Sustainable Solid Waste Planning and Management Infrastructure for the 2025 Maha Kumbh Mela: A Technical Review

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Abstract - Kumbh Mela is an event that allows millions of pilgrims to gather in a location for their spiritual and religious rituals. The 2025 Kumbh Mela introduced a new zoned structure within the event to help allow for better waste management and lessen pollution. This article will discuss the main religious rituals of Kumbh Mela and the waste streams, then examine how the merit of zoning provided solutions to the waste management problems presented using smart technologies and waste separation

Keywords: Large gatherings, solid waste management, river

I. INTRODUCTION

Kumbh Mela, occurring periodically at four main stations Prayagraj, Haridwar, Nashik, and Ujjain, is an ancient Hindu pilgrimage in which pilgrims perform ceremonial acts. It is a sacred event that occurs every 12 years, rotating between these sites. The Kumbh Mela 2025 in Prayagraj attracted over 150 million pilgrims over a 46 day period, presenting both great religious exuberance, as well as a major waste management challenge.

The sheer number of visitors and the associated amount of waste generated (including organic waste, plastics, medical waste, and ceremonial waste) can be staggering and stress even the best waste management services to their limits. In Kumbh Mela 2025, zoning of activities was used to maximize resource crowds and develop an effective waste management system.

II. MAJOR RELIGIOUS PRACTICES AT KUMBH MELA

1. Shahi Snan (Royal Bath)

Considered the most auspicious ritual where millions of devotees take a dip in the holy rivers to cleanse themselves of sins. This occurs on designated dates determined by astrological alignments. During this activity huge volumes of floral offerings, plastic packaging, and organic waste were generated along riverbanks.

2. Yajnas and Havan (Fire Rituals)

Activities of offerings to Agni (fire god) with the belief that it purifies the atmosphere and invokes divine blessings happened during entire 46day period. During the practice of such offerings, the waste produced, belongs to the categories of ash, burnt wood, and residual organic matter in an enormously huge quantity.

3. Pind Daan and Tarpan (Rituals for Ancestors)

Practice of ritualistic acts addressing the ancestors to provide spiritual offerings helping them in attaining liberation. During these activities at such a massive scale, huge scale of waste got generated which were categorised as organic waste from grains, flowers, and biodegradable materials.

4. Religious Discourses and Satsangs

These are the structures activities involving public in a large-scale gathering to cultivate a kind of association with truth. On case-to-case basis they vary a lot but falls under same stream of prayer. During such activities, lot of waste like paper pamphlets, plastic cups, and food packaging got generated at a large scale.

5. Annadaan (Mass Feeds)

The sacred offering of food to large scale community, meals were provided to millions of piligrims on a very consistent practice during the 46day period. A lot of rejected food waste, disposable plates, and plastic cutlery got generated on a regular intervals on day to day basis during entire period.

6. Kalpavas (Month-long Stay)

A commitment of pilgrim/s, spending entire duration with intense spiritual penance by staying at temporary tented accommodation provided by the authorities. Due to large foot fall of pilgrims, it has been estimated of 1.5lakh metric tons of solid waste in the categories of daily household waste, sanitary waste, and biodegradable waste.

III. TYPES OF WASTE GENERATED AT KUMBH MELA

As per the major religious practices at khumba mela, the different types of waste generated are as mentioned

