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Design of a sustainable urban household organic waste handling system

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Abstract:

The management of household waste faces issues across aspects of segregation, transport, disposal, storage, and treatment. In the urban scenario where water supply can seasonally get scarce and intermittent, household waste management solutions that are dependent on continuous supply of sufficient water fail to deliver. It is also observed that subsidised potable water supply is being used indiscriminately as a vehicle for transporting waste. Though systems for recycling wastewater for reuse exist, these do not aim to decrease the quantity of water required for transporting waste. Categorising toilet and kitchen waste as household organic waste, this paper discusses the design aspects of collecting, handling, transporting, and partially digesting household organic waste onsite, using less water. Further, systemic aspects for managing the products of digestion and handling the partially digested waste are suggested. Aiming at closing the loop or what is called the cradle-to-cradle cycle for household waste, the present paper describes design aspects of sustainably managing urban household organic waste that require necessary intervention from various stakeholders involved.

Keywords: *urban organic household waste management, sustainable urban sanitation*

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1 Introduction

Water is a vital connecting link between many nutrient and ecological cycles. The availability of water for these cycles has been declining due to increasing quantities being utilised by human beings. The problem gets compounded as water supplies get scarce and people stick to using existing water-intensive solutions of waste disposal that also pollute water indiscriminately. The latter scenario is further exacerbated by the fact that rural population migrating to urban cities resort to urban ways of using water sooner or later and intensify the demand for water. Currently, close to 60% of the world's population is urban. The urban population accumulated so far is expected to double in the coming decades and 96% of this urban growth is expected to occur in the developing and underdeveloped countries (Planning Sustainable Cities: Global Report on Human settlements, 2009). Catering to this increasing population puts enormous pressure on urban infrastructural systems such as those concerning water supply, sanitation, and sewerage and requires these systems to change rapidly (IBM/BWSSB, 2014). In cities such as Bangalore where the state subsidises a significant (close to 50%) proportion of the cost for supplying potable water to the public, the use of water for flushing waste is inappropriate and needs to be curtailed. Though solutions for providing recycled water exist, they only solve the problem partially. It has hence become necessary to reduce the per capita utilisation to ensure availability of water to the rest and to redesign the system for handling waste end to end, taking culturally sensitive requirements into account. This is also supported by the fact that developing and underdeveloped nations need to pursue different growth trajectories, which are unlike that of the developed world, to ensure that their growth is sustainable.

The urban management of waste in India is problem-ridden from collection to disposal. Problems of segregating organic and inorganic waste arise during collection. Problems concerning acceptability by the locals arise during land-filling and other forms of treatment (Sindhuja, 2012). Management of household organic waste comprising black water (faecal and urinal matter), grey water, and kitchen refuse is replete with problems, too. At present, the management of black and grey water is separated from that of kitchen refuse. Wherever an underground drainage system is in place, black water is directly led to empty into these covered sewers. However, due to the seasonal availability of water in cities such as Bangalore and Chennai, sewers do not get sufficiently drained, resulting in their drying up and clogging (Nadella, 2013). The 150 litres or so of water required per individual to properly flush the waste down the gravity-based central sewers puts tremendous pressure on the Bangalore Water Supply and Sewerage Board's (BWSSB) resourcefulness (resource availability and service capability). This is because of three reasons: one, the water is potable and can be put to better use than for flushing toilets; two, the state significantly subsidises the cost of making water available from far-off rivers (FAQ); and three, 45% of water being supplied is lost in transmission (IBM/BWSSB, 2014). Consequently, the necessity for drawing an increasing amount of groundwater has become unavoidable in many localities and very frequently agricultural bore wells fill this gap, supplying water to residential areas. This has resulted in an appreciable loss from the groundwater table and the situation gets aggravated at multiple localities in the summer. Averting these situations requires redesigning the system of managing waste right from the collection stage.

