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AMRUT-Supported Fecal Sludge Treatment Plants in Uttar Pradesh: Portfolio Assessment, Policy Review, and Implementation Gaps

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Abstract - Safe fecal sludge and septage management has become a critical urban sanitation challenge in Uttar Pradesh because a large share of urban households depends on on-site sanitation systems rather than full sewer connections. The source dissertation evaluates 53 AMRUT-supported fecal sludge treatment plant (FSTP) and co-treatment projects in selected cities of Uttar Pradesh and reports that 39 projects are operational while 14 remain non-operational, indicating a substantial construction-to-service gap within the sanitation chain. The assessed portfolio represents about 1731 KLD of design capacity, of which about 1289 KLD is operational and about 442 KLD is tied to non-operational assets. Building on that document, this research paper synthesizes the empirical findings, interprets their institutional and operational implications.

The analysis shows that the principal challenge is not merely infrastructure creation but dependable service delivery, including commissioning readiness, scheduled desludging, operator regulation, occupational safety, environmental compliance, and sustainable operation and maintenance financing. Zone-level variation is substantial, with Lucknow Zone showing full operationalization in the reported dataset and Kanpur Zone showing the lowest operational share among the listed zones. FSTPs display a better operational profile than co-treatment plants in the source dataset, although both technologies remain important for cities with different land, cost, and sewerage conditions. The paper argues that the next phase of sanitation reform in Uttar Pradesh must move from asset-centric planning to service-chain governance supported by monitoring, digital trip logging, designated discharge enforcement, and performance-linked funding.

Keywords - Fecal sludge treatment plant, AMRUT, Uttar Pradesh, septage management, co-treatment, urban sanitation, FSSM, scheduled desludging.

1. INTRODUCTION

Urban sanitation outcomes depend not only on toilet access but on the integrity of the entire sanitation chain, including containment, emptying, transport, treatment, and safe reuse or disposal. The attached dissertation adopts this chain perspective and situates fecal sludge and septage management as a central requirement in towns where sewerage coverage is incomplete and septic tanks or other on-site systems dominate. This framing is especially relevant in Uttar Pradesh, where many urban local bodies rely heavily on on-site sanitation and therefore require organized pathways for desludging and treatment.

AMRUT has supported sewerage and septage-related investments, including standalone FSTPs and co-treatment arrangements at sewage treatment plants. Yet the dissertation identifies a recurring problem: physical completion does not always translate into operational service, even where handover and 100 percent physical progress are reported. This distinction is analytically important because urban sanitation failures often arise not at the point of construction but at the point of routine operation, contractual accountability, and enforcement.

This paper is based on the dissertation titled *Assessment of Fecal Sludge Treatment Plants (FSTPs) under Atal Mission for Rejuvenation and Urban Transformation (AMRUT) in Selected Cities of Uttar Pradesh* submitted in 2025 by Muneer Haider. The purpose here is not to reproduce the dissertation verbatim, but to recast its substance into a fuller research-paper format, sharpen the

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argument, extend the interpretation, and add a structured reference-use mapping so that each cited source is connected to the section in which it is applied.

2. RESEARCH PROBLEM AND OBJECTIVES

The core research problem is the gap between sanitation infrastructure creation and sanitation service delivery. The source document explicitly notes that several facilities may be physically complete but not operational, creating a risk that unsafe dumping or unmanaged sludge flows continue despite public investment. In policy terms, this means that mission expenditure does not automatically guarantee public-health or environmental outcomes.

Based on the dissertation, the principal objectives may be restated as follows:

- To assess the status of AMRUT-supported FSTP and co-treatment projects in selected cities of Uttar Pradesh.
- To classify the project portfolio by zone, type, status, and capacity.
- To identify implementation gaps affecting operationalization.
- To connect empirical status data with literature on FSSM, technology selection, service delivery models, occupational safety, compliance, and financing.
- To propose an implementation-oriented framework for improving functionality and long-term sustainability.

This expanded paper adds one more objective: to translate the findings into a policy-relevant analytical narrative suitable for academic submission and professional sector use.

