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Refining the shit flow diagram using the capacity-building approach – Method and demonstration in a south Indian town

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ABSTRACT

In cities of the Global South, faecal sludge management (FSM) has arisen as an acceptable and economical alternative for managing excreta. Shit flow diagram (SFD) has emerged as the preferred tool for the planning and advocacy of FSM services. Besides context-specific challenges, FSM planning, especially the use of SFD is impeded by the lack of data related to on-site sanitation systems (OSSs) and lack of capacity at the local level. This paper sets out to demonstrate how the capacity-building approach can be extended to overcome these two challenges in planning FSM with a substantial share of the information collected through household surveys. We argue that even the resource-constrained towns in the Global South have access to college students, smartphones and open source applications and demonstrate how they can be harnessed to collect the data in a cost-effective manner. Using the data collected by 150+ university students, participants of a summer school, we prepare a SFD for Alleppey, a town in Kerala, India. We argue such repeated exercises by subsequent batches of students can help understand local problems, arrive at context specific solutions and monitor them to instill better accountability of local governments. We also identify two issues with the current SFD preparation process and find it is necessary to contextualise the output of the tool to use it for planning. We suggest that the methods demonstrated here be incorporated in the future refinements to the SFD tool to make it more useful for planning city-wide FSM services.

1. Introduction

Research over the last decade highlights that urban areas in the Global South demand non-conventional wastewater management solutions like faecal sludge management (FSM)[1] and decentralised treatment to increase the efficiency of use of water and protect freshwater sources, protect public health, and achieve the SDG sanitation targets (Andersson et al., 2016; Berendes et al., 2017; Larsen et al., 2016; Lüthi et al., 2011b; McGranahan, 2015; Öberg et al., 2020; Van Drecht et al., 2009). To meet the SDG targets, Berendes et al. (2017) estimate the need to provide FSM services to 1.8 billion people in low and middle-income countries where millions of toilets connected to on-site sanitation systems (OSSs) have been constructed to reduce open defecation. However, planning such non-conventional systems is not the same as planning a conventional system because of the differences in their very nature, function, the scale of operations, ownership, etc. From the decision-making perspective, they increase choices available to decision-makers, thereby increasing the complexity of the process (Spuhler et al., 2020). Unlike sewerage, where the State generally takes full responsibility for the entire service chain, FSM requires collaboration and cooperation between many stakeholders operating in parts of the service chain. The households get the OSS built and emptied; often, private service providers empty and convey the faecal sludge to the treatment facility (if any), which are operated by state agencies. The responsibility of integrated planning rests with the state agencies like local governments or public utilities along with overcoming the challenges involved in the process.

In India, the 74th Constitutional Amendment Act of 1992 (enacted in 1993) recognised urban local bodies (ULBs) as the third tier of urban governance and conferred them with the functions of urban planning, drinking water supply and sanitation. Yet almost all reports (HPEC, 2011; MGI, 2010; XV FC, 2020) and published research (Bisen, 2019; Doron and Jeffrey, 2018) in the last decade have consistently highlighted the lack of technical and managerial capacity, and financial resources with ULBs to perform these functions. A study of 6 cities across

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[1] Faecal sludge management (FSM) refers to the process of emptying, conveyance, treatment and disposal or reuse of faecal sludge contained in on-site sanitation systems (OSSs) like pits and septic tanks (Strande, 2014).

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three states in India found that the gaps in understanding and knowledge at the local level as the key challenge for the provision of FSM services (NIUA, 2017). Ganapathy (2020) notes that despite a ten-fold increase in the number of connections, the number of engineers in Kerala Water Authority (KWA), a parastatal agency responsible for drinking water supply, has remained the same since 1984. Such lack of capacity is observed across the Global South and for other environmental services as well. For instance, in Hungary, South Africa, and Uganda, Ostrovskaya et al. (2013) found the capacity for wetland management was weak at all levels and weakest at the local or policy implementation level. In Bangladesh, the local governments were not even aware of their role and had very limited opportunities in planning sanitation services (Begum and Renouf, 2018). In India, the lack of awareness amongst the citizens manifests itself in low demand, and low willingness to pay for services[2] which only exacerbates the challenge for local governments (Jyotsna et al., 2009).

Over the last decade, numerous approaches, planning and decision support tools have been developed to aid the planning of sanitation services in a comprehensive manner. The city sanitation plan (CSP) (CPHEEO, 2013; GoI, 2008), Community led urban environmental sanitation (CLUES) (Lüthi et al., 2011a), Sanitation 21 (Parkinson et al., 2014), shit flow diagram (Peal et al., 2014a), design for service approach (Murray and Buckley, 2009), capacity-building approach (Narayanan et al., 2018b) SaniPlan (PAS Project, 2016), and Santiago (Spuhler et al., 2020) are a few examples. Except for the CSP and SFD, most are not widely used despite substantial efforts of governments, academic and research institutions, and international organisations in their development and promotion. The SFD, in particular is widely used for planning and advocacy of FSM across the Global South. The SuSanA website, www.sfd.susana.org, a global repository of SFDs, currently holds reports of 118 cities and towns (Evans and Peal, 2020) and the number is continuously growing.[3]

SFD conveys the status of the entire service chain in a single graphic that is easy to understand for both technical and non-technical audiences (Peal et al., 2020). At the city and sub-city levels, it helps identify technological interventions needed to improve services (Peal et al., 2014b). At higher levels, it has been used to identify policy gaps and decide priorities as in Uttar Pradesh, India (Eales and Blackett, 2020; Luthra, 2020). Since all SFDs follow a common framework to collect and analyse the information as provided in the SFD manual (SFD-PI, 2018, 2017), they can be useful to understand the variations across geographies, and the information can be collated for global monitoring (Peal et al., 2020). SFD thus serves varied purposes, and its use is not limited by the size of the geographical entity.

The unavailability of data, especially related to OSS and emptying practice, has been identified as one of the main challenges in planning FSM (Devaraj et al., 2021; Luthra, 2020; Mtika and Tilley, 2020; NIUA, 2017). Acknowledging that the data is unlikely to be readily available, the SFD manual (SFD-PI, 2018) suggests collecting data through key informant interviews (KIIs), observations of available facilities (including at household level) across the chain, and focus group discussions (FGDs) with all the stakeholders involved. In towns across various states in India where FSM has been implemented recently, 100% of households were surveyed (Devaraj et al., 2021; Mehta et al., 2019; Mohanty and Mohapatra, 2020; Sahoo et al., 2020).