Supplying an estimated 150 litres per head, close to 800 sq. km of Bangalore has piped water (IBM/BWSSB, 2014) though close to 475 sq. km has no sewerage system (Verhagen, et al., 2012). Hence, households resort to constructing storage or septic tanks inside or outside their plots. These tanks store black water and are emptied periodically by private mobile sanitation tanks that suck the waste and dispose it onto farmlands of consenting farmers without any treatment. The practice of honey-suckers operating outside of law and legislation in Bangalore is exemplary in this regard (Verhagen, et al., 2012). The disposal of untreated toilet waste is harmful to agricultural labourers coming in direct contact with it or consumers of the agricultural produce soiled by untreated waste. The World Health Organization (WHO) recommends a standing time of at least a year for separated faecal sludge before being used in farms by which time the pathogen proportion is reduced to tolerable limits for humans and agricultural uptake (WHO, 2006). Human excreta is a rich source of required nutrients for plants. A study estimates that annually the amount of food grain necessary per individual can be grown out of a crop fertilised by the nutrient in that individual's waste (Vinnerås, 2001). Areas assigned by the Bruhat Bangalore Mahanagara Palike (BBMP) and BWSSB for such safe disposal do not attract private players, as they levee a fee and they are better off disposing waste in the lands of consenting farmers nearby. Before the sewerage system is laid and irrespective of whether the locality has potable water supply, there is a need to solve the problem of disposing toilet waste irresponsibly. Ensuring that minimum water is used in the process and least harm done to natural resources is necessary in this process. This article presents the design of a sustainable system of handling household organic waste, considering the stakeholders involved.

Section 2 describes the methods used for research and design. Section 3 identifies requirements based on the results of a customer survey and market survey to formulate problem statements aligned to proposing a solution. Section 4 details aspects of the selected solution. For developing an end-to-end holistic solution, Section 5 discusses the inclusion of stakeholders, giving due consideration to their requirements. Section 6 concludes with findings and recommendations, and lays out directions for further work.

2 Method

A survey was conducted amongst typical houses in Bangalore and Chennai to understand the composition of urban household organic waste generated daily. This includes kitchen and human waste. As the existing solutions for sewerage and sanitation handling are long established, another survey to understand public perception of aspects of a new system of handling household organic waste was carried out amongst 60 respondents spread over Bangalore, Chennai, and Trichy. These surveys provide information on systemic requirements for the design of a new system. An extensive market survey of existing products in the domain of improved sanitation was conducted online to understand aspects of their solutions and amenability to urban Indian requirements. Based on these surveys, the whole system of managing organic waste has been functionally decomposed and candidate solutions conceptualised against all sub-functions. These candidates have been critically evaluated using the weighted objective method for criteria of evaluation drawn from the requirements that surfaced from the surveys. On having solutions across the sub-functions arranged in decreasing order of preference, a design that meets most of the urban requirements gauged from the surveys is selected.

3 Identifying stakeholders' requirements

In the rural scenario, as in the villages surveyed around Trichy, Ecological Sanitation or EcoSan is a widespread concept and its acceptability here is primarily driven by the dignity (freedoms) it ensures women. The products of EcoSan are also accepted locally. Practices of open defecation have decreased, as EcoSan has provided a secure alternative for women who were otherwise vulnerable to animals and antisocial elements late in the evenings. The practice of dry sanitation as part of EcoSan and the local agricultural demand for the composted waste as a source of fertiliser on the farms has made it prevalent. The practice of 'honey-suckers' comes close to adapting EcoSan in the urban situation, albeit in an unsafe way. The prevalent use of water for flushing in the commodes of urban toilets and the Indian practice of ablution makes the option of having dry toilets culturally incompatible. Also, the real estate required for a dry toilet and its unavailability on an average plot in Bangalore (and urban India) makes the option less feasible and unattractive. However, to sensitise people of the necessity to manage toilet waste better and understand their perception of aspects of EcoSan that could be emulated in the urban situation, a survey was conducted among households. The survey was particularly targeted to assess water usage, gauge customer requirements and expectations of such a new product/system as waterless toilets, and gain quantitative understanding of issues such as space, time, and investment. The households surveyed belonged to middle and upper middle classes in Bangalore, Chennai, and Trichy. The results are as follows:

- Ninety per cent of the respondents wish to use the new toilet and its end product.
- Forty per cent of men do not prefer to sit (like in a Western commode) to urinate.
- People living in apartments preferred the treatment system to be underground or in the basement while individual householders preferred underground or their backyard.
- Even if the muck (faecal matter) is safely treated, few respondents showed willingness for in-house treatment/storage.
- Respondents were willing to spend up to INR 10,000 on an average for the new toilet from a minimum of INR 3,000.
- Respondents emphasised that the system should operate without electricity or consume as little as possible.
- Agricultural labourers spend 80% of their monthly income (INR 1,250) towards building an EcoSan toilet.

