Progressive Circularity

Why Safe Emptying is a Prerequisite for Circular Sanitation in African Cities



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WASTE

WASTE is an international NGO catalysing sustainable solutions to the world's most pressing waste management, sanitation and water challenges, with a focus on low-and middle-income countries.

www.waste.nl

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PRACTICA

Practica is a non-profit technical advisory organisation that aims to strengthen skills and tools in low- and middle-income countries. Practica develops and promotes affordable technologies with a high potential to improve livelihoods. They integrate technical innovations into business models to ensure sustainable water, irrigation and sanitation access.

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1. Introduction

The growing popularity of circular economy approaches has generated considerable optimism within the sector. Across academia, policy, and practice, increasing attention is being directed towards resource recovery, waste valorisation, and the transformation of faecal sludge from an environmental liability into an economic asset. Concepts such as nutrient recovery, biosolids as soil conditioner, co-compost production, biochar, waste-to-energy systems, and circular business models have become central features of contemporary sanitation discourse (Rao et al., 2017; Mallory et al., 2020).

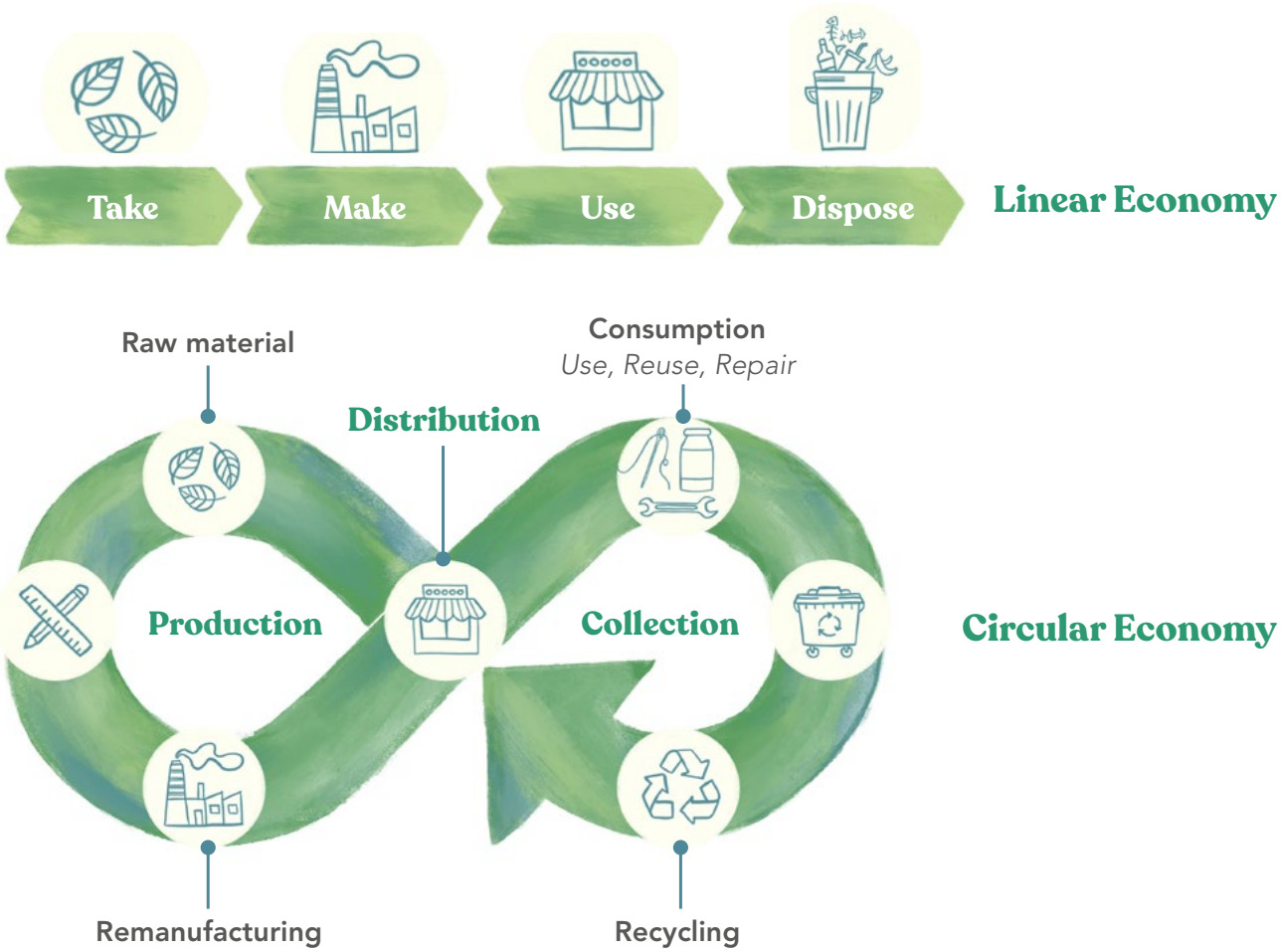
This shift has been both necessary and timely. Conventional linear systems, in which waste is collected and discarded, are increasingly recognised as environmentally unsustainable and economically inefficient. Circular economy approaches seek to minimise waste generation while maximising resource utilisation through reuse, recycling, regeneration, and recovery (Ellen MacArthur Foundation, 2013; Schroeder et al., 2019). Applied to sanitation, these principles have stimulated growing interest in nutrient recycling, resource recovery, and market-based solutions capable of generating value from sanitation waste streams.