Systematic sanitation planning needs data and maps, and capacity, all of which are unreliable in small-towns. One of our earlier studies developed an approach for sanitation situation assessment that reflects the social and spatial arrangements within the town through local participation (Narayanan et al., 2018b). For decentralised sanitation planning, the study also demonstrated how the two challenges of data and capacity could be overcome using the approach. This paper sets out to extend this capacity-building approach for planning FSM using the SFD. We use data collected through an extensive household survey conducted by more than 150 university students and early career researchers during their participation in a week-long summer school.[4] The school was organised by CANALPY, an initiative of the Indian Institute of Technology Bombay (IITB), an academic institution, and Kerala Institute of Local Administration (KILA), a state government agency. We also identify opportunities for refinement of the SFD tool, find it is necessary to contextualise the output to use it for planning and demonstrate how it could be done. In our understanding, this is also the first independent feedback to SFD: all the earlier publications have originated from research funded by the World Bank or the Bill and Melinda Gates Foundation for development of the tool (Peal et al., 2014a), it's testing (Furlong et al., 2016; Peal et al., 2014b), development of other tools to complement SFD (Ross et al., 2016a, 2016b; Scott et al., 2019), and its advocacy (Peal et al., 2020).

After introducing the town below, we discuss the methods used for household survey and employing university students as enumerators. In section 4, we present the results of the survey, a SFD prepared using the SFD-PI method, its limitations and a context adapted SFD. We discuss our findings in section 5 and then conclude.

2. Study area: Alleppey town

Alleppey, also known as Alappuzha, is a town approximately 50 km south of Kochi in Kerala, India. The town is sandwiched between the Arabian Sea on the west and the Vembanad Lake on the east. The topography is extremely flat. According to the draft master plan, a large part (18% of its area) in the east is part of the Kuttanad eco-system, which lies below the mean sea level (GoK, 2014). The groundwater table at 3m below the surface is very shallow. The Kerala Municipal Act, 1994 mandates the ULB, Alappuzha Municipal Council (AMC) to manage all the waste generated within its jurisdiction. Piped drinking water which has a coverage of 85%,[5] is supplied by the Kerala Water Authority. According to the Census 2011, the town has a population of approximately 175 thousand.

The 'Alappuzha model' of decentralised solid waste management system[6] is well acknowledged and is in the process of scaling up within the town and replication across the state. Households are encouraged to manage organic waste within their plots, and others deposit segregated waste at one of the community aerobic treatment units spread across the town. The organic waste is composted, and the inorganic waste is sorted and sent for recycling. For its efforts, the town was recognised globally as one of the five cities working to curb pollution through sustainable SWM practices by the United Nations Environmental Program (UNEP) in 2017 (Agarwal, 2017). Earlier in 2016, the town was adjudged as the cleanest city in the country by Delhi based Centre for Science and Environment (CSE) (Mohan, 2016). Important to note that the town was forced to transition from centralised to decentralised system in 2014 after a series of protests by residents in the vicinity of its dumpsite in a neighbouring village (Ganesan, 2017; Sambhyal and Suchitra, 2016). All

[2] The two have been identified as key issues that need to be overcome to make cities sanitised and healthy by the National Urban Sanitation Policy of India (GoI, 2008).

[3] In practice, the use of SFD is much wider; for instance, of the 66 Indian towns in the Ganga river basin for which SFDs were prepared, reports of only a handful of towns are currently available on the SuSanA website. Similarly, though city sanitation plans (CSPs) of Indian towns like Sinnar, Dhenkanal, Puri used the tool or its variant, their SFD reports are not yet available on the website.

[4] Two such summer schools were conducted by CANALPY in May 2018; this study is based on data collected from the first one.

[5] Source: http://urbanaffairskerala.org/index.php/slb accessed on 15th September 2019.

[6] See Sambhyal and Suchitra (2016) for a detailed documentation of the model and the process.

the concerned stakeholders were involved in the transition and were led by the health section of the AMC (Ganesan, 2017).

The Arabian Sea and the Vembanad lake are connected by two canals constructed to carry goods from warehouses along its banks to the then functional Alleppey port.[7] Currently, they provide embarking and disembarking points for boat rides to the backwaters and houseboats, major tourist attractions in the region. The sub-canals which feed into these two main canals also carry pollutants from distant sources. Besides domestic wastewater, small hotels and commercial establishments are also major sources of water pollution in the town (Narayanan et al., 2018c). Big hotels and industries are required to have treatment systems by regulation and tend to comply as it is a condition for renewal of licences. This study focuses on domestic faecal sludge and the pollution it entails.

3. Materials and methods

This section details the methods employed for the collection of data - household surveys and employing students as enumerators for the purpose.

3.1. Household survey

A critical concern for CANALPY is the pollution in the canals; however, a vector map of the canals was not readily available. The IITB team trained a group of local college students to map secondary and tertiary sub-canals using the process discussed by Narayanan et al. (2018b). Such catchment area from which wastewater flows into each canal (referred to as canal sheds henceforth) were demarcated using a QGIS plugin. Our sampling area was restricted to these canal sheds. The selection of houses for the survey was limited to 2–3 rows of residential properties along the canals.

The questionnaire (Annexure S1) was designed to capture the socio-economic situation of the households and their FSM related practices. The choices of answers included in the questionnaire were guided by informal conversations with local officials, masons and construction contractors, and our experience of working in another town in the state (discussed in Narayanan et al., 2018b). The questionnaire was pilot tested by trained student volunteers from a local college before the commencement of the summer school. Their feedback regarding the sequencing of questions, alternatives provided to answer the questions, etc. were noted and incorporated in the final version. The surveys were conducted using ODK (Open Development Kit) - Collect, an open-source android application, and stored on Google drive. A total of 2155 households were surveyed; Fig. 1 shows the spread of houses.

3.2. University students as enumerators

More than 150 students and early career researchers from all over the country were competitively selected to participate in a weeklong summer school organised by CANALPY in May 2018. The participants were exposed to various facets of water and waste management through expert lectures. They also acted as enumerators for the household surveys. Before beginning the surveys, they were introduced to ethical research practices, do's and don'ts, and trained to use mobile applications. Each question was explained, including the choices of answers, and their significance was discussed. The volunteers who had pilot tested the questionnaire enacted mock surveys in Malayalam, the regional language.