Table 3.1 Market survey of products for improved sanitation

Aspect Brand	Urine diversion	Mode of water saving	Composting and Tech	Technology for urine handling	Innovation	Remarks
Sensor flow	Urinal only	Senses and solenoid regulates dispensed water	--	--	Infrared sensor, adjustable time for water flow	Requires 12 V and a thermostat
Eloo	Source separation	No flush; Dry toilet Toilet water evaporated	Aerobic Composting, self-contained Bacterial and biological technology	Diversion and vented evaporation	Ventilation, use of radiant heat to aid composting	Tank large enough to hold a year's waste and emptied then
Envirolet	--	No flush; Dry toilet Toilet water evaporated	Aerobic Composting, Self-contained Fans and chimney aid odour escape Automatic six-way aeration process. Dual fans, C acceleration by microbe addition. Occasional garden peat moss added Aerator bar (with mulcherator blades) aids composting)	Diversion and vented evaporation Thermostatically controlled heat element evaporates	Automatic six-way aeration process	Cleaned once in a year (since 90% of toilet waste is water that can be evaporated); Three variants 120 V AC type; ($1,750) 12 V DC type; ($1,725) Non-electric ($1,550)
Kiwibog	Source separation	Almost no water use (claim)	Aerobic Composting	--	--	12 V & 230 V models
Separett	Source separation	No flush; Dry toilet	Aerobic Composting, self-contained Fans and chimney aid odour escape	--	--	110 V or 12 V models
Sun-mar	--	No flush; Dry toilet Toilet water evaporated	Aerobic Composting, self-contained. Fans and chimney aid odour escape, three chamber design. Evaporation chamber Bio-drum for better composting	Filtering and seeping of excess grey-water and vented evaporation. Thermostatically controlled heat element evaporates	Three chamber design; Evaporation chamber; Bio-drum for better composting	110 V Self-contained and centrally located modules available
Roevac	--	Vac. i.e. flush with air	--	--	Central and decentralised vac pumps	Vac systems
Falcon-free	Urinal only		Cartridge with sealant prevents odour and saves water per flush	Bio-degradable liquid sealant	Bio-degradable liquid sealant	Possible smell
Uridan	Urinal only		Cartridge with sealant prevents odour and saves water per flush	Bio-degradable liquid sealant URILOCK	Bio-degradable liquid sealant URILOCK	Possible smell
Urimat	Urinal only	Float seals odours	--	Sensor activated float seals off odours	Float design Recyclable PC pan	Possible smell
Cotuit	Source separation	No flush; Dry toilet	Aerobic; self-contained Humus (5–10 days), oxygen limiting (for hot weather) and dehydrator modes	3:1 dilution and direct application as fertiliser	Two modes & absence of moving parts; anti-splash back filter pad	Hardwood planer shavings to aid composting
Naturum	Source separation	No flush; Dry toilet	Aerobic, rotating drum aids self-contained composting	No treatment, drained out	Rota-drum	Drum can hold 30 litres of compost mass

Table 3.1 (contd...) Market survey of products for improved sanitation

Aspect Brand	Urine diversion	Mode of water saving	Composting and Tech	Technology for urine handling	Innovation	Remarks
Rota-loo	Source separation	No flush; Dry toilet	Aerobic Requires basement installation, rotating drum aids composting	Rotaloo: Evaporation Aided by SOLTRAN module Ekolet: Biological pre-cleansing liquid mixed with compost	Rotating sectors of containers SOLTRAN module for providing composting environment	Turntable No raking Forced ventilation possible
Nature-loo	--	No flush; Dry toilet	Aerobic, self-contained			Possible smell and vectors
Bio-sun		No flush; Dry toilet	Aerobic, basement tank Humus (2 – 5 yrs) Batch-type	Evaporation	Mixing with kitchen garbage	Excel-aerator™ forced ventilation system; Suction through ventilating pipes
Ecolet	--	No flush; Dry toilet	Aerobic; self-contained; Humus in 2–3 months or a year depending on use. >18ºC maintained by thermostats etc.	Heated thermostats Evaporates excess liquid; fans forced draught aids evaporation	Composting acceleration	25 W fan; 225–310 W heater Electric and non-electric model available
Clivus Multrum	--	No flush; Dry toilet	Aerobic Composting, self-contained under the basement	Drained out	Uses starter bacteria	Heavy duty 12 V fan NO extra heater Wood shavings mix
Phoenix	Separated later with baffles	No flush; Dry toilet	Aerobic Composting; (2, 4, or 8 toilets can feed a composting tank). Liquid spray to keep moist. 1 or 3 shafts with tines for aeration	Liquid spray to keep moist Excess is leached, evaporated, or stored in holding tank	Improvements over Clivus Multrum	5 W fan for circulation consuming 45 kWh per yr
Equaris	--	Vacuum flush One pint per flush	--	--	BMRC technology	Draws 4–6 amps in use
Ekologen	Source separation	One-pint flush	--	--	Vacuum flush	--
Biolet	--	No flush; Dry toilet	Aerobic Composting (> 2 yrs regulation), self-contained	Thermostat evaporates, forced ventilation	Motor driver turner puts waste out of sight	--
Watermatrix	Urinal only	Liquid sealant Eco-trap	~	Liquid sealant Eco-trap	Liquid sealant Eco-trap	Possibility of smell

