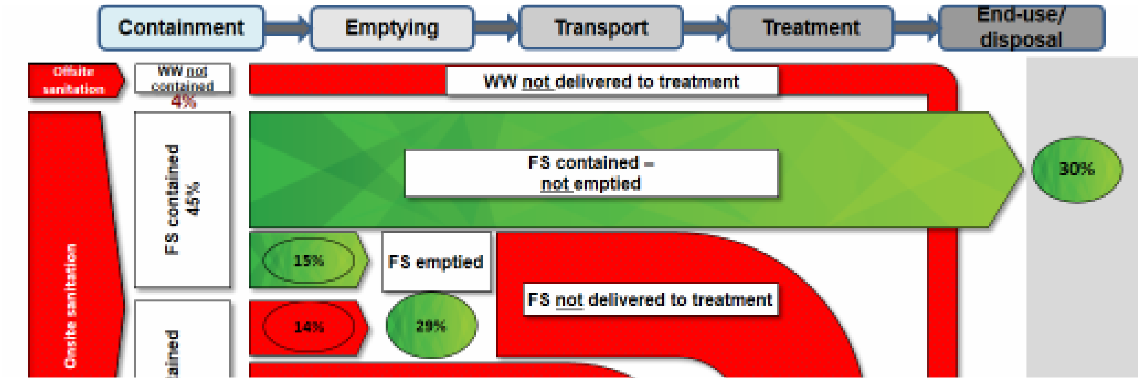
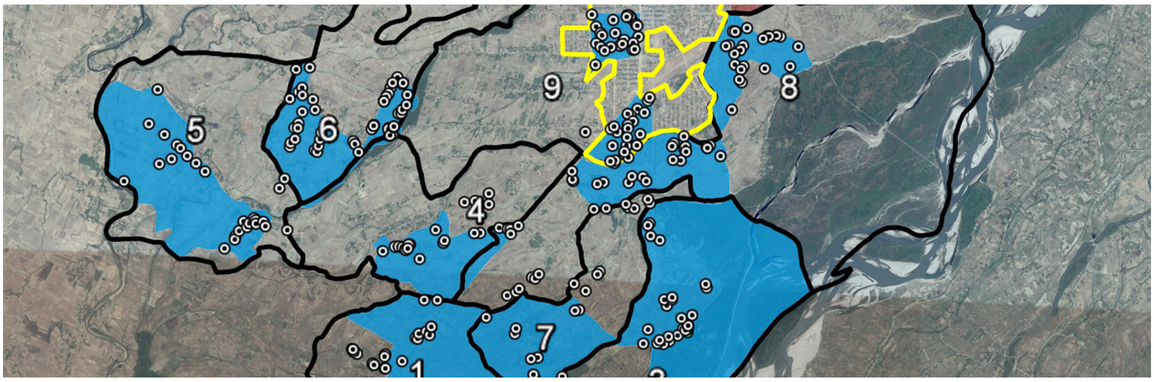
Tikapur Municipality

Tikapur City Sanitation Plan

January 2018





500B solutions

In collaboration with

eawag
aquatic research

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Contributions

This Tikapur City Sanitation Plan was written by Mingma Gyalzen Sherpa and Anjali Manandhar from 500B Solutions Pvt. Ltd. They led the planning process with support from various individuals and experts. The baseline survey was led by Dibesh Sayami with support from Marius Klinger. Marius played a key role in data compilation, analysis and in preparation of the baseline report. Birendra Kayastha provided his expertise to develop the baseline survey sample design. Tobias Kraft provided inputs in the sanitation system selection process. Christoph Luthi from Eawag-Sandec technically backstopped the planning process. Tikapur Water Users and Sanitation Committee were instrumental in coordinating with the local stakeholders.

Eawag-Sandec provided financial support to develop the plan. The Third Small Town Water Supply and Sanitation Sector Project provided the enabling environment to work in Tikapur.