Surveys were conducted in teams of 2 with at least one Malayalam speaker. Each team was assigned a segment of the canal shed demarcated on a map that could be accessed using the application 'Maps' on their phones (android or ios). In each segment, they were instructed to start randomly and skip two houses along the street. The volunteers who had pilot tested the questionnaires acted as captains and supervised five teams in each other's vicinity. The team leads provided telephonic support to manage the failure of the application, saturation in the assigned segment, etc. Each day, participants discussed their experiences with the respective team leads and issues faced. On the last day, select volunteers amongst the participants compiled the data and presented a preliminary analysis to other participants and the local stakeholders. All the participants were provided with certificates of participation as a token of appreciation. They used their own mobile phones and data packages with their lodging, food, and local travel provided by CANALPY.

4. Results and findings

Of the 2155 households approached for the survey, 215 refused to participate, while responses of 251 households were removed in the cleaning process. Data of households that chose to end the participation mid-way or where the enumerators spent inadequate time was cleaned before analysing. The assessment and SFDs presented here are based on an analysis of responses of the remaining 1689 households.

4.1. The state of FSM in the town

According to the 2011 Census, 97% of households in the town have a toilet. Under Swachh Bharat Mission (SBM), the Government of India's flagship programme to eradicate open defecation, more than 450[8] households were provided with subsidies to build toilets. The municipality declared itself open defecation free (ODF) in June 2017. In our survey, all households reported having access to a toilet, and none practised open defecation. In the 2011 Census, more than 15% of households reported that their toilet is connected to a sewer system, nearly 57% had septic tanks and, more than 18% reported having pits, while the remaining ~10% had unsafe OSS. However, neither AMC, the agency mandated with sanitation service provision nor the KWA, which provides sewerage services in two large cities in the state have laid sewer system in the town. Our survey brought out that 65% of households have septic tanks, 32% have pits, and 3% were not aware of their OSS type.

Our interactions with masons and local officials had revealed confusion regarding the terminology used to describe OSS; in local parlance, all types of OSS are referred to as septic tanks. Hence, the types of OSS were characterised based on the responses regarding the materials used for construction and the mechanism of disposal of supernatant along with the enumerators' observations of the latter. The combination of responses and observations used to characterise the type of OSS is presented in Table 1. It is found that only half of the responses reported as septic tank served as such and the rest are pits. A comparison of responses in Census 2011 and our survey with the technical analysis is presented in Table 2.

The municipality does not provide emptying service, nor has it licenced any private service providers. Alappuzha district septic tank cleaning contractors association (ADSCCA) has 25 members who provide emptying services in the town, adjoining panchayats, and parts of neighbouring districts. They provide service only in night to avoid harassment by law-enforcement agencies who penalise them for dumping the sludge in water bodies and vacant lands. Each of the 50 trucks cumulatively owned by these members makes about 5 trips each week. This estimate, however, is much lower than the daily disposal of 2500 thousand litres of faecal sludge equivalent to 500 trucks estimated by a KSPCB study (as reported by Paul, 2019). Our survey found that 43% of OSSs have never been emptied. Though not permitted by law, households also reported getting their OSS emptied manually. Almost 40% of the OSS that have never been emptied are relatively new

[7] The port and consequently the canals lost their economic significance after a bigger port became operational in Cochin in the 1930s.

[8] Source: http://geourbanmissions.gov.in/accessed on March 27, 2021.