- The elderly preferred a portable toilet.
- Treated compost should be absolutely safe to handle.
- Product should be hygienic to use. It should not smell at all.
- Solid waste should not be visible after flushing (by whatever means the new system achieves it).
- Cleaning should preferably be carried out every six months.
- Fifty-five per cent of the respondents showed considerable unwillingness to sit while urinating.
- Product should be easy to operate, requiring minimum maintenance. The system should automatically handle and discharge waste.

Customer requirements translated to system/ technical requirements

- Complete (or to an extent that is harmless to humans) killing of pathogens.
- Pungent odours from H_2S, Indoles, Mercaptans should be trapped/treated well.
- Generated waste has to be transported: first, out of sight without a trace, and; second, to the treatment centres with minimum user involvement.
- Moving parts need to be avoided as far as possible to reduce the maintenance required.
- Toilet needs to be accessible to people unable/ unwilling to sit for urinating.
- Menstrual waste has to be handled by the same toilet pan.

A market survey was also conducted online to understand how different products/systems in the domain of sanitation deal with the problem of managing toilet waste and to enable classification of the problem/system into broad sub-problems/ sub-systems.

On surveying the market extensively for products in this domain, we found that no single product existing in the market meets all of the customers' requirements. Further, the following functions (Table 3.2) are identified as essential to a waste handling system in this domain. Against these, in the adjacent column, are functional descriptions. The identification of functions and describing them allows a systematic consideration of the different stakeholders involved beyond the users. Possible stakeholders are listed in the last column of Table 3.2. Understanding the varied nature of requirements of these stakeholders in the broad Indian and local context provides the basis for holistic solutions that function inclusively and systemically.

Table 3.2 Stakeholder identification across problem functions

Function	Functional description	Possible Stakeholders
Collection	Collect all types of muck effectively at point A	Manufacturer; users of different genders, abilities and capabilities; cleaner/maintainer/servicing personnel; civic sewerage, water supply, pollution control, and town planning bodies
Conveyance	Transfer collected muck completely to point B	Manufacturer; private players; householder; apartment association office bearers; civic sewerage, water supply, pollution control, public health, and town planning bodies
Sanitisation	Render muck harmless to humans henceforth	Manufacturer; private players; householder; apartment association office bearers; civic sewerage, water supply, pollution control, public health, and town planning bodies; local residents
Treatment	Convert safe muck into a form acceptable to earth (i.e. that which could be taken up by agriculture and which does not despoil aquifers, water bodies etc.)	Manufacturer; private players; householder; apartment association office bearers; civic sewerage, water supply, pollution control, public health, and town planning bodies; local residents
Despatch	Conversion into a saleable/carry-able form and delivery	Agriculturists; horticulturists; farmers; private players; nurseries; householders; public health and safety bodies; pollution control bodies

The following are the perceived requirements of the stakeholders. These are partially raised by the customers being surveyed out of concern for an appropriate system while the others are perceived personally from the experience of the authors.