Yet the growing emphasis on circular sanitation does not align with the realities of sanitation service delivery in many low- and middle-income countries. While increasing attention is being given to treatment technologies and reuse pathways, many cities continue to struggle with a more fundamental challenge: *ensuring that faecal sludge from latrines can be safely emptied, transported, and managed in the first place.*

In much of Sub-Saharan Africa, sanitation systems remain dominated by onsite technologies such as pit latrines, ventilated improved pit latrines (VIPs), and septic tanks. These systems contain excreta for a period of time, but they inevitably generate a requirement for faecal sludge management (FSM) once containment structures become full. This challenge is becoming increasingly significant in urban locations and when sanitation coverage expands. Over the past two decades, governments, development agencies, and civil society organisations have invested heavily in increasing access to sanitation facilities. These investments have generated substantial gains in toilet coverage and have contributed to progress towards Sustainable Development Goal 6.2. However, every sanitation investment simultaneously creates a future service obligation.

Experience from WASTE's FINISH Mondial (FM) programme in East Africa illustrates this emerging reality. From 2021-2025, 275,000 sanitation systems were facilitated by FM through market-based approaches across Ethiopia, Kenya, Tanzania, and Uganda. While these investments significantly

Linear Economy vs Circular Economy



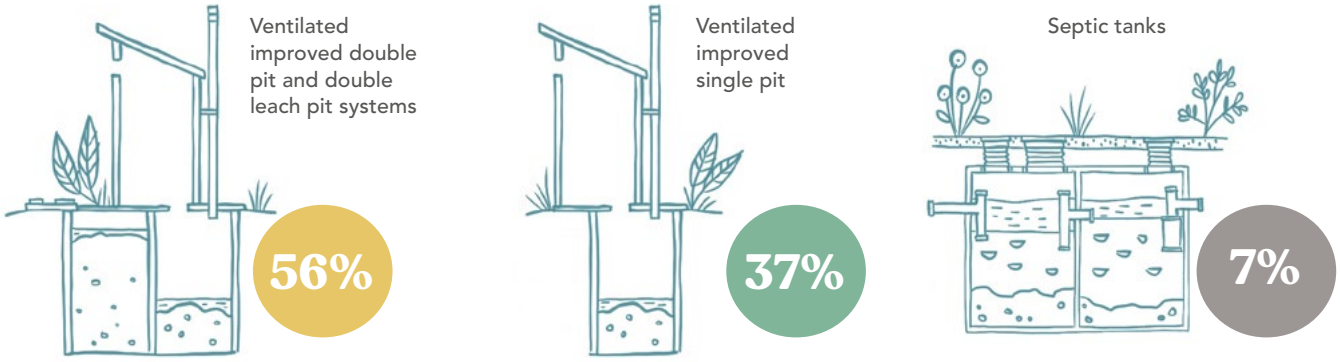
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expanded access to sanitation, they also generated a growing future demand for faecal sludge management services and challenge to fulfil this.