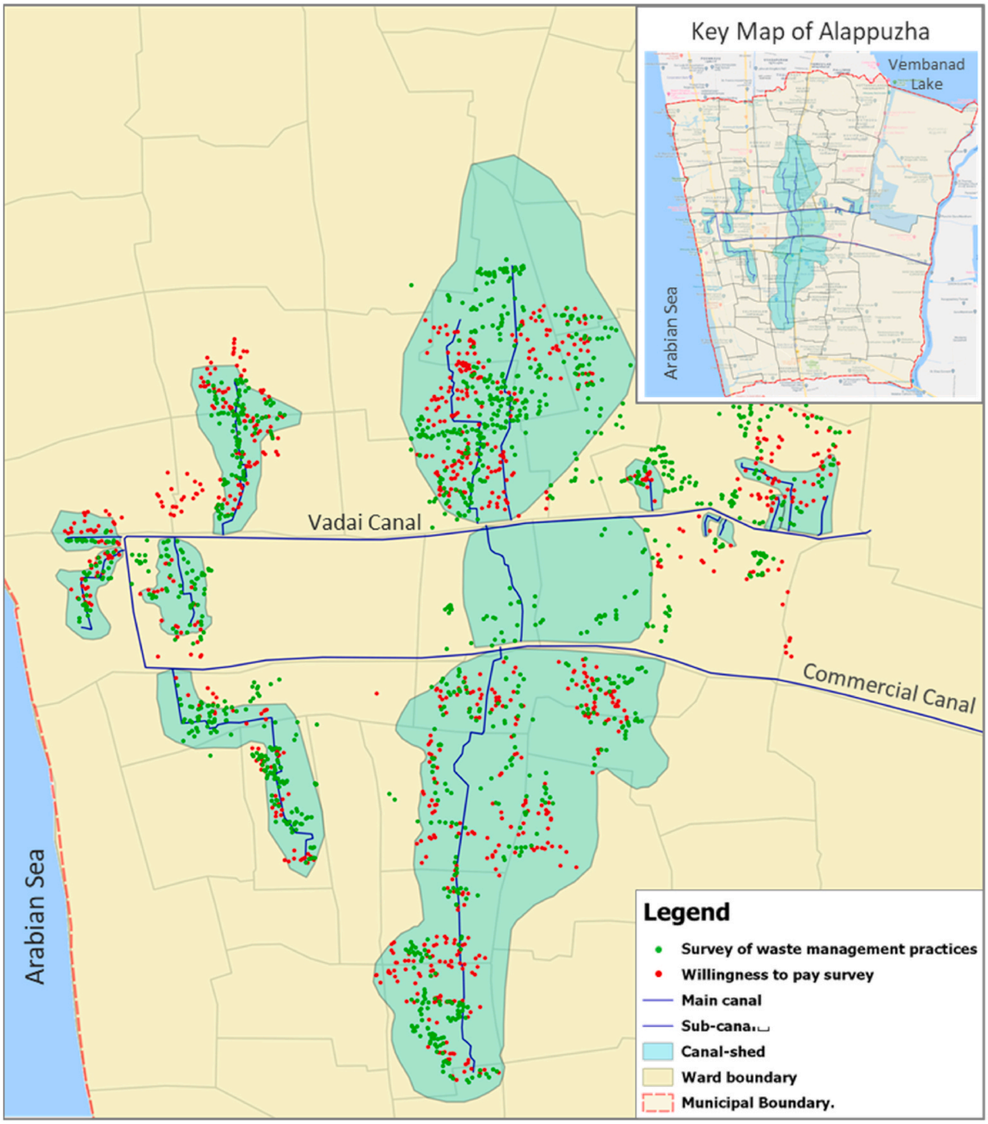

Fig. 1. Spread of houses surveyed.

Table 1
Combination of wall material, bottom material and outfall used to charaterise type of OSS.

Wall material	Bottom material	Outfall	Conclusion (OSS type)
Prefabricated plastic OR precast concrete	Plastic/ concrete	–	Prefabricated septic tank (FRP/concrete)
Masonry OR concrete	Concrete	Yes	Septic tank
Masonry OR concrete	Concrete OR None	No	Pit
Rings OR perforated rings OR Perforated brick wall	Concrete OR no bottom	–	Pit

Source: Authors, based on discussions with local masons and construction contractors

Table 2
Comparison of type of OSS in Census 2011, as reported by households in the survey and deciphered through a technical analysis.

OSS type	Census 2011	Reported	Technically characterised
Septic tank	57%	65%	33%
Pit	18%	32%	55%
Others/Do not Know/Could not be deciphered	25%*	3%	12%

*Includes ~15% respondents who reported toilets connected to sewer system.
Source: Census (2011) and Primary surveys

(constructed in the previous 5 years). However, more than 30% were built more than 10 years earlier. Of those emptied, the duration between successive emptying (emptying cycle) ranged from 1 year to 20 years. The average emptying cycle of emptied OSS is 3.5 years which is close to the standard of 2–3 years suggested by CPHEEO (2013) and GoI (2013).

The AMC has never had facilities to treat sewage or faecal sludge from domestic sources. According to an official of the Kerala State Pollution Control Board (KSPCB), there are three government owned establishments with spare capacity at their sewage treatment plants, viz; (1) T D Medical College, located 9 km south of Alleppey; (2) Info park, Cherthala in village Pallipuram approximately 30 km north of Alleppey and (3) Rajiv Gandhi power plant in Kayamkulam 40 km south of Alleppey. Partnerships between these facility operators and private emptying service providers formed at the behest of the KSPCB did not last long for various reasons. When OSS are manually emptied, the FS is either disposed in a pit, dug for the purpose, or just spread around. Thus all the FS from the town returns to the environment without any treatment. Quality tests conducted as part of another study confirmed contamination of groundwater as e-coli was detected in 93% samples from dug wells and 82% samples from borewells (Narayanan et al., 2018a).

Fig. 2 graphically represents the status of the sanitation service chain in the town using the traffic lights analogy. The user interface is green as all the households have access to toilets. The collection is partially green with some FS safely contained and partly orange denoting that the remainder pollute groundwater. Emptying is orange for three reasons, viz; many OSS have never been emptied in more than a decade and therefore likely pollute groundwater, the emptying service providers are not licenced, nor is the service monitored, and households reported employing manual labour for the purpose. The emptied FS returns to the environment without any treatment, and hence the last two components, viz; treatment, and disposal are red. Thus, the issues in the FSM service chain include inappropriate containment structures, irregular and unregulated emptying, lack of treatment facility and indiscriminate dumping of emptied faecal sludge.

4.2. SFD produced using the SFD-PI method

Using the data available from the household surveys and the methodology laid out in SFD-PI (2018), we prepared a SFD for Alleppey. The types of OSS in use in the town and the share of population dependent on them are presented in the SFD matrix in Annexure S2 in the supplementary material. Despite the groundwater table being very high, the threat to groundwater pollution is considered 'low' as suggested by the risk estimation tool available with the graphic generator.

The SFD so prepared (Fig. 3) gives the impression that the majority (68%) of OSS safely contain excreta. This is contrary to Narayanan et al. (2018c) finding that inappropriate OSS contribute to pollution of groundwater in the town. It also does not adequately highlight the indirect nutrient load in the canals from seepage of this contaminated groundwater leading to their eutrophication, thereby hampering tourism - one of the main economic activities in the town.

Besides, we identify two other issues with the process used to prepare the SFD presented in Fig. 3. One, septic tanks not connected to soak pits or sewers are considered unsafe even if they safely contain the faecal sludge (FS) and only dispose supernatant (SN) in an unsafe manner. This gives an incorrect impression that the septic tank needs repair or replacement, while all it means it that the SN needs to be safely managed. Two, OSS that are periodically emptied conforming with the suggested frequency are not explicitly considered to be different from those not conforming with the recommended frequency. Periodic emptying of septic tanks is necessary as otherwise its supernatant is not adequately treated (CPHEEO, 2013; ISF-UTS, 2019). A lack of emphasis on periodic emptying will obviously not highlight the issue and not prompt decision-makers to amend the situation. We contend that a SFD prepared without addressing these issues will fail to guide decision-makers towards requisite action, the very purpose of planning.

4.3. A context adapted and refined SFD

A context adapted SFD is a city-specific graphic that is manually corrected to convey the true picture of excreta management in the city (Rohilla et al., 2018). That is, such a graphic can be used to address or demonstrate specific concerns by taking into consideration the appropriateness and safety of extant practices in the city's specific context. Below, we discuss the issue of concern in the town, followed by an analysis of the appropriateness of extant practices and potential solutions to deal with the issue. In the light of this analysis, we state our assumptions and present the contexted adapted and refined SFD.