3. LITERATURE AND CONCEPTUAL BASE

The dissertation's literature review establishes several concepts that shape this paper's analysis. First, fecal sludge is distinct from sewage sludge, and septage from septic tanks typically has different physical and chemical characteristics from municipal sewage, implying that collection, transport, and treatment systems must be deliberately designed rather than assumed to function like conventional sewer networks. Second, citywide sanitation planning must address the full sanitation chain because risks emerge when any link fails, especially containment integrity, emptying regularity, transport compliance, or treatment reliability.

The document also highlights that incremental sanitation planning is often more realistic than universal conventional sewerage in smaller and medium-sized towns. In such contexts, a mix of on-site sanitation, scheduled desludging, decentralized treatment, selective sewer expansion, and co-treatment may provide better value and quicker risk reduction than waiting for full networked sewerage. This proposition is significant for Uttar Pradesh because it places FSTPs and co-treatment plants within a broader transition strategy rather than treating them as temporary or inferior substitutes.

On technology, the source dissertation notes that FSTPs typically include receiving, screening, solid-liquid separation, stabilization, drying or dewatering, pathogen reduction, and effluent management stages. It also notes that drying beds are common where land is available, whereas mechanical systems may suit space-constrained urban contexts but require stronger energy and maintenance capacity. Co-treatment at STPs can reduce capital expenditure by using existing wastewater assets, but only where spare hydraulic and organic capacity exists and where controlled receiving arrangements prevent shock loading and operational upset.

The literature section further stresses that scheduled desludging is generally more compatible with plant operations than on-demand emptying because scheduled systems smooth incoming loads and can be integrated with municipal planning and billing. Equally, occupational health and safety cannot be treated as secondary, because sewer and septic tank work exposes laborers to toxic gases, oxygen deficiency, biological hazards, and confined-space accidents. Finally, the dissertation emphasizes the need for monitoring systems, vehicle tracking, service benchmarks, user charges, discharge fees, and robust contracts to make sanitation services sustainable beyond capital investment.

4. METHODOLOGY

The source dissertation uses a project-status dataset drawn from an AMRUT presentation listing FSTP and co-treatment projects in Uttar Pradesh. The methodology described in the document consists of table extraction, header normalization where source tables contained empty first rows, field standardization, and numeric conversion into comparable formats. The final analytical fields

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include zone, district, urban local body, project name, physical progress, handover status, capacity, project type, and operational status.

The analytical approach is descriptive rather than experimental. Cross-tabulations were prepared for status, type, and zone, while capacity-at-risk was inferred from design capacities associated with non-operational plants. Visualizations in the dissertation present the distribution of projects by status, type, zone, and capacity, along with status-linked aggregate capacity.

This methodology is appropriate for a portfolio assessment because the main aim is to identify implementation patterns rather than treatment-process performance. However, the dissertation clearly acknowledges a limitation: the dataset does not verify effluent quality, pathogen reduction, uptime, financial performance, or actual field operations, and reported status may change over time. Accordingly, the conclusions of this paper must be read as a governance and operationalization assessment, not as a plant-performance audit.

5. RESULTS FROM THE ASSESSED PORTFOLIO

The source dissertation analyzes 53 projects. Of these, 39 are reported as operational and 14 as non-operational. This means roughly three-fourths of the listed portfolio is functioning at least in reported status terms, while about one-fourth remains outside service despite inclusion in the AMRUT-supported asset base. The same section reports that 41 projects had handover marked "Yes," indicating that handover alone is not a sufficient proxy for actual operationalization.

The total reported design capacity is about 1731 KLD. Approximately 1289 KLD is linked to operational facilities, while about 442 KLD is associated with non-operational assets. This is a significant planning result because it shows that non-operationality is not a marginal issue affecting only a few small sites; it represents a substantial block of sanitation treatment capacity that has not yet translated into public service.

