R4D PROJECT:

CHALLENGES OF MUNICIPAL WASTE MANAGEMENT: LEARNING FROM POST-CRISIS INITIATIVES IN SOUTH ASIA

PROJECT WORKING PAPER #11

INTRODUCING CIRCULARITY IN DECENTRALI-ZED SOLID WASTE MANAGEMENT

LESSONS FOR SCALING-UP TECHNOLOGY OPTIONS FROM ALAPPUZHA, KERALA

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Abstract

This paper examines Alappuzha's ongoing effort to shift to a decentralized solid waste management regime. Recounting the solid waste crisis that came to a head in 2012, the paper traces the evolution of the town's decentralised solid waste management practices to glean the key lessons and the considerable challenges that remain in adopting an alternative service management regime. Specifically, the paper reflects on the challenges to scaling up available technology options for integrating circularity and livelihoods in solid waste management. Alappuzha's experience with decentralised solid waste management indicates that the social dimension in innovation (ensuring buy-in from the local community) is no less significant than the innovation in the technological realm. In fact, the Alappuzha case shows that a relatively rudimentary set of technologies can lead to quantum jump in efficiency of the waste management regime when the local community plays a proactive role in the functioning of the system. The Alappuzha experience indicates that decentralised SWM requires continuous engagement with the end-users and is not easily amenable to top-down technocratic solutions. It was observed that community participation in technology selection led to better buy-in with the end-users conscientious of operations and maintenance requirement.

Key Words: Decentralised Solid Waste Management, Technology Adoption, Circular Economy, Social Innovation, Kerala

1 Introduction

Our dominant collective cultural attitude to waste, during the turn of this century, has seen it as undesired and unusable material which by dint of its worthlessness requires disposal. As the world population grew, so did the amount of waste. In general, as human societies got more automated and industrialised, more waste got produced. However, confronted with multiple crises of climate change, biodiversity loss, increased pollution and economic stagnation, the idea of waste is currently undergoing a fundamental transformation. We have collectively started recognizing the necessity of a circular rather than a linear paradigm in dealing with the overall production and consumption cycle. This phenomenon is not limited to any particular part of the global economic system. Both the developed as well as the emerging economies are confronted with the challenge of shifting to a more sustainable waste management regime.

India's rapid economic growth over the last three decades has brought the issue of Solid Waste Management to the forefront of urban governance. India's population has grown to 1403 million in 2022, from 1252 million in 2013 (Sunil Kumar et. al., 2017). Urban local bodies (ULBs) across India, tasked with managing solid waste, are wilting under pressure faced by the enormity of the challenge facing them. Addressing long term sustainable solid waste management rests on introducing changes - subtly and creatively - to the existing practices. However, the rapidity of the production and consumption cycle leaves decision-makers no time to breathe.

India's conventional solid waste management systems, essentially centralised collection and disposal systems have become giant dump yards polluting the atmosphere and groundwater in its vicinity. The under planned, in most cases unplanned, character of these facilities is only part of the problem. Centralised approaches to waste management have been essentially technocratic exercises that have failed to incorporate the views of multiple stakeholders in the decision-making process. These include waste generators (individual citizens and business establishments), civil society organisations and local governments. The failure of centralised approaches to integrate livelihoods in solid waste management undermines not only the economic dimension of the service provision, but also the overall acceptability of the enterprise in the community. The widespread reluctance to shift to non-centralised waste management strategies has exacerbated the situation across the country.

The Solid Waste Management scenario in Kerala is no different from the rest of India. However, Kerala is an exception in that solid waste dump yards have become a major political issue in the state due to concerted protests by affected communities. Kerala's successful implementation of decentralisation reforms not only strengthened the administrative and financial bases of local governments in the state, it has also resulted in increasingly assertive panchayats, protecting their turf against corporations and municipalities (Ramachandran 1997; Drèze and Sen 1991; Tharamangalam 2010). The state has witnessed local communities (primarily suburban communities living in the peripheries of major towns) across the state protest against indiscriminate dumping of solid waste within their community polluting groundwater resources, obliterating the sanctity of the local environment consequently debilitating public health and the local economy. The history of such protests in Kerala goes back to 1988 when residents of Laloor objected to becoming the dump yards for the waste generated by Thrissur. The issue, which has remained a major issue for peri-urban communities across the state for more than two decades, shot into the state's public consciousness with the protests in Vilappilsala in the 2000s. Almost all the major urban centres protested against dumping of solid waste in their area after the confrontation between the local and state government in Vilappilsala (Krishnakumar R 2012; John 2016, 2018; Ganesan 2017).

Alappuzha's effort to decentralise solid waste management began in 2012 on the back of protracted protests by a small village community that bore the brunt of pollution (and its negative externalities) from the town's solid waste. This paper documents and evaluates the 'technology adoption' dimension in the ongoing shift to a decentralized solid waste management in Alappuzha. Recounting the solid waste crisis that came to a head in 2012, the paper traces the evolution of the town's solid waste management practices to glean the key lessons and the considerable challenges that remain in adopting an alternative service management regime. Specifically, the paper reflects on the challenges to scaling up of available technology options for integrating circularity in solid waste management. The role of technological innovation (as well as improvisation of available technology options) and the appropriateness of deploying specific technologies at the household and the community levels is also explored in this paper. Alappuzha's experience with decentralised solid waste management indicates that the social dimension in innovation (ensuring buy-in from the local community) is no less significant than the innovation of new technology options. In fact, the Alappuzha case shows that a relatively rudimentary set of technologies can lead to quantum jump in efficiency of the waste management regime when the local community plays a proactive role in the functioning of the system.