As discussed earlier, the eutrophication of canals due to pollution is a major concern in Alleppey as it hampers tourism. Further, faecal contamination of groundwater and piped water has also been observed (Narayanan et al., 2018a). However, faecal contamination of groundwater may also occur during its extraction, post-collection storage and handling, and at the point of consumption (Ravenscroft et al., 2017). The severity of contaminated groundwater is not felt in Alleppey due to the deeply rooted cultural practice of boiling drinking water. The practice is observed across the state of Kerala. The apparent rarity of water borne diseases in Thiruvanthpuram, the state's capital city, despite similar levels of contamination in well waters was attributed to the practice in an earlier study (Ananth et al., 2018).

For an OSS to not pollute groundwater, vertical separation between the bottom of the OSS and the water table is needed; the minimum separation required depends on soil and hydrological conditions (Banerjee, 2011; Kliger, 1921 cited in Graham and Polizzotto, 2013). Pits directly disperse the liquid component of toilet waste and rely on the soil in this vertical column for treatment before it reaches the groundwater (Tilley et al., 2014). Since this vertical separation is not available, the most common type of OSS in use in Alleppey directly pollutes groundwater. The supernatant from a well-functioning septic tank is only partially treated and laden with e-coli; its dispersal or disposal using any method directly or indirectly pollutes the groundwater. Thus all types of OSS pollute groundwater to some degree and none of them can be considered completely safe in Alleppey.

As a solution to managing wastewater, laying sewers is not feasible in Alleppey due to the narrow road widths and shallow groundwater (GoK, 2014). In early 2019, a decentralised treatment plant (DEWATS) for approximately 50 households was implemented with the support of CANALPY, but its replication across the town is a challenge due to the high population density and unavailability of such strategically located land parcels. Household-level solutions like the urine-diverting dry toilets (UDDT) or container-based sanitation (CBS) have not been tried in Kerala and are unlikely to be acceptable for cultural reasons. A well-designed and periodically emptied septic tank reduces TSS, BOD and COD; that is, it partially treats wastewater before releasing the supernatant (CPHEEO, 2013; Tilley et al., 2014). It also safely contains FS, a big advantage over pits, especially during the annual floods. A tank with impermeable walls and open bottom can be considered to perform as a septic tank as the bio-mat formed at the bottom practically seals the tank. Further, the soak-pit filters the supernatant and further reduces the BOD and TSS before dispersal. It is also the most hygienic of all the alternatives practised in the town as it ensures no human or animal contact with the supernatant. An anaerobic baffled reactor (ABR) or an improved septic tank is superior in terms of removal of BOD, but is inefficient in removing pathogens and nutrients (Tilley et al., 2014). Also, compared to a septic tank, they take more space and cost more money (CPHEEO, 2013), both of which are constraints in Alleppey. Thus, a well-designed and regularly emptied septic tank followed by a soak pit, even if only partially safe, is the most pragmatic solution in Alleppey. Of course, they need to be complemented by regular emptying of septic tanks, and the treatment of FS. The quality of water in the canals can be further enhanced by the installation of natural treatment systems like the ones discussed by Jamwal et al. (2020) and Starkl et al. (2013); they can be strategically located in the canal network in sections that are not used for navigation.

To contextually adapt the SFD and address the two issues identified in the previous sub-section, we make the following assumptions based on the preceding discussion. Table 3 presents the implication of these assumptions on each type of OSS in use in the town.

i. Septic tanks that are emptied once in less than 5 years[9] are considered to safely contain the FS. Disposal of the supernatant of such systems through soak pits is also considered safe. Disposal of supernatant in other ways, including into open-drain or

[9] The Indian standards suggest an emptying cycle of 2–3 years while the US EPA suggests 3–5 years. We choose to use 5 years as in practice the septic tanks are often constructed bigger than the size suggested by standards.

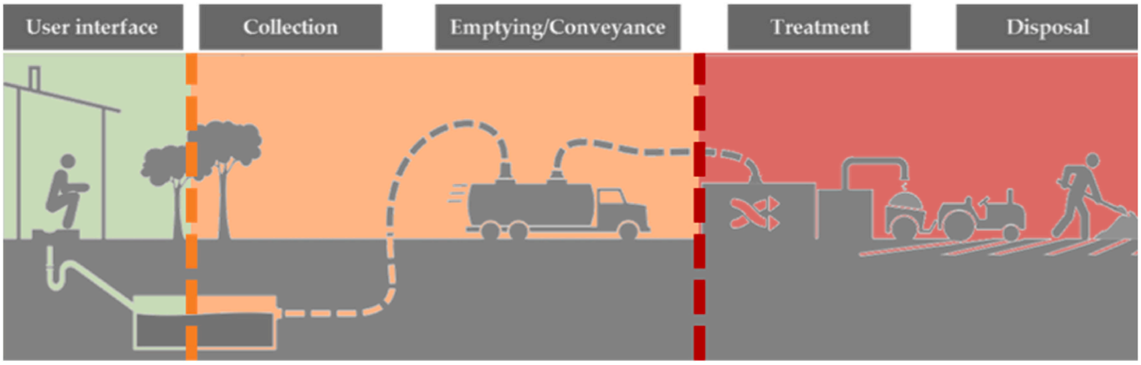

Fig. 2. The status of FSM service chain in Alleppey. Source: Traffic light analysis by the authors on base graphic from http://www.wastewaterinfo.asia/sites/default/files/downloads/S9-01-Intro.pdf.