The FM experience in Ethiopia provides a useful illustration of this challenge. Analysis of the sanitation technology portfolio between 2021 and 2025 reveals substantial variation in future faecal sludge management requirements. Approximately 56% of facilities consisted of ventilated improved double pit (VIDP) and double leach pit systems, technologies designed to reduce immediate emptying requirements through alternating pit use and in-situ sludge stabilisation. However, the effectiveness of these systems depends heavily on accurate construction, appropriate sizing, and operation. Where pits are not constructed according to technical specifications, or where households are unable to alternate pit use as intended, desludging may still be required. In addition, approximately 37% of facilities consisted of ventilated improved single pit (VSIP) toilets, which require periodic emptying once storage capacity is exhausted, while a further 7% were septic tank systems requiring desludging interventions, typically within intervals of three to five years. These figures highlight that although sanitation technologies differ in the timing and intensity of service requirements, all generate future demands for FSM. As sanitation coverage expands, so too does the need for systems capable of providing safe emptying, transport, treatment, and disposal services.

In this regard, PRACTICA has been supporting the development and strengthening of FSM service chains in Africa and Asia for more than 15 years. Its

Sanitation Technologies Facilitated by FM in Ethiopia 2021-2025



approach covers the entire sanitation value chain, including containment, emptying, transport, treatment, resource recovery, and reuse. Through active research, technology development and capacity building, PRACTICA supports utilities, municipalities, private service providers, and local entrepreneurs to establish sustainable and inclusive FSM services. Particular attention is given to low-income and underserved areas where conventional sewerage systems are not feasible.

Over the years, PRACTICA has developed and tested a range of technologies, including pumps and tools to empty pit latrines, transport solutions, treatment systems, and resource recovery applications. By combining technical innovation with business development and institutional strengthening, PRACTICA aims to create viable FSM ecosystems that improve public health, protect the environment, and support circular economy objectives.

Although derived from the Ethiopian experience, these findings reflect a broader trend observable across many African cities. As investments in onsite sanitation continue to expand, so too do the future service obligations associated with FSM. The challenge facing cities is therefore not merely one of increasing sanitation access, but of ensuring that the systems required to manage faecal sludge evolve alongside sanitation infrastructure. This broader reality opens up an important question for sanitation policy and practice.

If expanding sanitation access simultaneously generates growing FSM obligations, how can cities transition towards circular sanitation when significant parts of the service chain remain underdeveloped? It is on this basis we argue that achieving circular sanitation outcomes first requires addressing the upstream bottlenecks that constrain FSM systems.

To address this gap, we explore the concept of *progressive circularity*.

For this article, we refer to progressive circularity as a phased sanitation transition in which improvements in containment, emptying, transport, and safe disposal create the enabling conditions necessary for future resource recovery and circular economy outcomes.

Rather than viewing circularity as a destination achieved through treatment and reuse alone, progressive circularity recognises that circular sanitation depends on the existence of functioning service chains capable of moving faecal sludge safely through the system, so it can become feedstock for circularity.

While circular economy approaches frequently focus on treatment and reuse, the stages of emptying and transport remain among the weakest links in urban sanitation systems. Pit emptying plays a critical role in enabling circular sanitation systems by connecting on-site sanitation facilities to resource recovery and reuse pathways. In many low-income and densely populated areas, pit latrines are abandoned when they become full, leading to the construction of new pits and the inefficient use of existing infrastructure.

Safe and affordable pit emptying services extend the lifespan of sanitation assets, reducing the need for new construction and associated costs. Pit emptying prevents the uncontrolled discharge of faecal sludge into the environment, reducing public health and environmental risks. By capturing and transporting sludge, these services transform waste into a managed resource stream that can be treated and converted into valuable products. In addition, pit emptying supports local entrepreneurship, creates employment opportunities, and enables the participation of underserved communities in the circular economy. As such, it represents a fundamental link between sanitation service delivery and sustainable resource recovery.