Manufacturers, as stakeholders here, include those manufacturing all aspects of the system end-to-end. For example, within the existing system, they include manufacturers of pans, commodes, and flushing tanks such as Parryware and Roca at the collection stage and manufacturers of plumbing, storage, and holding tanks at the conveyance and storage/treatment stage. Apart from timely surface cleansing, the ceramic ware of existing commodes do not generally require service within their lifetime though the plumbing may need maintenance twice or thrice in the lifetime of the commode. As the plumbing work is separated from the 'pans' and 'western commodes', this maintenance is performed by plumbers (in absentia, masons) available locally. Currently practitioners follow masonry procedures similar to that related to the construction of water retention tanks. Consequently, problems of seepage to the water-table cannot be ruled out. Apart from this, installation of the pans/commodes is done by the masons whose availability and skill levels are reportedly fast depleting.

Users of different genders expressed their interest as stakeholders in requiring the system to handle menstrual waste at the collection stage just as the existing system does. Men were reluctant to sit while urinating. Unless using an Indian commode or what is called the Orissa Pan, children below three feet height cannot use the western commode, resulting in them urinating in the bathwater sewers or open drains sometimes. Combining the requirement of men and the children requires the urinal to reach the users as a possible feature in the system. As this reduces the amount of contact with the system, it scores well on the hygiene front. Also, this feature aids the elderly and women at the collection stage and can potentially reduce the amount of water required to flush. There remains a significant amount of stigma related to changing the existing system of collection and storage irrespective of the respondents accepting that these are water intensive and need replacement.

The private players include entrepreneurs who make the concrete rings necessary for building septic tanks or storage tanks, the architects/civil contractors who design and build tanks onsite or on public space adjacent to the householder's plot, those who make the PVC plumbing and holding tanks privately, particularly for holding toilet waste, and those who periodically collect the faecal sludge from such tanks and transport it onto farmlands or composting sites. People who transfer the products of treating faecal sludge and the farm produce fertilised with it to prospective markets of users also fall within this category. Agriculturists producing edibles using products of treating faecal sludge and horticulturists and nurseries producing non-edibles are some other stakeholders whose interests vary widely.

Mahatma Gandhi considered improving sanitation more important than independence for India. The public benefits of improved sanitation are enormous. In Bangalore, existing sewage treatment plants (STPs) operate below their maximum limit while new STPs are slated to be installed by 2016 by which time all sewage would be completely treated. Thereafter it will be let out into natural water bodies or storm water drains wherefrom it can be re-used. Insufficiently treated water let into water bodies is a major cause of infant mortality resulting from water-borne diseases. Pollution of water bodies is a significant public health issue and the Karnataka State Pollution Control Board (KSPCB) has many times pulled up the BWSSB, BBMP, and the Bangalore Development Authority (BDA) together for aspects related to inappropriate disposal of sewage, lack of monitoring of dumping yards, and insufficient standards in granting no objection certificates to plots that do not construct toilets (Deccan Herald, 2013). The lack of sewerage coverage at many places in Bangalore has resulted in individuals and commercial establishments letting out their sewage into storm water drains (DNA, 2011). Consequently, the re-use of water that otherwise did not require treatment poses serious public health risks.

The survey conducted in Trichy revealed that most of the small-scale farmers were users of the produce of the composting toilets and had a mixed response to questions of acceptance. However, due to the widespread work of NGOs such as SCOPE, the concept of EcoSan is widely prevalent and has come to be accepted well at the household level. The demonstration of these dry toilets and the nature of the result of composting, coupled with appropriate education in using diverting toilets were said to be reasons for their acceptance (as stated by SCOPE personnel). People who have built an EcoSan toilet on their plot spent close to a third of their monthly income on it while the state of Tamil Nadu sponsors the rest.

4 Selection and aspects of a solution proposal

Table 4.1 shows the various solutions that have been evaluated against each sub-function laid from the most desirable (right) to the least desired (left). The zigzag line shows the solutions chosen under each of these sub-problems. The proposed system of managing urban household organic waste end-to-end comprises all these solutions.