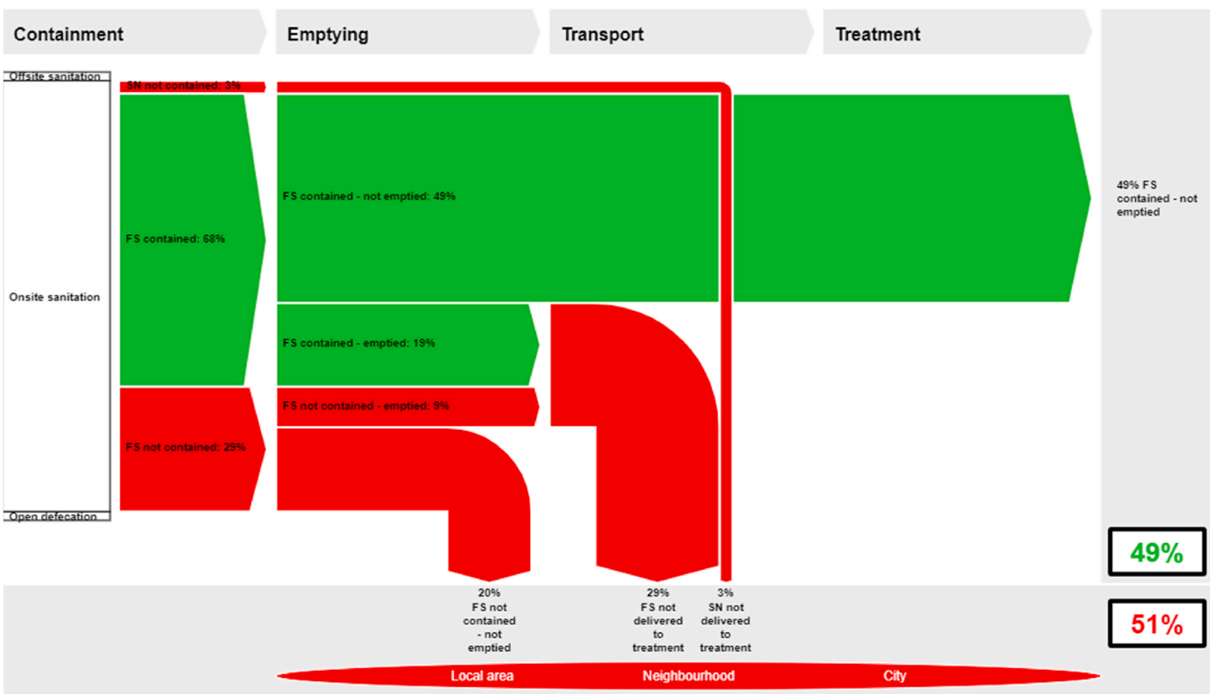

Fig. 3. Shit flow diagram of Alappuzha prepared using the SFD-PI methodology.
Source: Prepared by the authors using graphic generator available at www.sfd.susana.org

stormwater sewer, open ground, and 'don't know where' is considered unsafe.

ii. Septic tanks not emptied once in less than 5 years are considered unsafe containment, disposal of the supernatant of such septic tanks through any mechanism is also considered unsafe.

iii. All types of pits, whether regularly emptied or not, are considered unsafe.

A context adapted SFD which delinks the safety of containment of FS from the safety of dispersal of SN and takes into consideration time duration between successive emptying is presented in Fig. 4. Unlike Fig. 3, it clearly shows that most of the OSS do not safely contain FS. Further, SN from most OSS is also not safely disposed. The lack of treatment is evident in both the SFDs.

5. Discussion

5.1. The SFD process needs refinement and the outcome contextualised

In section 4.2, we identified two issues with the SFD-PI method that need to be addressed to make the tool more useful for planning: (1) the clubbing of safety of containment of faecal sludge (FS) in septic tanks and the disposal of its supernatant (SN), and (2) the lack of explicit attention to the time duration between successive emptying of OSSs. Though the quality of the SN depends on the emptying frequency of FS from a septic tank, the two are recognised as distinct products (Tilley et al., 2014) and are separately handled after they leave the septic tank. The safety of the processes for their handling, therefore should be independently assessed as is already done for septic tanks that discharge SBN into sewers. Similar caution needs to be exercised when the SN is dispersed through soak-pit or let off in stormwater drain or onto open ground or when its fate is not known. It is precisely for this reason, the Administrative Staff College of India (ASCI) developed a variant of the

Table 3
Assumptions regarding safety of containment of FS and SN.

System Code	System Description	SFD-PI method		Context adapted SFD: If emptied periodically		Context adapted SFD: If not emptied periodically	
		FS	SN	FS	SN	FS	SN
T1A2C5	Septic tank connected to soak pit	Safe		Safe	Safe	Unsafe	Unsafe
T1A2C6	Septic tank connected to open drain or storm sewer	Unsafe	Unsafe	Safe	Unsafe	Unsafe	Unsafe
T1A2C8	Septic tank connected to open ground	Unsafe		Safe	Unsafe	Unsafe	Unsafe
T1A2C9	Septic tank connected to 'don't know where'	Unsafe		Safe	Unsafe	Unsafe	Unsafe
T1A4C5	Lined tank with impermeable walls and open bottom, connected to a soak pit	Safe		Safe	Safe	Unsafe	Unsafe
T1A4C6	Lined tank with impermeable walls and open bottom, connected to an open drain or storm sewer	Unsafe	Unsafe	Safe	Unsafe	Unsafe	Unsafe
T1A4C8	Lined tank with impermeable walls and open bottom, connected to open ground	Unsafe		Safe	Unsafe	Unsafe	Unsafe
T1A4C9	Lined tank with impermeable walls and open bottom, connected to 'don't know where'	Unsafe		Safe	Unsafe	Unsafe	Unsafe
T1A4C10	Lined tank with impermeable walls and open bottom, no outlet or overflow	Safe		Unsafe		Unsafe	
T1A5C10	Lined pit with semi-permeable walls and open bottom, no outlet or overflow	Safe	NA	Unsafe	NA	Unsafe	NA
T1A6C10	Unlined pit, no outlet or overflow	Safe	NA	Unsafe	NA	Unsafe	NA

Note: A vertical line between FS (faecal sludge) and SN (supernatant) indicates that their safety is separately considered. An absence of vertical line indicates that the two are not delinked

tool for supporting local and State governments in Telangana and Andhra Pradesh in India[10]. The need to delink safety of containing FS in septic tank and disposal of its SN is also highlighted in the SFD report of Gangaghat,

> *According to the stakeholders, properly designed septic tanks, which are regularly emptied, should be considered contained even if the supernatant is discharged into open drains .... According to SBCLTF (the stakeholders), the solid FS collected in the septic tank should be considered (safely) contained as it is neither polluting the groundwater nor the solid excreta is overflowing in the open drain.* (Rohilla et al., 2018, p. 9, p. 9)

Periodic emptying of septic tanks is necessary for them to function optimally and not pass on additional load to the SN receiving system (CPHEEO, 2013; ISF-UTS, 2019). However, households tend to delay emptying and use OSS beyond what is considered safe to save money (Jenkins et al., 2015). Other means like the construction of bigger OSS and altering their design have also been observed (Devaraj et al., 2021). Our survey in Alleppey found that as many as 43% OSS in the town have never been emptied and one-third of them were built ten or more years earlier. To ensure OSSs are emptied periodically, Mehta et al. (2019) suggest scheduled emptying instead of on-demand emptying as currently practised in most towns. Scheduled emptying also maintains a steady flow of FS for treatment, ensuring optimal use of the conveyance and treatment capacity. More than 100 towns in Odisha have adopted resolutions to enforce periodic desludging of OSS (Dasra India, 2020).[11] That is, once treatment facilities are commissioned, scheduled desludging seems to be the way forward to ensure their optimal use. In section 4.3, we demonstrate a method to address these two issues.