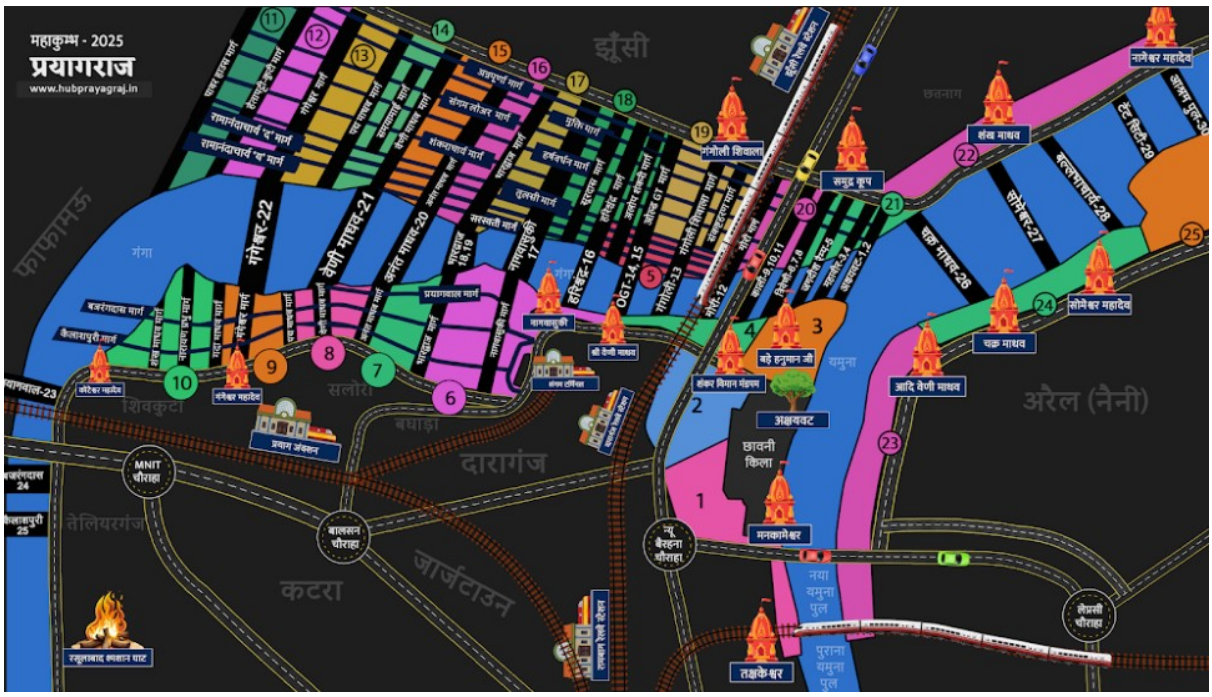
Type of Waste	Percentage	Sources
Organic Waste (Biodegradable)	55%	Food waste, flowers, leaves, and offerings
Plastic Waste	20%	Packaging, bottles, and containers
Medical Waste	5%	Used syringes, masks, and gloves
Ash and Residuals	10%	From yajnas and fire rituals
E-waste	3%	Mobile chargers and electronic items
Construction & Demolition Waste	7%	Temporary structures and pavilions

5. Zoning of Activities at Kumbh Mela 2025

In 2025, authorities adopted an **activity zoning model** that designated specific areas for different activities, ensuring efficient crowd control and waste segregation.

Key Zones Identified:

1. Religious Zone**:** For rituals, dips, and prayer ceremonies.
2. Residential Zone**:** Designated for Kalpavas pilgrims with sustainable accommodations.
3. **Commercial Zone:** Markets for vendors and eateries.
4. Medical and Emergency Zone: Equipped with first aid, waste management, and sanitation services.
5. Cultural Zone: For discourses, spiritual events, and community interactions.
6. Waste Processing Zone: Exclusive area for waste segregation and treatment.



Source: https://kumbh.gov.in

IV. IMPACT OF ZONING ON WASTE MANAGEMENT

1. Improved Waste Collection and Segregation
   - Designated waste bins with color codes were placed in each zone.
   - Volunteers guided pilgrims on waste segregation practices.

2. Efficient Resource Allocation
   - Zoning enabled streamlined manpower deployment.
   - Increased surveillance and real-time monitoring reduced littering.

3. Reduction in Cross-Contamination
   - Waste segregation at the source reduced contamination of recyclable materials.
   - Compostable and organic waste was collected separately for biogas generation.

V. COMPARISON: WASTE MANAGEMENT EFFICIENCY (2019 VS. 2025)

In connection with the waste management and statistics, to have an understanding, the waste generated as per the respective categories have been listed below.