Drawing on implementation experiences from Ethiopia, Kenya, and Tanzania, as well as lessons from the use of context-appropriate emptying technologies such as the PuPu Pump, we argue that safe emptying should not merely be recognised as a technical requirement but as a critical step towards circular sanitation. Rather than waiting for ideal circular systems to emerge, sanitation practitioners, utilities, municipalities, and development partners should prioritise interventions that strengthen existing service chains while laying the foundations for future circularity.



Lessons from the use of context-appropriate emptying technologies such as the PuPu Pump show that safe emptying should merely be recognised as a technical requirement but as a critical step towards circular sanitation.

2.
From Circular Economy to Circular Sanitation

The concept of the circular economy has gained considerable traction across multiple sectors as governments and institutions seek alternatives to linear models of production and consumption. Within sanitation policy and research, this shift represents a broader transition from infrastructure-centred approaches towards resource-oriented service systems.

Historically, sanitation interventions focused primarily on the safe containment and disposal of human waste. Circular sanitation expands this perspective by recognising human excreta as a potential source of nutrients, organic matter, water, and energy that can be recovered and reintegrated into productive systems (Andriessen et al., 2019).

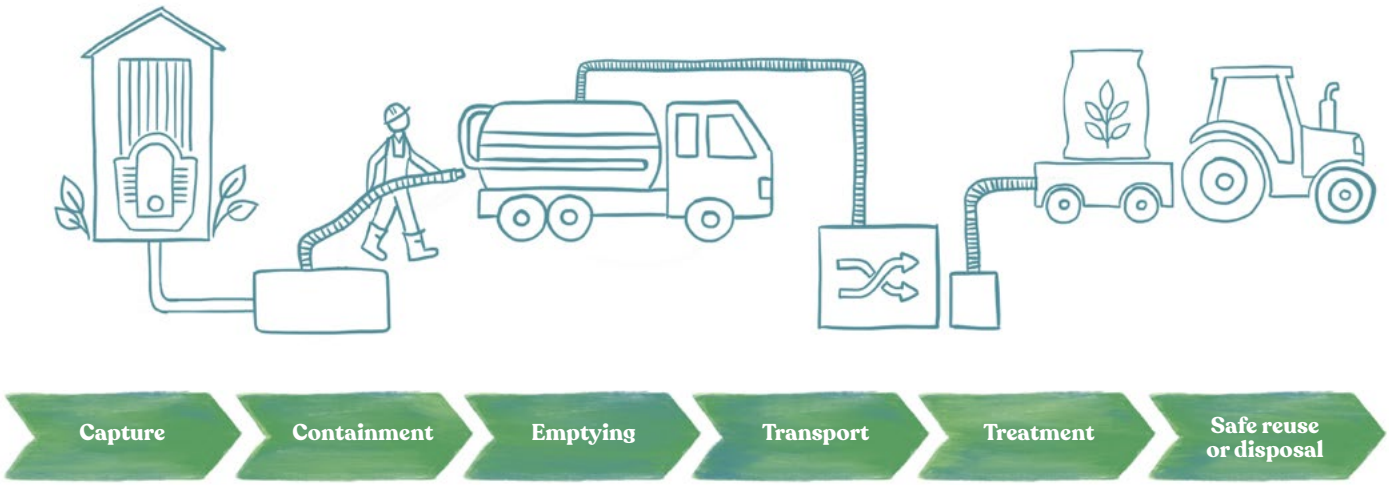
The appeal of circular sanitation is clear. Human waste contains significant quantities of nitrogen, phosphorus, potassium, and organic matter. When appropriately treated, these resources can be transformed into agricultural inputs, soil conditioners, biofuels, and other products capable of generating economic value while reducing environmental impacts. In theory, circular sanitation simultaneously addresses waste management challenges, resource scarcity, climate mitigation objectives, and the chronic financing constraints that have historically characterised sanitation service delivery (Mallory et al., 2020; Nicholas et al., 2023).