[10] Source: Presentation by ASCI during a webinar titled “Different variations of SFD” held on 14 September 2018. The recording is available at https://www.cseindia.org/webinar-series-on-shit-flow-diagram-part-1-different-variations-of-sfd-9015.

[11] Statement by Mr Mathivathanan, the Principal Secretary, Housing and Urban Development Department, Government of Odisha.

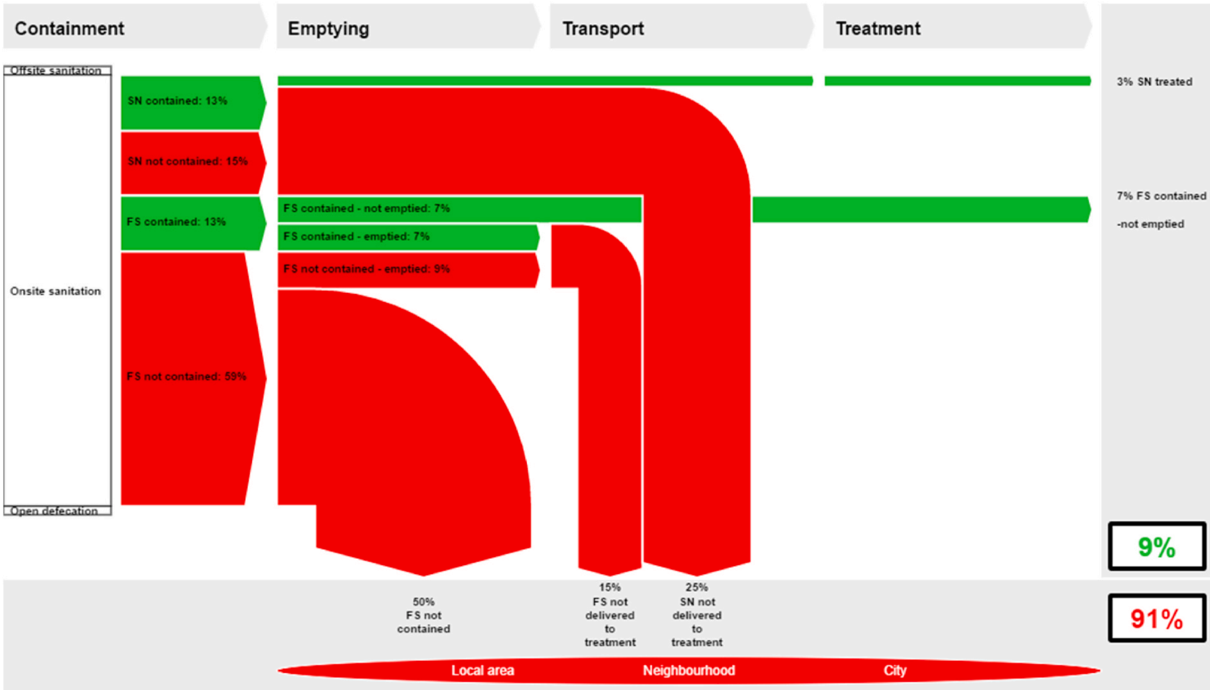

Fig. 4. Context adapted and refined SFD for Alleppey.

Finally, in its current form, the SFD preparation process places only the public health impacts of unmanaged excreta at its centre. The environmental impacts are not considered if they do not impact public health. The following quote from a recent paper by researchers involved in the development and refining of the tool is telling:

> *"Safety" is assessed in terms of whether the hazard (pathogens in excreta) are likely to enter the environment at each point along the sanitation chain and* ***if human exposure to that hazard at that point is also likely to result in a public health risk***. (Peal et al., 2020, p. 3) (emphasis added)

This was the reason the risk estimation tool suggested 'low risk' from groundwater pollution as less than 25% households depend on groundwater for consumption in Alleppey. If environmental concerns overshadow public health concerns, the SFD graphic needs to be adapted to highlight specific concerns, in our case, pollution of groundwater and the eutrophication of canals. Contextualising the SFD is necessary in such a situation so that the required sanitation interventions can be identified and investments appropriately directed. In such an adaptation process, we demonstrate that each sanitation system type in use needs to be assessed for its impact on the issue of concern. Further, the process should take a pragmatic view of potential solutions for the concerns being addressed.

5.2. Household surveys are necessary and need to probe deeper

In the Global South, often due to a legacy of non-existent systems, the data related to OSS is not available with local governments or public utilities. In India, the Census 2011 is the only source of information; many SFDs and city sanitation plans depend on it. However, we find that it is inadequate and also inaccurate. For a town in Tamil Nadu, Devaraj et al. (2021) also found the Census information related to OSS to be incorrect. This is because the Census relies on responses, and respondents may not understand the technical nuances that differentiate a pit from a septic tank. Earlier researchers have found that terms used to describe OSS are used interchangeably (Furlong et al., 2016) and confusion over words commonly used to describe sanitation systems is widespread (Peal et al., 2020). The other inaccuracy in the Census is related to connection with sewers; in many towns including Alleppey, households report connection to sewer where no such systems exist. This is probably because the distinction between sewers (drainage) and (stormwater) drains is also not very clear to the public.

Where treatment facilities are yet to be established, much of the information required for planning such facilities and preparing SFDs can be collected through household surveys. They can help acquire reliable data regarding the types of OSSs in use, their emptying frequency, and mechanisms employed for disposal of supernatant from septic tanks. In towns across various states in India where FSM has been implemented recently, 100% of households were surveyed (Devaraj et al., 2021; Mehta et al., 2019; Mohanty and Mohapatra, 2020; Sahoo et al., 2020).