The structure of the paper is as follows: The following section provides a detailed description of Alappuzha's solid waste management problem by tracing the town's approach over the last two decades. The section, after a brief account of the protests in the face of worsening local environmental conditions, subsequently describes Alappuzha's adoption of a decentralised solid waste management regime in which citizens were equal stakeholders in the process. The following section delineates the methodology of this paper. Subsequently, the paper delves into Alappuzha's experience with decentralised solid waste management technologies – their current operational status, challenges to efficient functioning, and user perceptions on various technologies. Based on these findings, the paper discusses challenges to scaling up existing technology options and provides a peek into the thinking of municipal officials in their decision to scale-up rudimentary solid waste management technologies at the household level along with the promotion of technologically more sophisticated options like biogas plants and aerobic bins. The paper finally concludes by reflecting on the key lessons from Alappuzha for successfully evolving a decentralised solid waste management regime.

2 Background: Alappuzha’s Solid Waste Problem

Alappuzha’s solid waste used to be dumped in the Central Dumping Yard at Sarvodayapuram, a nearby village. This land, of about 20 acres, used to be the night soil dumping yard of Alappuzha town decades ago. In trenches, night soil, other solid wastes, and cadavers from the town were buried. Over time, it came to be settled by poor individuals who have been having problems with it as early as 1950. As the population in and around the landfill site increased, the issues related to waste dumping became a prominent socio-political issue (T. M. Thomas Isaac and M. Gopakumar, 2014). Discussions on a modern waste treatment plant in Alappuzha were in full swing during the period 2004-2005 and as a result of this the local government set up a windrow composting plant in 2005 with the support of the state government. The Municipality signed an agreement with Andhra Pradesh Technology Promotion and Development Centre (APTPDC) to set up a solid waste treatment plant. The plant could turn 50 tonnes of wet waste produced into compost on a daily basis. The project cost was Rs.3.77 crores. Contingent workers of the municipality collected wastes from the streets and carried them to the treatment site. With segregation essential for effective functioning of the waste processing plant, Kudumbashree volunteers (Women’s Self-Help Group) were employed in door to door waste collection. However, segregation did not take place. Unsorted waste was collected from households, shops, hotels, and markets by the units. The mixed waste reaching the plant reduced the operational efficiency of the plant. The treatment plant could not treat the desired quantity of waste, and it processed only 5-10 tonnes of waste daily. Rejects from the plant were land filled using a trenching method. Soon trenching became obsolete due to the increased amount of plastic in the municipal waste stream.

Waste continued to pile up in the landfill site which led to sporadic protests. However, the issue came to a tipping point in 2012 when a hundred-day long strike was called by the nearby residents with protests, hunger strikes and blockade of the road leading to the compost plant (Ganesan, 2017). Local residents stopped garbage trucks from the city with around 5000 protestors formed a human chain for many days thereby stopping the transportation of municipal solid waste which in turn led to the streets getting piled up with waste. After negotiations, they agreed to reopen the yard on the condition that municipal solid waste to be dumped at Sarvodayapuram should be brought down from 50 tons per day to 5 tons per day (Fig 1). However, the Mararikulam south panchayat withdrew the permission to transport waste to Sarvodayapuram in 2014 completely which forced Alappuzha administration to bury collected waste in open spaces in town for some time. Soon land available in town for disposing of solid waste was exhausted, resulting in waste accumulation in the streets, canals, and backwaters. Visitors to the town of Alappuzha would have been met by heaps of garbage and plastic debris at every other intersection with an eyesore with people unscrupulously throwing trash everywhere, on the road sides, along the canal banks and even in public places. Consequently, the unsanitary surroundings threatened its reputation as a tourist destination. The putrid stench coming from the piles of filth had made it practically impossible for people to take a stroll on public roads and along the town's canals. Vector-borne diseases like Chikungunya and Dengue became regular. Factors like people's protest, public health issues, and cancellation of the ‘No Objection Certificate’ (NOC) to transporting waste to Sarvodayapuram by the Gram Panchayat, forced the urban local government to look for alternative waste management strategies (Ganesan, 2017).

Figure 1. Waste heaped in the Central Dumping Yard at Sarvodayapuram
(Source: Mediaone TV Live, Protest over Sarvodaya Puram waste treatment issue)

2.1 Nirmala Bhavanam Nirmala Nagaram (NBNN)

Alappuzha adopted a decentralised solid waste management regime as the town's waste management system had crumbled following the closure of Sarvodayapuram garbage dumping site. A rapprochement was facilitated between Alappuzha and Mararikulam panchayat (affected by the dump yard in Sarvodayapuram) paving the way for Alappuzha's decentralised solid waste management experiment (Paul 2019)[1]. The deadlock was broken with the promise that the windrow composting plant (at Sarvodayapuram) would be phased out. Alappuzha's shift to a decentralised paradigm was

The Alappuzha municipality launched "*Nirmala Bhavanam Nirmala Nagaram*" (translated as Clean Home Clean City) campaign in August 2012 in a single ward on pilot basis[2]. It was subsequently expanded, covering the entire town in November 2012, with the slogan "*Ente malinyam ente utharavadithwam*" (my waste is my responsibility). The campaign, as a first-level intervention, decided to install waste conversion systems for treating biodegradable waste at the household level. These systems included technologies that would convert biodegradable waste into compost and/or biogas. The rationale for installing waste conversion systems at the household level was twofold: first was to understand the challenges to adoption and efficient functioning of specific technologies; second was to demonstrate the success of these systems that would enable the widespread adoption of these systems across the town.