The growing focus on resource recovery has generated important innovations and challenged long-standing assumptions that sanitation should be viewed solely as a public service rather than a productive sector. However, it also raises an important question: *at what point does circularity begin and what design choices need to be incorporated in the whole faecal sludge management chain to cater for circularity?*

Much of the current discourse implicitly situates circularity at the treatment and reuse stages of the sanitation chain. Treatment facilities, composting systems, biochar production, nutrient recovery technologies, and waste-to-energy systems frequently dominate discussions of circular sanitation. While these interventions are important, they often assume that faecal sludge can be reliably collected and transported to treatment facilities. This assumption does not always hold true. In reality sanitation systems operate as interconnected chains in which each stage depends upon the successful functioning of the preceding stage (the FSM service chain framework).

The existing FSM literature consistently argues that sanitation outcomes depend on the performance of the entire sanitation service chain, including containment, emptying, transport, treatment, and final disposal or reuse (Strande et al., 2014; Peal et al., 2014). Failure at

Sanitation Value Chain



any stage compromises the effectiveness of the entire system and can result in significant environmental and public health risks or simply reduced circularity output. Circularity therefore depends not merely on technological innovation at the treatment stage but on the existence of robust service delivery mechanisms throughout the chain to assure valorised products match the economic framework of market demand, prices, volumes and interest. This implies that not every situation has the ideal set-up to for circularity or cost-benefit pathway available.

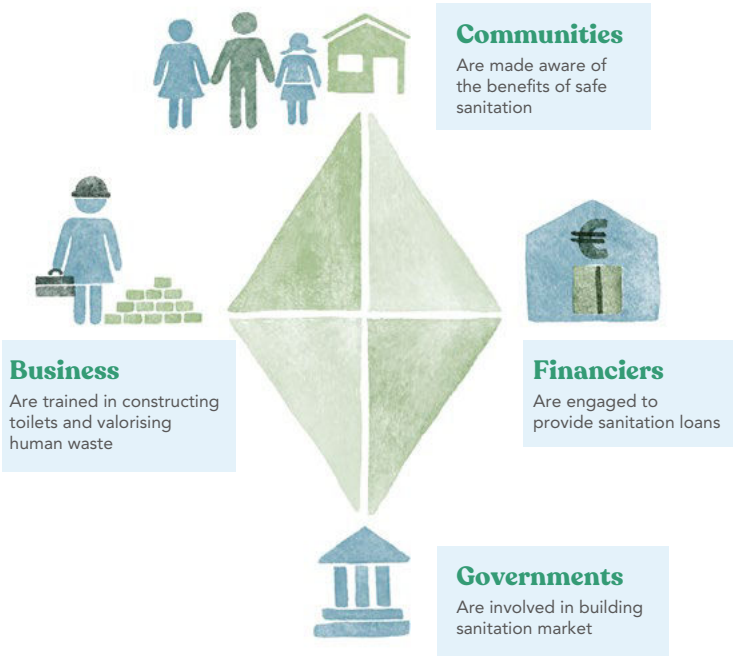
Despite the potential benefits of resource recovery from faecal sludge, social acceptance remains a significant challenge in many contexts. Recovered products derived from human waste are often perceived as unsafe or undesirable due to their human origin, even when treatment processes effectively eliminate health risks. This phenomenon can limit market uptake and investment in circular sanitation solutions. However, perceptions vary considerably across regions and cultures. In many agricultural communities, the application of human excreta, urine, or treated biosolids to land have a long history and are widely accepted as valuable sources of nutrients and organic matter. These contrasting perspectives highlight the importance of understanding local cultural norms, risk perceptions, market characteristics and alternative products as well as end-user preferences when designing resource recovery and reuse interventions

While excreta may be successfully captured through onsite sanitation systems, only a fraction ultimately reaches treatment facilities through safe and regulated service chains (Peal et al., 2014; Semiyaga et al., 2015). Physical accessibility constraints, affordability barriers, inadequate transport infrastructure, absence of services, weak regulation, and limited treatment capacity frequently undermine the movement of faecal sludge through the sanitation chain. As a result, many sanitation systems remain trapped between successful containment and unrealised circularity. It is this missing middle that frequently determines whether sanitation systems function in practice and whether circular economy ambitions can ultimately be realised.