However, to overcome the response bias noted above, such household surveys need to go beyond relying on responses about the type of OSS and probe deeper as confusion regarding the terminology used locally is widespread. We reverse-engineere the OSS construction in terms of materials used in construction and triangulate them with observations regarding presence or absence of outfall of supernatant and an understanding of local construction practices gained through conversations with masons and contractors. Devaraj et al. (2021) make the same argument and use a similar process to characterise OSS in a small town in Tamil Nadu, a neighbouring state.

We wish to point out that this study relies on the recall memory of members of households about construction practices followed. This was possible as most houses in the town are self-built; that is, the owners oversaw its construction, including that of the OSS. Where housing is supplied by real estate developers, such a method may not be adequate and will need to be accompanied by interviews of real estate developers. Devaraj et al. (2021) point out that such an approach does not eliminate response bias and we agree with them that more research is needed to devise methods to characterise OSSs more accurately.

5.3. Extending the capacity-development approach - employing students as enumerators for household surveys

Lack of reliable data hampers planning of developmental interventions, including sanitation planning across the Global South. The local governments or public utilities also do not have the required human resources to collect the data themselves or the financial wherewithal to hire private firms to collect the data. Our earlier study (Narayanan et al., 2018b) developed a methodology to work with ULBs, local university students and civil society organisations for sanitation planning referred to as the capacity-building approach. The approach builds the knowledge and capacity of – and for – the ULBs by training and then collaborating with university students from within the city. Such a strategy offers enormous downstream benefits if the ULB continues to work with local academics. With conventional sewage technologies failing or not being extended, capacity once generated for a situational analysis could potentially be leveraged for other geographies as well as towards a range of other actions -awareness generation, or design, operation and maintenance of systems – that can both institutionalise and democratise the governance of wastewater (Narayanan et al., 2018b).

This paper extended the capacity-building approach and focused on refining SFD by employing university students as enumerators for conducting household surveys. Local colleges, smartphones and free software are resources that even towns in low and middle-income countries have access to. We demonstrate how these resources could be tapped to overcome the twin challenges of data and capacity. We can expect students to be adept and comfortable with smartphones and applications, and curious about new tools and new ways of using them. The opportunity to learn about these new applications certainly enthused participants of CANALPY's summer schools. We argue that exposing university students to the various facets of sustainable waste and water management through case studies, real-life challenges, and engaging them in the collection and analysis of data, contributes to the development of capacity of the next generation of sanitation sector professionals. Others who pursue other career options will be more aware of the challenges and potential solutions, will likely support and elicit support for alternative solutions, thereby increasing demand for services. In the process, we also demonstrate to the local government how university students could be engaged to complement their efforts. We believe such repeated efforts will build the capacity of the system to overcome the challenges of collective action and co-production in the provision of sanitation services.

Like the UNDP, we use the term capacity to mean *the ability of individuals, institutions and societies to perform functions, solve problems and set and achieve objectives in a sustainable manner* (UNDP, 2010). We acknowledge that building capacity is a long term process, as observed by Edelmen and Mengers (1997) (cited in Lüthi et al., 2011b, p. 131). We also acknowledge that the approach presented here deals with only a part of the challenge. It does not deal with changes required in legal framework for example but hope a more aware citizenry will force the required changes from the bottom, and better-trained professionals can bring about the change from the top. Such an approach needs to be complemented by efforts aimed at changing perspectives and imparting sectoral knowledge and new skills to local government officials instead of the conventional program implementation focus of capacity development efforts as observed by Dash and Kapur (2021). Thus our study specifically highlights the strategic advantages of collaborating with local academics and students, and the strategic importance of keeping the priorities and constraints of the ULBs front and centre.

6. Conclusions

This paper set out to extend and demonstrate the utility of the capacity-building approach to overcome the two challenges of data and capacity for planning FSM services. Due to the legacy of non-existent systems to collect and collate data related to the construction of OSS and their emptying, household surveys become a necessity to prepare a SFD. The decadal Census reports, the only source of information in India, is inadequate and inaccurate for this purpose. Household surveys therefore become a necessity for planning FSM and they need to probe deeper to overcome response bias; we reverse engineer the OSS construction practice for the purpose, and triangulate with observations and an understanding of local construction practices acquired through discussions with masons. We demonstrate how university students equipped with smartphones and open source applications can collect and analyse granular data required for the purpose. Since these resources are available even to towns in low and middle-income countries, we argue tie-ups with local colleges offer a potentially cost-effective method of data collection at least till the time systems to collect and collate data are put in place. If such exercises are repeated, with each iteration focusing on different geography or a different issue, a database of entire city and of several layers can be built gradually. Such a database can be used for planning a multitude of services as well as their integrated planning. A long-term collaboration between local colleges and local government or public utility could be a potential gamechanger for various endeavours in development planning and cooperation, and urban planning.

We argue that such a planning process also builds the capacity to plan and sustain alternative systems in the long run. Building capacity is a long-term process, and training today's university students is important to have well-trained professionals in the future. A recent paper concludes that changes in curricula are needed for future generations to appreciate and implement alternative, non-conventional sanitation solutions (Öberg et al., 2020). Till the time such changes take place, avenues like summer and winter schools could be used to train students by exposing them to ground reality, alternative solutions, and emerging planning and data collection tools. Ensuring successive batches of students get exposed through long-term collaboration would *make colleges repositories of knowledge with analytical capabilities*. This will also help *instil accountability of local governments by the engagement by 'student citizens*'.

We also identify two issues with the current SFD preparation process: (1) for septic tanks, the safety of containment of FS is not delinked from the safety of disposal of its supernatant for all possible mechanisms of managing SN, and (2) the time duration between successive emptying of OSS is not explicitly considered. We demonstrate how these issues can be addressed using data from a household survey, thereby refining the SFD. Further, we argue for and demonstrate how the SFD can be contextualised to address environmental concerns even if they do not impact public health. The adaptation process should assess each type of sanitation system for its impact on the issue of concern. It should also consider potential solutions appropriate for the context to guide decision-makers. The SFD-PI project should incorporate these methods in the graphic generator and the next version of the SFD manual as it looks to accelerate the use of SFD through phase 3 of the project.

Author contribution statement

NCN ideated the summer schools, forged the collaboration with KILA and mobilized funding. PCP analysed the data and prepared the SFD and context adapted SFD. Both the authors made substantial, direct and intelletual contribution to the work, read, and approved the final manuscript for publication.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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