[1] The local unit of Communist Party of India (Marxist) (CPI(M)) initiated the compromise between Alappuzha town and Mararikulam panchayat. Dr.Thomas Isaac, then Finance Minister, played a key role in the process. The fact that Alappuzha and Mararikulam were held by CPI(M) helped in the compromise.

[2] It was launched in Kidangamparambu ward, predominantly consisting of middle-class dwellings.

3 Methodology

This working paper has evolved out of our experience (Indian Institute of Technology Bombay, more specifically, Prof. N C Narayanan and his research team) as academic practitioners in Alappuzha from 2017, under the CANALPY banner[3]. To aid the local government in introducing circularity in solid waste management, CANALPY supported an assessment exercise taken up by Alappuzha municipality to ascertain the progress of the *Nirmala Bhavanam Nirmala Nagaram* campaign that was started in 2012. In the detailed socio-economic household survey, user-perceptions on the three decentralised solid waste management technology options from select wards were gathered. Additionally, a technical assessment of the technologies was carried out to ascertain their physical status, functioning efficacy and other operational challenges[4]. These were complemented by key informant interviews (municipal officials, state pollution control board officials, and elected representatives). These field investigations were intended to provide a realistic assessment of challenges – from a technological innovation and scaling up perspective - that lay ahead for the Alappuzha municipality in realising an effective decentralised solid waste management regime.

To assess the shortcomings in decentralised technology options, the data collection was carried out in four stages. To begin with, the most accessible way to understand Alappuzha's decentralised solid waste management experiment was understand the view of the municipality and the council that lead the activities of various technologies in use. As part of this, the first meeting was with the chairperson of the standing committee on health of the municipality, which is responsible for maintenance of the infrastructure. Interviews were subsequently conducted with Health Officers, Health Inspectors and Junior Health Inspectors in charge of each circle, responsible for fulfilling the responsibilities of the municipality. Junior Health Inspectors are responsible for the main work of the units, supervision of each circle and giving necessary instructions to the workers.

From the information obtained from the interviews, a detailed assessment of various technologies was carried out through a combination of user/beneficiary survey and a physical inspection of the technologies. For biogas plants, Integrated Rural Technology Center (the agency that installed them in the town) provided information on the location, type, and date of installation of the technology. Based on this information, a user survey was conducted by CANALPY and Haritha Karma Sena. The survey covered all the biogas plants installed in 10 wards, which were selected through a purposive sampling strategy to ensure most comprehensive geographic coverage of the town. The survey collected information on the working condition, problems, issues raised, challenges, usage

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[3] The engagement with the town came to be formalised under the CANALPY banner. Formally, CANALPY is a collaborative initiative through an MoU between the Centre for Policy Studies, Indian Institute of Technology Bombay (IIT Bombay) and the Kerala Institute of Local Administration (KILA). It began with a study (aimed to eventually address) Alappuzha's liquid waste management issues in 2017. CANALPY's philosophy has been to demonstrate the strength of collaboration between students/academic institutions, local/State governments, and citizens. It strived to capacitate students to analyse concrete problems on the ground working with local people, elected representatives and civil society organisations. There is a dearth of capacity in local governance institutions, especially technical capacity and information needed to undertake interventions that are inclusive and sustainable. To this end, we have already developed protocols and conducted bigger activities to train engineering and other students (such as summer and winter schools) as well as more local activities for the SWM efforts in Alappuzha. The winter and summer schools carried out an assessment of Alappuzha's solid and liquid waste management practices. In addition to college students from across the country, local students also participated in the situational assessment exercises. A Winter School during November 2017 involving 36 students; a Summer School during May 2018 with 300+ students from multiple disciplines all over India and finally a winter school with 85 students were conducted to arrive at a town-wide analysis of integrated waste management through evolving contextual solutions.

[4] Preliminary Water and Sanitation Assessment for Alappuzha Town, November 2017(Working Paper 1); Preliminary Water and Sanitation Assessment for Alappuzha Town, May 2018 (Working Paper 2); Town Level Assessment of major polluters and pollutants in Alappuzha Town, November 2018 (Working Paper 3)

and life span of the plant and total cost of maintenance. A similar approach was followed for understanding the issues associated with pipe compost in the town.

For aerobic bins, the first and largest aerobic units in the city were identified. As part of that, a unit visit was conducted to understand the basics of how an aerobic unit works. The first part of the study was carried out at Watsan Park (the first aerobic unit at Alissery and the largest aerobic unit under the municipality and the one most household depend on in the city). Data such as location of aerobic units and number of bins were obtained from interviews conducted in the first phase. Based on this information, a survey was conducted to understand the following information about aerobic units in the city; Capacity of aerobic units to treat organic waste currently generated in the city; Number of households depending on each unit; Operational status the facility.

Data collection of bins was done using an open software application called ODK Collect. For this kind of information collection, the health department authorities of the municipality prepared the necessary transport facilities for the survey which allowed junior health inspectors to participate in the process. The survey was conducted from 7 am to 10 am taking into account the working hours of the units and the transport facility of the municipal vehicle. The survey included questions such as operating hours of aerobic bins, number of bins, which are functional and non-functional, how many household wastes reach the bins in a day, time taken to fill a bin, and whether the available inoculum is used for more than three months. The survey covered all the aerobic bins installed in Alappuzha.