Metrics	**Kumbh Mela 2019**	**Kumbh Mela 2025**
Waste Generated Per Day	800-1000 tons	750-900 tons
Percentage of Waste Recycled	45%	70%
Composting of Organic Waste	35%	60%
Plastic Waste Recovery	20%	50%
Manual Labour Required	80,000+ workers	60,000+ workers
Number of Waste Collection Points	250	400

Source: https://kumbh.gov.in

VI. IMAGES ILLUSTRATING ZONING AND WASTE MANAGEMENT AT KUMBH MELA 2025

1. Zoning Map: Kumbh Mela 2025
2. Waste Segregation Bins at Kumbh Mela
3. Bio-Methanation Plant for Organic Waste
4. Sanitation Facilities for Pilgrims

VII. INNOVATIVE TECHNOLOGIES IMPLEMENTED IN 2025

1. RFID-Based Waste Monitoring
   - Monitored waste generation patterns in different zones.
   - Enabled real-time data analytics for corrective action.

2. Bio-Methanation and Composting Plants
   - Organic waste converted to biogas and compost.
   - Reduced dependency on landfilling.

3. Automated Waste Collection Vehicles
   - AI-enabled waste collection systems mapped with zoning plans.
   - Reduced manual labor dependency by 25%.

4. Drone Surveillance for Cleanliness Monitoring
   - Drones identified waste hotspots and alerted cleanup teams.

VIII. CHALLENGES ADDRESSED BY ZONING IMPLEMENTATION

1. Reduced Overcrowding in Critical Zones
   - Optimized movement reduced chances of waste accumulation.
2. Enhanced Public Participation
   - Increased awareness through visual zoning signs.

3. Minimized Risk of Water Pollution
    - Proper waste segregation and controlled disposal near riverbanks.
4. Increased Efficiency in Emergency Response
    - Medical and sanitation zones were easily accessible in emergencies.

IX. ANALYSIS AND INFERENCES

Kumbh Mela 2025 had been one of the largest religious gathering on the planet which had attracted millions of pilgrims to the sacred rivers to take part in ritualistic bathing and some spiritual practices. While the event itself has significant cultural and spiritual value, the event also exerts enormous environmental stress on the river systems. Upon careful evaluation of the impacts of such large-scale religious rituals highlighted above, the concerns surrounding the environmental impacts range from many common environmental challenges faced in India, including both point-source and non-point-source pollution. Of these, the discharges of untreated sewage, increases in solid waste, oil and grease from ceremonial activities, and chemical substances from puja rituals/offerings and temporary installations are significant concerns. Best practices for these common environmental challenges had been developed in the past through a plethora of means mostly based on the specific problem identified for resolution. However, once the scale and complexity associated with Kumbh Mela is considered, it becomes clear that many of the established practices are insufficient. In addition, given the unique socio-cultural context of India, it is not feasible to blindly apply practices which worked in other parts of the world. Therefore, it becomes necessary to research the river-cleaning practises and mitigation practices that had been adopted in India, as outlined in the national policy reports such as the Ganga Action Plan, the National River Conservation Plan and the Namami Gange Programme. These frameworks provide frameworks of thought for how planning, infrastructure, and participation can be used to reduce pollution through rituals. The best way to approach Kumbh Mela 2025 is to bring an amalgam of these Indian policies with high-end international river-cleaning technologies and practices. This combination would help to support a more adaptive and sustainable approach to manage the environmental burden associated with the event, while also upholding the cultural sanctity of the event. A multidisciplinary coordinated planning process, including policy-makers, environmental experts, civil servants, and religious officials, had been implemented to ensure that sacred rivers not only provide for the spiritual practices of millions, but also are maintained as ecological resources for future generations.

Reducing River Pollution from Ritualistic Practices
During Kumbh Mela 2025, massive influxes of pilgrims lead to significant river pollution from untreated wastewater, pesticide-laden floral offerings, oil spills, and solid waste. A long-term river rejuvenation strategy had been implemented in minimizing the pollution through better waste management, water treatment facilities, and stricter controls at ritual sites.