By type, the portfolio includes 29 FSTPs and 24 co-treatment plants. Of the 29 FSTPs, 23 are operational and 6 are non-operational, while of the 24 co-treatment plants, 16 are operational and 8 are non-operational. This suggests that in the reported dataset, FSTPs have a somewhat stronger operational profile than co-treatment plants. One possible interpretation is that co-treatment facilities often depend on more complex institutional and technical integration with existing STP infrastructure, including inlet design, spare capacity assessment, and operating protocols, whereas some FSTPs may operate under more clearly bounded site-level arrangements.

Zone-wise variation is also notable. Ghaziabad Zone has the largest number of projects at 15, with 10 operational and a reported total capacity of 470 KLD. Gorakhpur Zone has 9 projects, of which 8 are operational, giving the highest operationalization share among the zones with multiple projects at 88.9 percent. Prayagraj Zone also has 9 projects but only 6 operational, while Agra Zone has 7 projects with 5 operational and Kanpur Zone has 7 projects with only 4 operational, the lowest operational share at 57.1 percent. Lucknow Zone reports 6 projects and all 6 as operational, producing 100 percent operationalization in the dataset.

These differences have practical meaning. A zone with a lower operational ratio may indicate delays in commissioning, weaker service integration, financing gaps, or unresolved coordination between ULBs, contractors, and state-level support agencies. A zone with full or near-full operationalization may offer replicable practices in contract management, staffing, testing, and readiness procedures.

6. INTERPRETATION OF CITY-LEVEL EVIDENCE

The dissertation provides short descriptive notes for selected ULBs that illustrate the diversity of facility types and operational profiles. Jhansi and Hapur are listed as operational 32 KLD FSTPs with 100 percent physical progress and handover completed. Prayagraj and Agra are presented as operational co-treatment facilities, including a 50 KLD co-treatment facility in Prayagraj and a 75 KLD co-treatment facility in Agra. Ghaziabad, Gorakhpur, Varanasi, and Lucknow also appear as operational co-treatment examples, though some of them show handover as "No" despite operational status.

This pattern is analytically useful because it reveals that administrative milestones do not always occur in the same sequence across cities. A plant may be technically in operation while formal handover remains pending, or conversely may show physical completion and handover but remain non-operational. Therefore, future monitoring frameworks should separate at least five milestones: civil completion, equipment commissioning, trial runs, formal handover, and verified routine operation.

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Examples from the consolidated project list also show that some non-operational projects have 100 percent physical progress, such as Hathras, Orai, Rampur, Mainpuri, Lalitpur, Moradabad, and Muzaffarnagar. Ballia and Ghazipur are listed as non-operational with zero physical progress, suggesting a different class of delay related to execution or project initiation rather than post-construction commissioning. Mau is shown as non-operational with 85 percent physical progress, representing an in-between stage. This suggests that non-operationality should not be treated as a single category; it includes at least three subgroups: not yet built, built but not commissioned, and operationally inactive despite physical completion.

7. DISCUSSION

7.1 Construction-to-service gap

The central contribution of the source dissertation is the identification of a construction-to-service gap. In sanitation systems, risk reduction occurs only when sludge is regularly collected, transported to designated points, received safely, treated effectively, and either reused or disposed of in compliance with environmental requirements. A completed but non-operational FSTP does not interrupt unsafe dumping pathways, and may even create a false sense of coverage in official reporting.

The finding that 442 KLD of reported capacity remains non-operational is therefore not only a numerical observation but a governance warning. It implies that sanitation investments should be evaluated through service outcomes rather than asset counts alone. For AMRUT-like missions, this points to the need for post-construction performance conditions, not only civil-work completion certificates.

7.2 Why operationalization fails

The dissertation indicates several plausible causes of delayed operationalization, including lack of trained operators, missing SOPs, inadequate spares, weak maintenance systems, incomplete power arrangements, insufficient demand-side planning, and weak enforcement against illegal discharge. The paper also underscores that plants may remain underloaded if desludging remains ad hoc, because on-demand emptying does not generate predictable inflows.

An additional interpretation can be added here. Sanitation infrastructure often sits at the intersection of engineering, municipal administration, procurement, contractor management, environmental regulation, and citizen behavior. When these institutions are not aligned, even technically sound assets can remain idle. Thus, operationalization should be conceptualized as an inter-institutional process rather than as the final stage of construction.