4 Innovation for Circularity: Alappuzha's Experience

The "Nirmala Bhavanam Nirmala Nagaram" campaign resulted in the creation of physical infrastructure required for decentralised solid waste management in Alappuzha. While the campaign did not cover the entire town, it succeeded in initiating the shift to an alternative waste management regime. More crucially, solid waste management emerged as a key issue in the local public discourse through the campaign which saw enthusiastic participation from Kudumbasree and various state institutions. This section details the trajectory of the campaign as it made its way through the process of adopting available solid waste management technologies. The multi-dimensional challenges – economic, technical and social – faced in Alappuzha in the institution of the technologies bring out certain general lessons for Indian towns for switching to decentralised solid waste management.

4.1 Initial Intervention: Household-level Biogas Plants and Pipe Compost

In the bid to usher in decentralised solid waste management, Alappuzha began with installing household biogas plants. While the experience with biogas plants - in dealing with household wet waste in India – has not been entirely successful, the planners' intention was to generate awareness about decentralised solid waste management in the town. It was hoped that the biogas plants introduced in the initial phase of the transformation can convince the larger community of the viability of a non-centralised waste management strategy. It was also to reinforce the critical role of citizens in solid waste management. While biogas plants were installed in residential plots having adequate land, pipe composting was chosen in homesteads that did not have adequate space.

Biogas Plants

A biogas plant is an artificial system where biogas is produced by anaerobic decomposition of biomass, i.e., it is a facility that provides oxygen-free conditions where anaerobic digestion can occur. Simply put, it is a system to turn waste into energy and fertiliser, with positive effects on the environment.

As part of the NBNN programme, Alappuzha municipality installed around 3000 biogas plants, 500 of which were fixed models designed by ANERT and 2500 of which were portable biogas plants designed by IRTC (Isaac and Gopakumar, 2014).[5] The scheme had a subsidy of 2.475 crore (out of the total project cost of 4.675 crore) provided by the Suchitwa Mission and the rest was to be beneficiary share. The existing household biogas plants were categorised based on the quality of construction, efficacy of maintenance activities, and operational status. Based on physical observation of the plants and questionnaire surveys conducted by team members during field investigation, the physical status of existing household biogas plants was classified into four categories: good, average, poor, and not working.

Alappuzha municipality has 52 wards, 14 of which were surveyed and 5 of which were selected for the infrastructure to be investigated. Out of 978 plants analysed, 449 (46%) plants were operating well, 101 (10%) plants were functioning satisfactorily, 71 (7%) plants were partially functional, and 357 (37%) were non-functional. Figure 8 shows a pie diagram representing the working condition of biogas.

[5] The installation of biogas plants began as a part of ANERT's (Agency for Non-conventional Energy & Rural Technology) then ongoing project. The first biogas plant was installed on November 3, 2012 at Kidangamparambu. More wards were ready to participate in the project after a month of deliberation and discussion. As a result, the NBNN campaign was expanded to 12 wards including Karalakam Thondankulangara, Ashramam, Kommady, Avalookunnu, Thumpoly, Chathanad and Municipal Stadium.

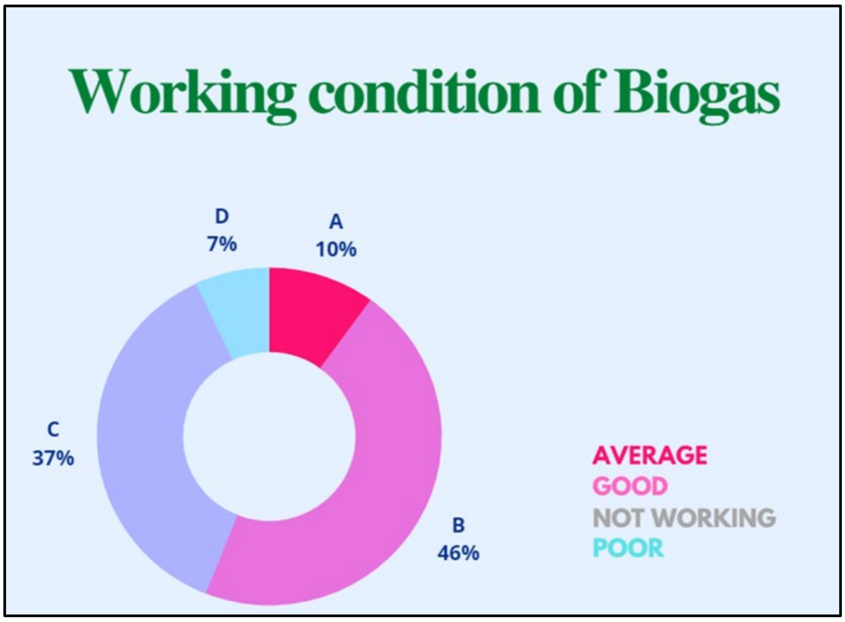

Figure 2: A pie diagram showing the working condition of biogas (Source: CANALPY)

It was found that most of the users do not adhere to user recommendations, resulting in unscientific handling of the plants. The floods of 2018 had an impact on several of the wards assessed, causing biogas plants to malfunction. In addition, the lack of a maintenance team in the town had a significant impact on the functioning of plants at the household level.

The majority of the biogas plants were installed between 2012 and 2013 as part of the "Nirmala Bhavanam Nirmala Nagaram" initiative. The plants that were installed during this time have been confirmed to be in good working condition. This was because from installation until commissioning, all authorities concerned would make a concerted effort and the people were enthusiastic about it because of it being a novel concept. There were also proper awareness programs in those days.

