, 2026)
- Covered slurry storage to reduce ammonia volatilization and odour emissions

- Effluent treatment through constructed wetlands, waste stabilization ponds or dissolved air flotation pre-treatment ahead of biological treatment
- Nutrient-budgeted, phosphorus-matched land application of manure at rates aligned with crop demand and soil-test results
- Dietary strategies based on improved feed quality and evidence-based, safe methane-mitigation options to reduce enteric methane intensity per unit of milk
- Water-use efficiency, safe recycling/reuse where appropriate, rainwater harvesting, and compliance with applicable extended-producer-responsibility requirements for plastic packaging

Economic and Livelihood Dimension

Effective waste management can create co-benefits as well as costs. Properly processed manure may partially substitute for mineral fertilizer when nutrient content and application rates are managed appropriately, while biogas can displace some purchased fuel or electricity. GOBARdhan is intended to stimulate rural income through feedstock supply, plant operation, CBG production and sale of organic manure (PIB, 2026). Cooperative and cluster-based systems may help spread capital, operation and technical-support costs across multiple producers, although their viability depends on feedstock supply, logistics, markets and plant management.

Challenges in Mitigation

Several barriers can limit mitigation in India's dairy sector: high capital and operating costs relative to smallholder margins; fragmented manure supply; limited land, finance and technical capacity; weak maintenance of treatment systems; and uneven monitoring of unorganized peri-urban clusters. Technology selection should therefore account for herd size, water use, land availability, manure characteristics, local markets and the capacity to operate and maintain the system.

Future Directions

Promising priorities include scaling technically viable biogas and CBG systems at household, cooperative and cluster levels; integrating waste management with existing dairy institutions; validating low-emission feeding strategies under Indian conditions; strengthening implementation and monitoring by SPCBs/PCCs and local bodies in line with CPCB guidance; and improving collection and producer responsibility for dairy packaging. More life-cycle assessments across India's agro-climatic and production systems would help identify where mitigation delivers the greatest environmental benefit per unit of investment.

Conclusion

Dairy farming will remain important to India's rural economy and nutritional security. However, nutrient-rich effluent, methane and ammonia emissions, high-BOD/COD wastewater, water-resource pressure, packaging waste and smoke from dung burning can impose environmental and health costs when poorly managed. The priority is not simply to limit dairy production, but to ensure that intensification is matched by proportionate environmental management: manure collection and covered storage, appropriate biogas/CBG systems, fit-for-purpose wastewater treatment, nutrient budgeting, efficient water use, evidence-based methane mitigation and better packaging recovery. Achieving this will require coordinated action by farmers, cooperatives, processors, regulators, researchers and policymakers.

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