As the main nutrient resides in urine, a pan that separately collects urine is chosen. Though some field experts of SKG sangha have found this not necessary, it is chosen as the separation affords the freedom of using just urine. Further, the pan has a facility wherein its urine collection portion can be dislodged so as to aid men, the infirm, differently abled, and women. The mode of collecting faecal matter is the same as any vacuum toilet. As the stigma for handling waste in any different way persists, it is suggested that the odour be neutralised before being masked by masking sprays or de-odourisers. A two-stage digester that occupies space that was otherwise meant for holding tanks or septic tanks onsite is proposed here. The volumes of the digester have been designed around the generated volumes of toilet and kitchen waste in an average household of five on a 1200 sq. ft. plot and the prescribed retention times for the sludge by the WHO. On partially treating the faecal sludge onsite, it is proposed to be collected by the municipal authorities or licensed private players who convey it to treatment centres for complete treatment before using it on farms. Figure 4.1 is a schematic of the proposed system. Waste from the kitchen is mixed with toilet waste and gravity flushed into a macerator where it is macerated and pumped into the primary phase of anaerobic co-digestion. The primary phase occupies less space and is situated above the ground level and over the secondary phase of partial co-digestion lying below. The mixture of faeces and kitchen garbage requires an equal amount of water for the bacteria to digest properly, which would be provided by the ablution water and urinals during defecation. The primary digester has a feature centrally to facilitate addition of neutralisers and bacterial potions to eradicate stench and improve co-digestion. Addition of a neutraliser (generally cow dung) 10% by weight is necessary to neutralise the shock to which the bacteria may be subjected to had the composition of feed material varied drastically. The addition of new waste can continuously take place over the period of 30 days. The difference in the densities of old and new sludge ensures that the latter floats up. So a tank is positioned beside the digester to collect the overflow of 5-6 litres a day for N days (depending on the space available onsite) as necessary. The primary digester, secondary digester, and the annular volume in between these two volumes ensures sufficient retention time for the generated waste to be partially safe by the time it comes out and collects in the appropriately constructed holding tank. This partially treated faecal sludge can be sucked out by licensed private players or the BBMP personnel, wherefrom it should be rendered completely safe. Similar to the subsidised provision of EcoSan in rural areas by some state governments, the cost of this system requires fillips for adoption (AECOM International Development, 2010). The responsibility and subsequently the costs of treatment are in this way divided between the major stakeholders, that is, waste generators (householders) and the government interested in preventing disease outbreaks at large.

Table 4.1 Functional decomposition of the problem of managing urban household organic waste end-to-end

Functional decomposition	Ways of achieving sub-tasks in order of priority (left to right)					
Collection	Package	Urine diverting pan	Separate ablution	Drop hole	Separate pans	Reaching toilet pan
Putting it out of sight	Package	Rotating cone	Rotating cylinder	Paddle wheel	Rotating table	Moving hole
Rendering it odourless	Odour neutralisers	Odour masking				
Conveyance to sanitisation centre	Vacuum pump	Bio-bags Manual transfer	Screw conveyor	Rotating cone	Rotating cylinder	Dung beetle
Killing pathogens (temperature)	Microwave	IR blowers	Solar UV	Incineration	Insulation (gen heat retention)	X-rays
ph	Urea Competing microbes	Ash	Lime	(SDS) Sodium Dodecyl Sulphate	Glutaraldehyde (disinfectant)	
Humidity	Natural / Forced draught	Microwave	X rays	IR blowers	Solar UV	Incineration
Conveyance to composting centre	Vacuum pump	Bio-bags Manual Transfer	Screw conveyor	Dung Beetle		
Composting (Aerobic)	Inclined drum	8 concept				
Composting (Anaerobic)	Multi-stage continuous	Single-stage continuous	Single-stage batch wise	Multi-stage batch wise		
Despatch or Delivery	Manual pack, wheeled drums	Screw conveyor	Packaging	Municipal service trucks		

The total organic waste per day from a family of five is approximately 8.5 kg comprising: Kitchen waste generated everyday = 300 g (from surveyed households in Chennai and Bangalore); faecal matter per individual per day = 300 g (*5 = 1500 g); ablution water per individual 1000 mL or 1000 g (*5 = 5000 g); and urine per toilet use = 300 mL (*1 use (considering toilet use at work, school, etc.)* 5 = 1500 mL). Further, 8.5 kg or litres of such waste would give 1 m^3 of bio-gas. This comprises 600 litres of combustible methane approximately, the calorific value of which is 23 MJ. With a thermal efficiency of 65% for the stoves in general, 0.5 m^3 of biogas is enough for an hour's cooking on a single burner stove (tapped energy) providing approximately 12 MJ. This is sufficient for cooking for three people a day for a month. Based on the space available onsite, the digester volumes co-digest waste generating methane gas over a cycle time of approximately 30 days, beyond which the partially digested sludge is emptied into the holding tank where it is retained for more days before collection by the authorities. The fully digested waste would be a rich soil conditioner having N, P, and K and is proven to produce a good harvest of harmless banana crop (Sunitha, 2009).