Most individuals wanted to install a biogas system to treat their biodegradable solid waste at household level. Some people, on the other hand, prefer biogas to LPG gas as a cost-cutting measure. If organic waste is available, a biogas system provides constant cooking energy in a household. One of the common problems noted was the lack of sufficient space for installation of biogas plants in households[6]. To obtain enough gas, the plant was required to be located within 10 metres of the kitchen. It is also recommended that they be placed in higher regions with a higher water table and clear sunlight during the day. Several biogas plants did not conform to this requirement. Financial constraints were another issue that many people faced, which included high capital expenditures as well as upfront charges such as transportation, installation, labour, and upkeep. Biogas plants, both fixed and portable, were both costly. The Suchitwa Mission subsidised 50% of this, but households were required to contribute an equivalent amount, which was not affordable for everyone. Several households did not wish to have biogas plants in their household - primarily due to cultural reasons - fearing ill health and foul odour.

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[6] During January 2019, CANALPY conducted a study on biogas plants installed in 14 wards, with an analysis of 5 wards completed. The purpose of this study was to determine the present state of these plants, how many people utilise them efficiently, and what challenges they encountered while maintaining them. The results of this technical survey of 693 households were divided into two categories: general and technical issues. For more details, refer to the Working Paper titled "Town Level Assessment of major polluters and pollutants in Alappuzha Town", published by CANALPY. URL: http://dspace.kila.ac.in:8080/jspui/bitstream/123456789/536/1/3.%20Town%20level%20assessment.pdf

Other technical issues identified by the team included blockages and scum formation in biogas plants, increased CO content due to increased carbohydrate intake into the plant, corrosion of the gas holder and burner due to poor quality of stove provided, water condensate inside the gas tube, pH variation that can affect the optimal growth of methanogenic bacteria, inoperative plants, and so on. It was discovered that once the biogas plants were damaged, they were difficult to repair. Biogas plants were also more likely to be damaged due to a lack of preventative maintenance. The municipality does not provide an annual maintenance allowance for biogas plants that may be utilised to replace or maintain facilities that are experiencing technical challenges. Inoculum should be applied on a frequent basis because it speeds up the decomposition process. However, no effective technique for delivering this inoculum to recipients was created. As a result of the lack of inoculum, foul odours result from insufficient digestion of the organic waste, and if effective slurry management is not practised, the leachate from the slurry could leak into the earth, causing groundwater pollution.

Status of Pipe Compost

Pipe compost units had their own set of constraints, despite being more economical for lower-income households. Residents who installed the system faced filthy backyards and hundreds of worms crawling through their pipe-composting installations. The lack of a bottom cap on the pipe composting system, which meant the pipe was directly buried in the soil, allowed groundwater to infiltrate the composting unit. As a result, they developed a bad odour and worms, and polluted groundwater.

Pipe Compost

Pipe composting is an air-assisted composting technology in which degradable trash was recycled at the source. This approach employs polyvinyl chloride (PVC) pipes installed above ground in households to store degradable kitchen waste for a period, allowing the waste to decompose into manure. Every day, a household's kitchen waste is dumped into PVC pipes, after which an effective micro-organism (EM) solution is sprayed to speed up the composting process[1]. This is a low-cost, simple approach for composting kitchen waste in a family of 4-5 people. Around 1800 pipe compost units were installed in the municipality as a part of the campaign.

Another issue with pipe composting was that the waste was not properly digested since the waste in the first pipe did not dry up even when the second pipe was used. It was caused by lack of air circulation in the pipes and a water content of less than 50%, which is essential for the waste to break down. Furthermore, the bulk of kitchen waste had a high-water content, which inhibited bacterial activity. Pipe compost's correct functioning was further hampered by a lack of soil contact and the inability to churn the waste, as well as the lack of approved inoculum. As a result of all of this, pipe compost units have had little success. Pipe composting method of solid waste management was not successful due to issues related to its design as well as implementation. Lack of technical experts, unskilled labourers and various other drawbacks of pipe compost ultimately led to people being reluctant in installing this system.

4.2 Community-Level Intervention: Introduction of Community Aerobic Bins

The challenges with biogas and pipe compost – especially end-user buy-in – led to Alappuzha innovate with an indigenously developed community-level technology option called the aerobic bin. This technology, developed at the Thumburmuzhi campus of the Veterinary University in Thrissur, has come to be known eponymously. This model is basically bin composting, adapted to the climate of Kerala. After studying the Thumburmuzhi model in detail, the first aerobic composting bin was set up in Alappuzha (T. M. Thomas Isaac and M. Gopakumar, 2014)[7]. As part of the campaign, 23 aerobic units with 235 aerobic bins were installed in Alappuzha municipality.

Community-Aerobic Bins

The decomposition of organic matter or biodegradable waste by the action of oxygen-requiring microorganisms is known as aerobic composting. The microbes responsible for composting are naturally occurring and live in the moisture surrounding organic matter. Oxygen from the air diffuses into the moisture and is taken up by the microbes. As aerobic digestion takes place the by-products are heat,

Watsan Park, the municipality's first aerobic unit, and Alishery, the municipality's largest aerobic unit, was established as part of the municipality's decentralised waste treatment campaign 'Nirmala Bhavanam Nirmala Nagaram' in 2014. The Alishery unit, which has a total of 43 bins, is the city's largest aerobic unit. It is also the city's largest bio-waste treatment plant and the city's largest household-dependent unit. Organic wastes from the municipality's various wards are treated here.

According to the survey, the most commonly used aerobic unit is from highly populated wards (Valiyamaram, Valiyakulam, Lejanath and Alissery wards) and people living in densely populated regions rely significantly on aerobic bins due to a lack of space in their households for depositing waste. The number of persons who rely on these - in units located (Beach and Gurumandiram wards) in sparsely populated areas - is low. Wards with low utilisation rates are primarily found in rural areas. People cannot utilise aerobic units in these places due to the low number of units, the usage of other waste treatment methods, and considerable distance to be travelled to access the aerobic bins.