Building on the sanitation service chain framework, we argue that the stages of emptying, transport, and safe disposal constitute a critical yet underexamined component of circular sanitation transitions. Resource recovery cannot occur if faecal sludge never reaches a treatment facility. Consequently, the ability to safely empty, transport and dispose of faecal sludge should be recognised not merely as a technical prerequisite, but as an integral component of circular sanitation itself. The following section examines how this missing link manifests itself across African cities and why strengthening these upstream stages of the sanitation service chain is essential for achieving both immediate public health outcomes and longer-term circular economy ambitions.

3.
The Missing Link in African Sanitation Systems

A less visible consequence of expanding sanitation access is the growing demand for faecal sludge management services that emerges as sanitation infrastructure matures and as cities rapidly expand due to urbanisation. While sanitation programmes are frequently assessed through indicators such as toilet construction and access rates, considerably less attention is paid to the service requirements that arise once containment systems begin to fill.



The experience of the FM programme illustrates this challenge. Across multiple African countries, FM has supported sanitation market development through the use of WASTE's multi-stakeholder Diamond Model, fostering partnerships between households, financial institutions, sanitation enterprises, local governments, and utilities.

This reflects a broader reality across many African cities: investments in sanitation infrastructure inevitably create future requirements for emptying, transport, treatment, and disposal. The implication of this is significant. Expanding access to sanitation without strengthening FSM systems, risks shifting sanitation challenges further downstream rather than resolving them. In this logic, sanitation access and FSM should not be viewed as separate interventions but as interconnected components of a single urban sanitation system. Yet, despite growing recognition of the importance of FSM many cities continue to struggle to move faecal sludge safely through the sanitation chain. This raises an important question: *if sanitation access has expanded considerably in recent decades, why do the service chains required to manage faecal sludge continue to break down?*

3.1 Why the Service Chain Breaks

Experience from WASTE and PRACTICA suggests that four interconnected challenges frequently constrain service delivery: accessibility, affordability, institutional fragmentation, and disposal infrastructure.

Accessibility Constraints

One of the most persistent barriers concerns physical access to containment facilities. Conventional vacuum trucks remain the dominant emptying technology in many urban areas, yet they are often unable to reach large sections of the population. Dense informal settlements, narrow alleys, unplanned urban expansion, steep terrain, and poor road infrastructure frequently prevent vacuum trucks from accessing pits and septic tanks and thus requiring alternative emptying solutions such as portable semi-mechanized systems, small and mobile transportation options and manual emptying using buckets and tools.

Evidence from Adama, Ethiopia, highlights the significance of this challenge. Service providers reported that many containment structures were located beyond the reach of conventional vacuum trucks, requiring labour-intensive alternatives or resulting in delayed emptying altogether. Similar challenges have been observed in informal settlements across Kenya and Tanzania, where settlement density constrains the use of large, mechanised equipment. Under such conditions, physical accessibility becomes a major determinant of whether faecal sludge can enter the sanitation service chain at all.

Typology Constraints

Pit emptying remains one of the most challenging components of faecal sludge management due to the highly variable and complex nature of pit contents. Unlike sewered wastewater, faecal sludge stored in pit latrines often contains a mixture of faeces, urine, solid waste, soil, sand, stones, and household refuse. In many settings, pits are used for the disposal of a wide range of non-faecal materials, including plastics, textiles, sanitary products, diapers, and other solid waste. Over time, these materials accumulate and can form dense, heterogeneous sludge with high solids concentrations. Pit latrines are generally not served by vacuum trucks for these typology constraints. The physical characteristics of pit contents can vary significantly between locations and even between neighbouring pits. Sludge may range from liquid and easily pumpable to highly consolidated, requiring mechanical agitation or manual excavation. The presence of trash and fibrous materials frequently causes blockages, increases equipment wear, and reduces the effectiveness of conventional vacuum-based emptying technologies. These technical and operational challenges contribute to high service costs, limited-service coverage, and continued reliance on unsafe manual emptying practices in many low-income urban areas.



Pupu Pump being operated by sanitation workers, demonstrating its ability to navigate narrow pathways and overcome accessibility constraints.