Public Participation in River Management
River maintenance during the Mela cannot be the sole responsibility of the government. Active community involvement is essential pilgrims, local residents, and volunteers had participated in clean-up drives, water quality monitoring, and awareness campaigns had been conducted through out the 46day period and cleanliness program happened for an extended period of 15days.

Rejuvenation of the River Zone
The areas adjacent to the riverbanks, particularly within the floodplain, had been revitalized to balance ecology and culture. Introducing features like eco-friendly ghats, biodiversity parks, herbal gardens, nature trails, and amphitheaters had enhanced the riverfront's environmental and spiritual value during the Mela.

Protection and Conservation of Riverine Biodiversity.
The ecological impact of Kumbh Mela necessitates a focused strategy for biodiversity conservation. This includes mapping local species, monitoring their status, and engaging the public in protecting aquatic and riparian ecosystems, through one-time or recurring conservation programs.

X. STRATEGIES FOR KUMBA MELA 2025

The strategic framework for managing river health during Kumbh Mela 2025 is designed around three core themes: Environmental**,** Economic, and Social. These themes guided the development of actionable, context-specific interventions to address the challenges posed by large-scale religious gatherings on river systems.

XI. ENVIRONMENTAL STRATEGIES

i. Effective Regulation of Activities in Riverine Areas

Given the anticipated intensity of rituals and pilgrim movement during Kumbh Mela 2025, it is critical to establish and enforce robust environmental guidelines and controls:

- Immediate littering prohibition and restriction on the discharge of sullied streams from religious sites and cremation grounds prohibition on dumping waste in river from puja samagri, ashes, plastics, dangerous offerings.
- Monitoring of sites through personnel in security roles with signage at ghats.
- Complete aesthetic, demarcation and control of floodplains and banks concentric with the "ecological" spur.
- Integrating field instructions and resources among the riverine zones regularly to monitor pollution concentrations and hazardous actions.
- Incorporating economic instruments "polluter pays" for individuals or some institutions who breach environmental specifications to obtain a penalty.
- Deployment of river guards and operatives to patrol and immediately enforce actions.
- Cross-agency coordination structures including urban local agency, environment agency, and religious representatives to engage in collective river ownership/manage.

ii. Keeping the River Free from Pollution

To preserve water quality throughout the duration of Kumbh Mela 2025, a mix of structural and non-structural measures had been adopted.

- Established a focused leadership and monitoring team to ensure real-time monitoring of pollution control and river management activities.
- Regular water quality sampling at all key bathing and ritual locations to evaluate the levels of pollutants and to provide for immediate corrective action.
- Established and implemented a geo-spatial monitoring framework to map and identify pollution sources across the Kumbh Mela zone.
- Evaluated existing sewage infrastructure in and around the event area to determine if it is properly collecting, treating, and disposing of wastes from camps, rituals, and temporary residences.

XII. POLLUTION TREATMENT STRATEGIES FOR KUMBH MELA 2025

Given the immense scale of Kumbh Mela 2025 and the potential environmental stress it places on river systems, a comprehensive approach to pollution treatment is essential. Both innovative technologies and nature-based solutions must be implemented to ensure the cleanliness and ecological health of the rivers during and after the event.

1. Surface Cleaning and Floating Waste Collection

In managing the large volume of floating debris and waste that accumulates during the Mela, the deployment of surface skimmers is vital. Technologies such as Watermills, The Ocean Cleanup Interceptor, and Alphamers Floating Trash Fence have been installed at key points along the river. These devices efficiently trap floating plastics, religious offerings, and other solid waste before they disperse downstream.

2. Structural Measures for Wastewater Treatment

The establishment of sewage treatment plants (STPs) near ritual and bathing points were very much effective in handling the wastewater generated by pilgrims. These plants been designed to treat polluted water efficiently and allow the reuse of treated water for non-potable purposes such as gardening, flushing, and construction activities within the Mela area.