In the municipality, there are 304 bins in 37 aerobic composting units run by public and private entities. There were 166 bins in 17 public units that operated under various circles, however six of them were found to be damaged. The residents who used these now started disposing of their waste in nearby units. Units in private institutions are unavailable for a variety of reasons. In the background of covid, 75 bins at 14 aerobic units set up in various schools and institutions were fully inoperative. The 63 dumpsters in the aerobic units in Pallathuruthy, Vadakkal, Kommady, Watsan Park, Vazhicherry Market, and Finishing Point Punnamada, on the other hand, are all in disrepair. The lack of interest, increased distance to the units, and political conflicts of the residents where these units are located are the reasons attributable to their failure. An aerobic bin can treat 6 tonnes

[7] The first Thumboormuzhi model aerobic composting bin was installed at a site adjacent to the Punnamada Lake in Alappuzha. They were to be installed on a property near a cemetery in Thondankulangara ward. The attempt was abandoned due to strong opposition from the locals. Consequently, another site (Radhamoola) became the focus of attention. Since it was a waste dumping spot, the waste from this location had to be removed for setting up the aerobic bins. The bins were constructed of concrete mesh and supported by concrete pillars. The engineering specifics were prepared by the experts of ANERT. The bin was a 4ft x 4ft x 4ft ferro-cement structure with a ventilated roof and had a waste carrying capacity of 2500 kg per bin. The structure of the aerobic bin is such that 70% of the walls of the bin were open which allows for ventilation, essential for aerobic composting. Moreover, to accelerate the composting process, a diluted inoculum that promotes the growth of aerobic bacteria, is sprayed over each layer. Dry leaves are placed at a height of 6 inch over which inoculum is sprayed and organic waste is added in layers over it

of garbage for 120 days, three times a year. Only if the aerobic unit system treats 996 tonnes (166 x 6) of waste per year from all the 166 bins now in use, can it be considered entirely effective.

Technical Challenges with Aerobic Bins

It was noticed that Alappuzha's high groundwater table, along with the flat topography, resulted in flooding of the bins during rains[8]. During the monsoon, rainwater entered the units as they were open on all sides. The rate of composting was slowed by the increasing water/moisture content which affected the grade of compost produced. The biodegradable waste leachate produced in the bins penetrated the subsurface soil, contaminating groundwater. During the monsoon season scarcity of dry leaves reduced the efficiency of the bins. Dry leaves are crucial in composting and assuring the quality of the compost produced since they help to reduce odours, maintain the proper temperature inside the bin, and absorb water. Due to a lack of inoculum and dry leaves, the waste was not transformed into manure, resulting in odour issues in the units.

Differential settlement was another issue. An aerobic unit can contain a minimum of four bins, each with a capacity of 2000 kg. To avoid uneven load transmission to the ground, all four bins in a unit should not be filled at the same time. However, the assessment revealed non-compliance, which, combined with the fact that the unit's base was composed of earth, resulted in the floor breaking/cracking. It was observed that the entire floor was destroyed within two years of construction. Rat infestation of bins was also noticed. The rats moved inside the bin and dug up the compost, increasing the burden of workers. A related issue was that the units had was odour issues caused by a lack of sufficient ventilation. The poor segregation of solid waste in the aerobic units also hampered the unit's ability to function properly. Furthermore, the composting process was hindered by putrefaction of untreated waste due to higher water content in food waste. The lack of resources, such as trucks for waste transportation, was a major issue for workers in the aerobic bin composting units. Additionally, the quality of compost produced in the bins were of inferior quality due to the above-mentioned limitations. Since it does not offer much value, local farmer collectives were unwilling to use it in their fields.

According to the findings of the study, 6 out of 23 units were found to be defective. Flooding was a major factor in the units' failure to function properly. Furthermore, because of the larger travel distance between households and the units, the units were not used widely by communities living in the vicinity use rate. According to the report, the city should have 720 bins instead of 235 bins to meet the present population density and volume of daily waste created. Similarly, certain sections appeared to have more bins than others, such as the Alissery unit (43 bins), while others had as few as four bins.

Each person produces 200 grams of organic waste every day, according to the Suchitwa Mission. Currently, the aerobic units receive organic waste from an average of 1,000 households, according to the survey data and each unit receives around one to two kg of waste per family. This means that each household's waste contributes to around 0.94 tonnes per day to the 17 aerobic units. Factors such as weather, waste disposal intervals, and public holidays can all influence assumptions. Under the current circumstances, 343 tonnes of waste per household reaches the aerobic units every year. As a result, only 34% of the entire processing capacity (343/996 x 100) is being utilised to treat organic waste.

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[8] CANALPY conducted a comprehensive technical appraisal of aerobic bins installed in Alappuzha in September 2020. A purposive sample was followed to identify the bins for appraisal. The sample included bins that could offer a glimpse into the functioning of bins across the entire geography of the town where bins were installed. A total of 23 out of 235 bins installed in the town were included in the sample. Along with assessing the design and performance, ease of access to the bins for the communities living in its vicinity was also examinedThe assessment was titled “Aerobic Unit: Alappuzha Nagarasabha” (Malayalam). URL: https://drive.google.com/file/d/138eWQiyR1GUJhRl5wSLC7CGBqqJJ9uiZ/view?ts=62b04d89

Aerobic bins will be beneficial only if the current issues are resolved and the processing capacity is enhanced to 80-90 percent. In the 138 aerobic bins, the municipality can treat an additional 828 tonnes of waste each year (138 x 6). According to the Municipal Statistics Department, the city generates 13413 tonnes of bio-waste from 183737 inhabitants, with 13 percent (1800 tonnes) of these wastes being disposed of in aerobic bins. However, 46% of the total bins remain unused.