5 Conclusion

The proposed system divides the problem of managing toilet waste in particular amongst the major stakeholders, that is, generators and the civic bodies interested in public health. The importance of handling household organic waste at the source more inclusively is the motivation behind the project. It may be noted that the co-digestion of kitchen and toilet waste is suggested along with urine and water during and after defecation respectively. The latter cannot be culturally done away with and the former is a source of the required nitrogen to keep up the C:N ratio within desirable limits. However, a urine-

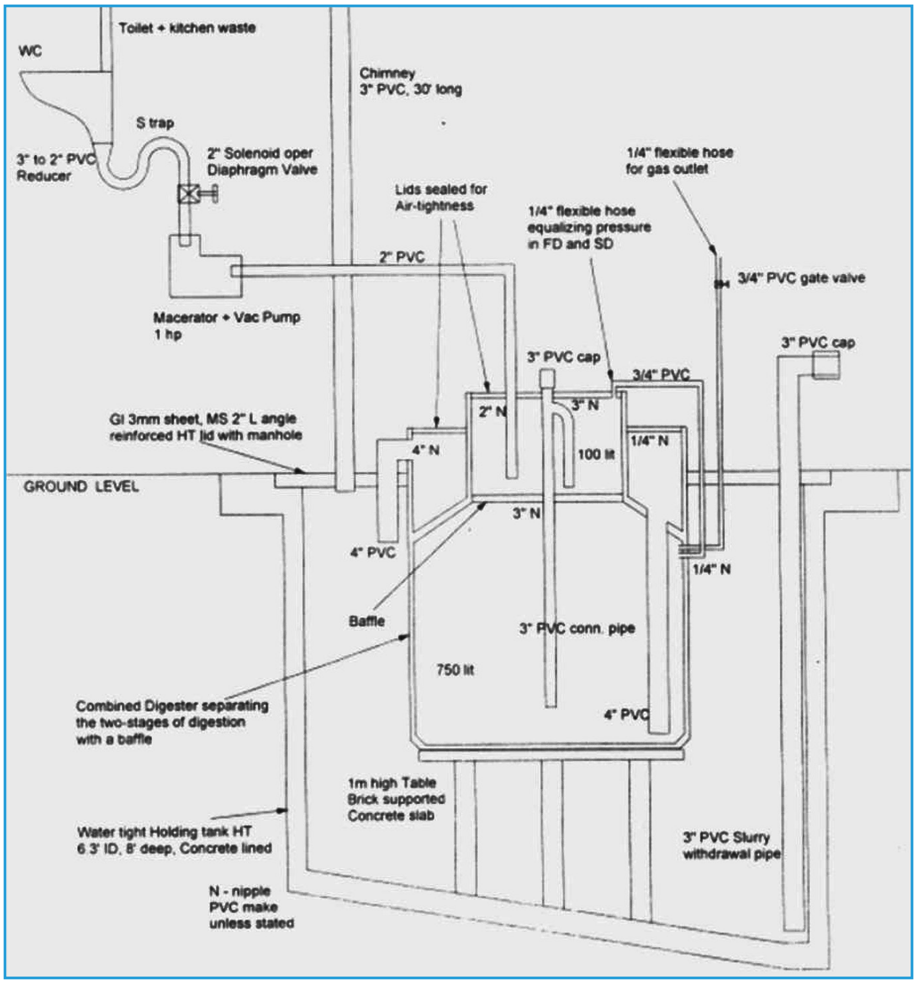

Figure 4.1 Recommended layout for partially digesting urban household-organic waste

diverting pan is still provided as a feature only to aid the profile of users at the collection stage. There is perceived requirement for a pan which further reduces the water usage that goes into cleaning the pan itself after every usage. Also, the products of digestion need to be piped or packaged separately, as the stigma around it remains prevalent even in rural areas. The associated stench while burning biogas requires the stove to be in the open, which in turn, drastically brings down the thermal efficiency of the stove. Hence, solutions for on-site storage and utilisation/sale of the gas generated are future requirements.

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