7.3 FSTP versus co-treatment

The portfolio data show a slightly better operational record for FSTPs than for co-treatment plants. This does not mean FSTPs are universally superior. Instead, it suggests that technology choice must be matched to urban context, land availability, spare STP capacity, sludge haulage distance, operator competence, and monitoring capability.

Standalone FSTPs can offer dedicated process control and clearer accountability at the facility boundary. Co-treatment can be highly efficient where STP capacity exists and receiving systems are well designed, but it also requires tighter process management so that septage inputs do not disrupt sewage treatment performance. The right choice is therefore not ideological; it is conditional and planning-specific.

7.4 Scheduled desludging as the missing service layer

One of the strongest policy insights in the dissertation is the need to institutionalize scheduled desludging instead of depending on overflow-based emptying requests. Scheduled systems can improve plant utilization, reduce emergency overflows, support route planning, enable billing integration, and reduce illegal dumping by making desludging a predictable public service.

This point deserves emphasis because treatment plants cannot function well without an upstream service model. In practical terms, an FSTP is only one node in a larger urban service system that includes household containment, licensed vacuum tankers, routing, discharge control, user payment, and grievance redress. Where these elements are absent, treatment assets remain technically available but functionally disconnected.

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8. STANDARDS, REGULATION, AND COMPLIANCE

The dissertation's compliance chapter identifies several regulatory pillars relevant to FSTP implementation. Proper septic tank design is linked to BIS IS 2470 (Part 1), municipal sewerage and treatment design guidance is linked to the CPHEEO manual, discharge norms are linked to general environmental pollutant standards, compost-related issues are linked to the Solid Waste Management Rules, and worker protection is linked to the Manual Scavengers Act and sewer/septic cleaning SOPs.

For a research framing, these references collectively show that fecal sludge management is not a regulatory vacuum. On the contrary, the sector already has multiple normative instruments. The implementation challenge arises because compliance is fragmented across departments and often weakly embedded in contracts, monitoring systems, and field-level routine practices.

A more mature compliance model for ULBs would include the following components derived from the source document and extended here in analytical form:

- Containment compliance audits based on septic tank design norms.
- Approved discharge-point notification and GPS-linked trip verification.
- Plant O&M checklists covering power, screening, grit removal, drying-bed rotation, laboratory protocols, and emergency contacts.
- Worker-safety compliance using PPE, gas detection, ventilation, rescue preparedness, and mechanized cleaning protocols.
- Environmental compliance checks for liquid effluent and stabilized solids before reuse or disposal.

9. OCCUPATIONAL HEALTH AND SAFETY

The source dissertation correctly treats occupational health and safety as a core governance issue rather than an optional annex. Sanitation workers engaged in septic tank and sewer operations face chemical, biological, and confined-space hazards that can be fatal in the absence of mechanization and standard procedures. The document specifically references MoHUA/CPHEEO guidance and related workforce and training material.

In academic and policy terms, this means that FSTP operationalization should be judged partly by labor safety indicators, not just by whether a plant receives sludge. A sanitation system cannot be called successful if it externalizes risk onto workers through unsafe entry, poor equipment, or untrained contractors. This point is especially important when municipalities rely on private desludging operators, because outsourcing can obscure accountability unless licensing and contract clauses explicitly require safety compliance.

The dissertation's readiness checklist offers a practical starting point. An expanded institutional checklist should include mandatory induction training, refresher training, incident reporting, mock rescue drills, documented no-entry protocols except under certified emergency conditions, and periodic third-party safety audits.

10. FINANCING AND INSTITUTIONAL SUSTAINABILITY

The dissertation notes that capital expenditure may be supported by mission grants and state or ULB contributions, but O&M requires predictable recurring revenue. It identifies sanitation taxes, user charges, tipping or discharge fees, and treated-by-product revenues as possible funding sources, while also mentioning PPP or DBOT models and escrow mechanisms to reduce payment delays.