3. Urban Forests for Phytoremediation

In selected zones along the river corridor, urban forests had been developed using plant species known for their ability to absorb and filter heavy metals and other toxins from river water. This phytoremediation approach not only enhances water quality but also improved the ecological landscape of the Mela site.

4. Constructed Wetlands for Natural Filtration

Creation of artificial or constructed wetlands as part of the river management system were very effective in natural filtration mechanism. These wetlands use aquatic plants (like reeds and duckweed), beneficial microorganisms, and layered filter beds (sand, soil, gravel) to purify contaminated water**.** During Kumbh Mela 2025, such wetlands acted as buffer zones that reduced the pollutant load before the water re-enters the main river channel, supporting long-term water quality improvement.

XIII. POLLUTION CONTROL STRATEGIES FOR KUMBH MELA 2025

To effectively manage the environmental impact of Kumbh Mela 2025**,** comprehensive pollution control measures have been implemented at key riverfront areas, especially around ghats, crematoriums, and ritual zones. These strategies aim to preserve river health while accommodating the spiritual and cultural significance of the event.

Ghats serve as the epicenter for ritual activities during the Mela. Therefore, it is crucial to carry out renovation and regular maintenance of all major ghats to ensure cleanliness, safety, and accessibility. This includes repairing structural elements, maintaining cleanliness, and managing high foot traffic during peak days.

XIV. A. ECONOMICAL STRATEGIES FOR KUMBH MELA 2025

The river resuscitation efforts linked to Kumbh Mela 2025 should not only aim at environmental preservation but also foster economic development by creating livelihood opportunities that align with sustainable practices:

- Floral Waste Management for Eco-Friendly Products: The enormous volume of floral offerings generated during the Mela been converted into a resource through “Floral Cycling”, the transformation of temple and ghat floral waste into biofertilizers, incense sticks, organic dyes, and lifestyle products**.**
- Established flower cycling units near the event site to create local employment, particularly for rural families and women’s self-help groups, boosting the regional economy through sustainable enterprise.
- Provided financial assistance and incentives to flower collectors and processing units to formalize this informal economy and reduce the burden on river ecosystems.

XV. B. SOCIAL STRATEGIES FOR KUMBH MELA 2025

The social aspect of river rejuvenation during Kumbh Mela is critical to ensure that rituals are preserved in an environmentally conscious way and that people feel a sense of ownership and responsible toward river conservation:

• Supporting Rituals Sustainably: Empower the local community to undertake culturally and religiously important actions sustainably through biodegradable offerings, established ritual spaces, and eco-safe immersion ponds to honour traditional practises and rituals without the risk of contaminating and harming the river.

• Awareness and Behaviour Change Initiatives: Engage tools like social media campaigns, children’s camps, informational hoardings, hands-on and interactive mobile apps, and with activities and games understanding the river to encourage pilgrims to take actions that are sensitive to the river. Potentially even promote and dedicate one day especially for the river where connections to rivers emotionally and spiritually become a priority.

• Citizen Orientation to Environment / River Management: Create greater public engagement through community activities like cleaning the river banks, tree planting, offering citizens eco-volunteer programs to engage people throughout the Mela. These sponsor the building of a continuous community based stewardship model for long-term health of the river.

XVI. CONCLUSION

The zoning of activities at Kumbh Mela 2025 marked a paradigm shift in waste management practices**.** By implementing a well-structured zoning model, authorities ensured seamless waste segregation, reduced cross-contamination, and maximized recycling efforts. Innovative technologies, combined with community awareness and proactive crowd management, significantly minimized the environmental footprint of the event.

As a result, Kumbh Mela 2025 not only upheld its spiritual significance but also emerged as a model for sustainable waste management in large-scale public gatherings worldwide. This is a biggest and ideal example for further studies in environmental issues for upcoming huge events that are going to happen in India as well as other regions.

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