4.3 Scaling-up of Household Level Technologies

The multi-dimensional challenges associated with household-level technology options (bio-gas plants and pipe composters) as well as community aerobic bins reinforced the fact that decentralised solid waste management required scaling-up of more simpler technology options that would make it possible to include all the households – irrespective of economic status – in the process of solid waste management (Fig 2).

Alappuzha opted for the kitchen bin to scale up processing of biodegradable wet waste in the town. A kitchen-bin could be conjured up by households using readily available materials like buckets, coconut shells and very minimal piece of land. The municipality pegged the cost of a kitchen bin at Rs.500, which was more affordable than the steep capital required for adopting biogas plants. Additionally, there were no substantial technical challenges with kitchen bins compared to the operation of biogas plants. In order to overcome the limitations of kitchen bins (low efficiency leading to foul smell within household premises), NBNN introduced bio-bins. Bio-bins use inoculum (similar to aerobic bins) that expedite the decomposition of biodegradable waste.

While aerobic bins were more widely used by households in densely populated areas, it had a steep operating cost. Additionally, the technology faced technical challenges in treating biodegradable waste due to high moisture content due to high water table as well as mixing of non-biodegradable dry waste in the bin. The below optimal functioning of the technology resulted in foul odour which made the option unattractive to the residents living in its vicinity.

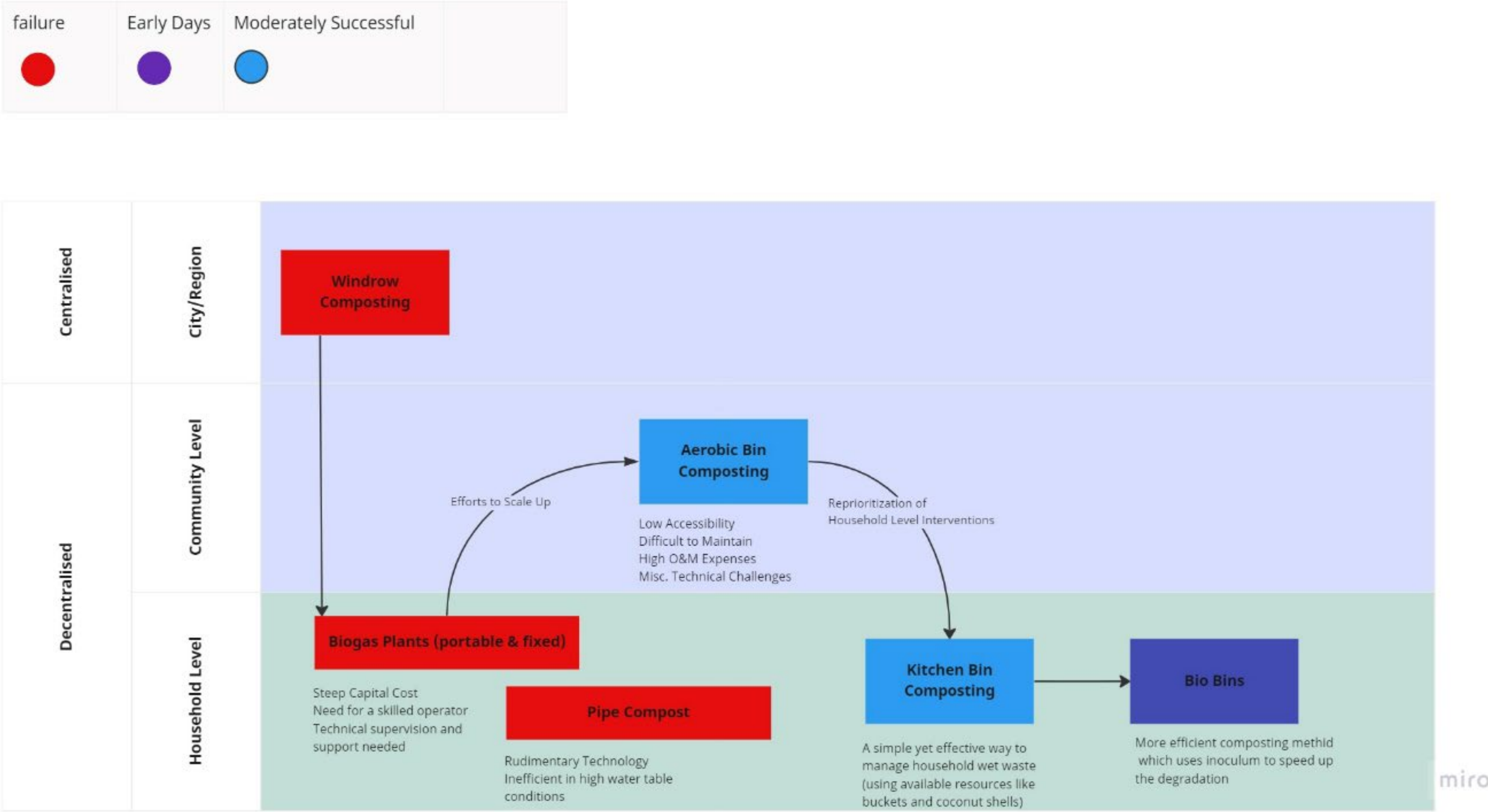

Figure 3 NBNN Technology Choice Evolution

Scaling-up in Alappuzha did not amount to discarding the technologically more sophisticated options like bio-gas plants and aerobic bins. To integrate circularity and more importantly, livelihoods in the mix, members of Kudumbasree (Women's Cooperative) involved in collecting waste from households in Kerala (Haritha Karma Sena) were trained to identity and troubleshoot issues in the functioning of bio-gas plants. While handling technically complex overhaul of these technologies might prove difficult, the skilling of local women in identifying and repairing bio-gas plants serves to integrate livelihoods and circularity in solid waste management. However, the Alappuzha experience highlights the importance of having a heterogeneous mix of technology options to achieve the maximum possible efficacy in decentralised solid waste management.