Affordability Constraints

Even where services are physically available, affordability frequently limits uptake. Households often postpone emptying until pits become completely full, increasing the likelihood of overflow, environmental contamination, and unsafe disposal practices. In some cases, households request partial emptying to reduce costs, limiting the effectiveness of desludging operations and increasing the likelihood of repeated service requirements.

For service providers, irregular demand creates additional challenges. Low and unpredictable service volumes undermine business viability, reduce incentives for investment, and limit the development of sustainable faecal sludge management enterprises. As a result, many cities struggle to develop markets capable of delivering regular and affordable desludging services.

Institutional Constraints

The governance of FSM remains fragmented in many urban contexts. Responsibilities for sanitation infrastructure, desludging services, transport, treatment facilities, and environmental regulation are often distributed across multiple authoritative bodies with overlapping or poorly defined mandates. This fragmentation creates uncertainty for both households and service providers and can undermine accountability across the sanitation chain. Experience from Kenya suggests that stronger utility involvement can improve coordination and strengthen service delivery. In Nakuru, utility participation has helped create clearer pathways for sludge transport and disposal while improving oversight of faecal sludge management activities. In Lusaka, Zambia, over 5,500 LSP toilets (Lusaka Sanitation Program) have been constructed by the water and sanitation company to enable the ease of mechanised emptying (external access) and build lined pits to reduce percolation to the groundwater. In addition, manual emptying teams have been formalised and certified as service layer to empty latrines of households. They service a critical layer of pits that cannot be emptied mechanically. However, such institutional arrangements remain uneven across cities and countries.

Disposal Constraints

The final disposal of collected sludge remains one of the most significant yet least visible challenges facing FSM systems. Emptying services can only generate environmental and public health benefits if operators have access to authorised disposal or treatment facilities. Yet, in many cities, treatment infrastructure remains limited, disposal sites are located far from urban centres, and regulatory enforcement is weak. Under these conditions, service providers may face strong incentives to dispose of sludge informally. The absence of viable disposal pathways therefore undermines the effectiveness of upstream investments in emptying and transport services.



Through FM, local teams in Tanzania have been trained how to safely dispose of faecal sludge at treatment plants like this one. Many cities lack access to these kinds of facilities.

3.2 Context-Appropriate Technologies and the Missing Link

The persistence of these bottlenecks has stimulated growing interest in technologies specifically designed to address the operational realities of FSM in dense urban environments. One example is the PuPu Pump, developed by PRACTICA as a portable emptying technology capable of operating in contexts where conventional vacuum trucks face significant accessibility and pumping constraints.



The PuPu Pump (pictured) is a portable emptying technology capable of operating in contexts where conventional vacuum trucks face significant accessibility and pumping constraints.

The PuPu Pump was developed in response to a challenge commonly encountered across African cities: the gap between hazardous manual emptying practices and large-scale mechanised solutions. Using a Pull - Push mechanism based on suction and compression of air, flexible duckbill valves and water/air injection tools to mix the sludge prior to emptying, the technology enables sludge to be removed from pits located in narrow alleys and densely populated settlements. It does not rely on an expensive and large vacuum tank but directly pumps from the pit to any type of storage over long distance, e.g a simple plastic water on a transport vehicle positioned at accessible locations. By linking emptying and transport functions, the technology helps address one of the most critical bottlenecks within the sanitation chain.

Importantly, the significance of such technologies extends beyond their technical characteristics. Their value lies in their ability to strengthen upstream service delivery functions that are frequently overlooked within circular sanitation debates. Experiences from Ethiopia, Kenya, and Tanzania suggest that context-appropriate technologies can improve accessibility, reduce occupational health risks, increase service provider productivity, and create opportunities for more professionalised faecal sludge management services.

3.3 The Missing Link

Taken together, these challenges reveal what this paper describes as the 'missing link'. Considerable attention has been devoted to increasing toilet coverage on one hand and promoting resource recovery on the other. Yet the intermediate stages of emptying, transport, and safe disposal often receive comparatively little attention despite determining whether sanitation systems function in practice.