This financial diagnosis is highly relevant. Many sanitation assets underperform not because treatment technology is inappropriate, but because post-construction budgets do not cover staffing, electricity, consumables, repairs, vehicle interfaces, testing, and contract payments. In such situations, the plant gradually shifts from newly completed too nominally functional to intermittently active to effectively idle.

A stronger sector model would combine three financing layers. First, municipalities need a guaranteed basic O&M allocation so that minimum operations are not dependent on uncertain sludge inflow revenue. Second, user-facing sanitation charges or integrated billing should recover part of service costs over time. Third, performance-linked grants should reward verified operationalization, scheduled desludging coverage, safe disposal, and safety compliance rather than only project completion.

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11. IMPLEMENTATION FRAMEWORK FOR UTTAR PRADESH

The dissertation proposes recommendations on operational readiness, scheduled desludging, operator licensing, financing, KPI monitoring, and a 12-month roadmap. Those elements can be synthesized into a staged implementation framework.

Stage 1: Commissioning readiness

Before a plant is declared operational, the ULB should verify staffing, power supply, SOP display, safety equipment, receiving arrangements, sludge flow pathways, and basic testing protocols. A plant should not be classified as functional only because construction is complete.

Stage 2: Demand aggregation

A ward-wise containment inventory should be developed and linked to a scheduled desludging calendar, ideally on a two- to three-year cycle as suggested in the dissertation. Without this, treatment assets may remain underutilized and illegal discharge may continue.

Stage 3: Transport regulation

All desludging vehicles should be licensed, route-tracked, and allowed to discharge only at designated facilities. Digital trip logs and QR- or receipt-based discharge confirmation can improve traceability.

Stage 4: Performance monitoring

The dissertation recommends indicators such as trips per day, KLD received, plant uptime, drying-bed cycles, complaint resolution, and financial recovery. These should be combined into a zone and city dashboard reviewed monthly at the ULB and state levels.

Stage 5: Continuous compliance

OHS, environmental monitoring, and contractor performance should be audited periodically, with corrective-action timelines and financial consequences for non-compliance. This converts sanitation from a one-time engineering activity into a managed public service.

12. Additional analytical contributions beyond the dissertation

To strengthen the manuscript to a higher academic standard, several analytical observations can be added beyond the original dissertation while remaining grounded in its evidence.

First, the dataset suggests that “operational” should be defined more rigorously in future work. A plant may be listed operational while still lacking validated throughput records, quality monitoring data, or stable desludging demand. Future studies should therefore classify plants by verified operational maturity: commissioned, intermittently operating, routinely operating, and performance-compliant.

Second, the current portfolio should be analyzed in relation to urban form and haulage economics. Cities with long haul distances, weak road access, or fragmented service jurisdictions may struggle more even when assets exist. Incorporating GIS travel time, tanker fleet size, and septic tank density would enrich future planning models.

Third, performance assessment should move beyond design capacity to actual utilization and compliance. Capacity of 32 KLD or 50 KLD is useful for planning, but the more important policy question is how much sludge is actually delivered, safely processed, and prevented from entering drains, open land, or water bodies.

Fourth, the portfolio presents an opportunity for comparative governance research. Why does Lucknow Zone report 100 percent operationalization while Kanpur Zone reports 57.1 percent in the same source dataset? Answering that question could reveal transferable administrative practices, procurement approaches, or institutional support mechanisms.

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13. CONCLUSION

The source dissertation demonstrates that AMRUT-supported fecal sludge infrastructure in Uttar Pradesh has reached meaningful scale, with 53 listed projects and about 1731 KLD of total design capacity. It also shows that operationalization remains incomplete, with 14 non-operational projects and about 442 KLD of capacity not yet translated into service. The most important conclusion is therefore not simply that FSTPs matter, but that sanitation missions must be judged by service-chain functionality rather than asset creation alone.

A robust sanitation strategy for Uttar Pradesh requires more than construction. It requires scheduled desludging, licensing and monitoring of private operators, verified commissioning, worker-safety enforcement, environmental compliance, and recurring O&M finance. If these elements are institutionalized, FSTPs and co-treatment plants can become durable components of citywide inclusive sanitation; if they are neglected, even completed assets risk underperformance or idleness.

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