5 Discussion

5.1 State of Waste Management Practices post-NBNN

After six years of introduction of decentralised solid waste management regime, the situation on the ground was as follows:

a) About 17% of the sampled households reported resorting to unhealthy solid waste management practices; i.e., dumping waste in nearby areas or canals.

b) Close to 50% of the households manage their dry waste (plastic, paper, metal etc.) in improper ways; i.e., by burning, dumping on nearby land or canals.

c) Households were predominantly utilising the community aerobic bin (municipal designated places) disposal mechanism more for the dry waste (21%) disposal than for the kitchen waste (15%).

d) Many households continued to resort to burning of sanitary napkins.

e) Even though the extent of waste segregation at the household level is impressive, the city has failed to translate it into an effective solid waste management model. Close to 50% of the respondents expressed dissatisfaction with the services as compared to 24% who found the services to be satisfactory. The key issue highlighted during the survey was the inability of the government to provide door to door waste collection.

f) The absence of such a system has led to indiscriminate dumping of waste into canals and other water bodies turning them into sinks. The Summer School - 2018 findings corroborate the results of the Winter School held in December 2017 and thus, were a clear indication of the need for a door-to-door collection system in the city.

The shortcoming in the regime were multi-dimensional. The behavioural component continued to be the critical element in successfully decentralizing the service provision. However, behavioural patterns were also shaped by specific characteristics of technologies adopted in the town.

5.2 Lessons from NBNN Campaign

Limited Purchase of a Top-Down Technocratic Approach in Fostering Innovation

Decentralised SWM requires continuous engagement with the end-users. The Alleppey experience showed that it was not entirely amenable to top-down technocratic solutions. Technology choices are also prone to contingent environmental and institutional conditions. While the former is acknowledged widely, the latter is not given much attention by decision makers. In Alappuzha, the household-level technology options (Biogas Plants and Pipe Compost) were introduced after substantial community engagement. It was observed that technologies installed during this phase had better buy-in with the end-users conscientious of operations and maintenance requirement. With household-level technology options, the end-users' role was critical in ensuring their efficient functioning.

The challenges with household-level options (inability of user to bear portion of the initial capital burden, basic technical knowhow and need for operations and maintenance support) led to Alappuzha innovating with the Thumburmuzhi aerobic bins that were deployed at the community level. The local government, with superior resources and capacity, was deemed to be better placed to ensure efficient management of community-level technology options. While the aerobic bins suffered from certain technical limitations (high water table, unavailability of inoculum and sinking of the infrastructure due to its weight), they were used widely by low-income communities. With Kerala's low-income families lacking the space to install household-level technology options, community-level technology options like aerobic bins emerged as a key alternative to enabling circularity in SWM. The fact that the technology was indigenously developed and has been receiving continuous feedback on functioning from the community and civil society organisations is a good beginning. The process of fine-tuning technologies dependeds on the technology developer’s continuous engagement with the local government and the community.

The engagement with end-users also highlighted the oversight in dealing with inorganic waste from households. It was believed that the efficacy of the waste management regime would be greatly enhanced if households take care of – to the best possible extent – organic waste within the household premises. However, the absence of a mechanism to ensure effective collection and processing of inorganic waste led to indiscriminate dumping of inorganic waste in the town.

Nurturing Operations and Maintenance Knowhow in the Community for Upkeep of Technologies

Few years after Nirmala Bhavanam Nirmala Nagaram campaign, litter had made a comeback to public roads and canals. This caused flooding during the monsoon season due to choking of canals. The problem was discovered after three years of obvious urban flooding. Most of the community was evacuated to various shelters since the roads were inaccessible. The “Nirmala Bhavanam Nirmala Nagaram” campaign was only focused on the installation of decentralised waste management systems and least with maintenance. The decentralised technologies received the most attention. However, no team was formed to oversee the compliance of these procedures. This failure was partially remedied by providing training in troubleshooting to women’s self-help groups whose members were part of the local community. Instead of being completely dependent on external actors (the state and the market), the involvement of local community members was expected to ensure better outcomes in the upkeep of technologies.

Afterword: NBNN1.0 v NBNN 2.0

In August 2021, the second phase of the campaign, “Nirmala Bhavanam Nirmala Nagaram 2.0 - Azhakode Alappuzha” aiming to make Alappuzha completely waste-free, was launched. The campaign's goal was to address the issues faced in the first phase of NBNN in implementing decentralised solid waste treatment systems and have Haritha Karma Sena (HKS) collect inorganic waste from each household. The municipality chose to provide household waste treatment solutions such as biodigester bins through this campaign to make Alappuzha waste free in one year. While the issue of inorganic waste and door-to-door collection has been addressed, institutional mechanisms have to be firmed up that bring together the local government, elected representatives, technology providers, civil society organisations (especially Haritha Karma Sena) and the local community to fine-tune technology designs through continuous user engagement.

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