This imbalance has important implications for circular sanitation ambitions. Resource recovery depends upon the reliable movement of faecal sludge through the sanitation chain. If sludge is not collected (co)-compost production is not possible and if sludge is not treated properly Biochar cannot be generated. Circular economy outcomes therefore depend fundamentally on the effectiveness of upstream service delivery functions.

The challenge facing many African cities is therefore not simply how to recover value from faecal sludge, but also how to ensure that sludge can move safely through the sanitation system in the first place. Recognising and addressing this gap is a prerequisite for achieving both immediate public health benefits and longer-term circular sanitation outcomes.

4.
Conclusion: Reframing Circular Sanitation: Towards Progressive Circularity

The experiences discussed in this paper raise a broader question about how circular sanitation transitions are conceptualised and implemented in rapidly urbanising contexts. While circular economy principles have generated considerable enthusiasm within the sanitation sector, the evidence from Ethiopia, Kenya, and Tanzania suggests that achieving circularity is often less a question of technological innovation than of service delivery capacity.

While these interventions are important, they often assume the existence of systems capable of moving faecal sludge safely from containment structures to treatment facilities. The experiences presented in this paper suggest that this assumption cannot be taken for granted.

In many cases, faecal sludge struggled to enter the sanitation chain at all. Under such circumstances, discussions of nutrient recovery or circular business models risk becoming disconnected from the realities of urban sanitation service delivery.

This observation does not imply that circular sanitation ambitions are misplaced. On the contrary, the environmental, economic, and social benefits associated with resource recovery remain highly relevant, particularly in regions facing increasing resource pressures and rapid urban growth. However, it does suggest that circularity should be understood as the outcome of a functioning sanitation system rather than as an intervention applied at the treatment stage.

The idea of progressive circularity proposed in this article offers an alternative way of understanding sanitation transitions in contexts where service delivery systems remain under development. **Rather than treating circularity as a destination achieved through treatment and reuse alone, progressive circularity recognises that circular outcomes emerge through improvements across the sanitation chain.** Containment, emptying, transport, treatment, and reuse are not separate objectives but interconnected stages of a broader transformation process. Strengthening any one of these stages contributes to the effectiveness of those that follow.

From this perspective, safe emptying should not be viewed merely as a technical prerequisite for circular sanitation. It should be recognised as a circular sanitation intervention in its own right. By reducing environmental contamination, protecting public health, improving occupational safety, and ensuring that faecal sludge enters formal management pathways, safe emptying creates value, long before resource recovery takes place.

Progressive circularity is not limited to pit emptying alone. Alternative service delivery models, such as container-based sanitation, also illustrate this principle. In dense informal settlements or areas where conventional toilets are technically, spatially, or financially unfeasible, container-based sanitation provides safe containment through regular collection services that transport excreta into formal treatment and resource recovery pathways. Although the technologies differ, both approaches share the same objective: ensuring that human waste enters a safe, managed service chain capable of supporting future circular economy outcomes.

The experience of PuPu Pump provides a useful example. The technology was developed in response to a specific service delivery challenge. By enabling safe emptying in locations where mechanised services face operational constraints, the technology helps strengthen a critical link within the sanitation chain. Yet its effectiveness ultimately depends on the existence of entrepreneurs capable of providing services, financing mechanisms that support enterprise development, utilities and municipalities that facilitate disposal pathways, and treatment infrastructure capable of receiving collected sludge. The lesson is therefore not simply that appropriate technologies matter, but that technologies generate impact when they strengthen broader sanitation systems.

For policymakers and development practitioners, this has important implications. Investments in emptying and transport services should not be viewed as secondary to circular economy ambitions or treated merely as transitional measures until more advanced resource recovery systems emerge. Rather, they should be recognised as foundational investments that create the conditions necessary for future circularity.

Ultimately, the challenge is not whether circular sanitation is desirable. The challenge is how circularity can be achieved in contexts where sanitation systems remain incomplete. Progressive circularity offers one possible answer by recognising that circular sanitation does not begin with resource recovery. It begins with the uptake of safe sanitation, appropriate system design, and the establishment of reliable collection and treatment services that ensure faecal sludge remains within a safely managed service chain.

To hear more on this topic from experts across sectors, catch up with our recent webinar on: Rethinking Sanitation through Circularity in Africa

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