The report was reviewed by Phillippe Reymond and Vasco Schelbert from Eawag-Sandec and designed by WPS.

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Acronyms

ABR	Anaerobic Baffled Reactor
ADB	Asian Development Bank
AF	Anaerobic Filter
BDA	Building Design Authority
BOD	Biological Oxygen Demand
CAPEX	Capital Expenditure
CBO	Community Based Organisation
CSP	Citywide Sanitation Plan
CW	Constructed Wetland
DDC	District Development Committee
DWSO	District Water Supply Office
FCHV	Female Community Health Volunteer
FGD	Focus Group Discussion
FS	Faecal Sludge
FSM	Faecal Sludge Management
HFCW	Horizontal Flow Constructed Wetland
MoFALD	Ministry of Foreign Affairs and Local Development
MoU	Memorandum of Understanding
NPR	Nepali Rupees
O&M	Operation and Maintenance
OBA	Output Based Aid
ODF	Open Defeacation Free
OPEX	Operating Expense
PVC	Polyvinyl Chloride
SFD	Shit Flow Diagram
SLA	Service Level Agreement
TDF	Town Development Fund
TPO	Town Project Officer
TS	Total Solids
TSTWSSSP	Third Small Town Water Supply and Sanitation Sector Project
TVS	Total Volatile Solids
VDC	Village Development Committee
WASH	Water, Sanitation and Hygiene

1. Introduction

The Third Small Towns Water Supply and Sanitation Sector Project (TSTWSSSP) is designed to improve the health and economic and environmental living conditions of people in small towns in Nepal. The expected outcome of the project is improved, affordable and sustainable water supply and sanitation services, which are governed and managed by locally accountable representative bodies. The project is funded by the Asian Development Bank (ADB), the Government of Nepal and the local users. The third phase project is currently being implemented in 21 towns. The project follows a successful, well-structured planning framework for the water supply component.

The TSTWSSSP seek to improve its sanitation planning approach and seeks to implement innovative, proven approaches on sanitation planning in some of its small towns. Based on the experience and outcomes from this piloting, TSTWSSSP along with stakeholders aims to contextualize and build evidence to institutionalize the planning approach for urban sanitation planning in small towns and emerging settlements in Nepal. As part of the collaboration, Tikapur, a town located in Kailali District in the far western part of Nepal, was selected as the first town to implement the planning approach.

This report provides an overview of the planning process, and the plan is based on the participatory consultation with the communities and relevant stakeholders.

1.1 Objectives

The key objective of the sanitation planning was to develop a City Sanitation Plan (CSP) for Tikapur based on a participatory planning approach and to recommend set of actions for improving the environmental situation based on the discussions and feedback from the community and stakeholder consultations.

1.2 Scope and limitations

The scope covers the prioritized sanitation components among the competing environmental sanitation needs. The report outlines a conceptual framework for the proposed solutions and not a detail engineering design and cost estimates of the solution. However, based on the experiences of implementing similar solutions, tentative investment costs have been included for the proposed service options.

1.3 Project area

Tikapur is a municipality of over 60,000 inhabitants (56,136, 2011 census), located on the right bank of the Karnali river in the Terai district of Kailali, in Nepal´s far western region. It is a "new town" and was founded about 50 years ago and is composed of four main different socio-economic settings. There is a well-planned core-urban area in Ward 9, which is based on a master plan prepared in 1972, which allocated land for future infrastructure like roads, drinking, storm and waste water, health and education services or electricity.

In the eastern part of Ward 9 and 8, ex-bounded labourers from Tikapur have been allocated land and now form a dense settlement with access to the road network and electricity. Around this area, there are also illegal settlements of displaced people that have built their homes on municipal land. They have no access to electricity nor proper sanitation and are in the process of negotiating their relocation. The rest of the municipality consist of peripheral semi-urban and rural areas which cover Wards 1, 2, 3, 4, 5, 6, and 8 (Figure 1).

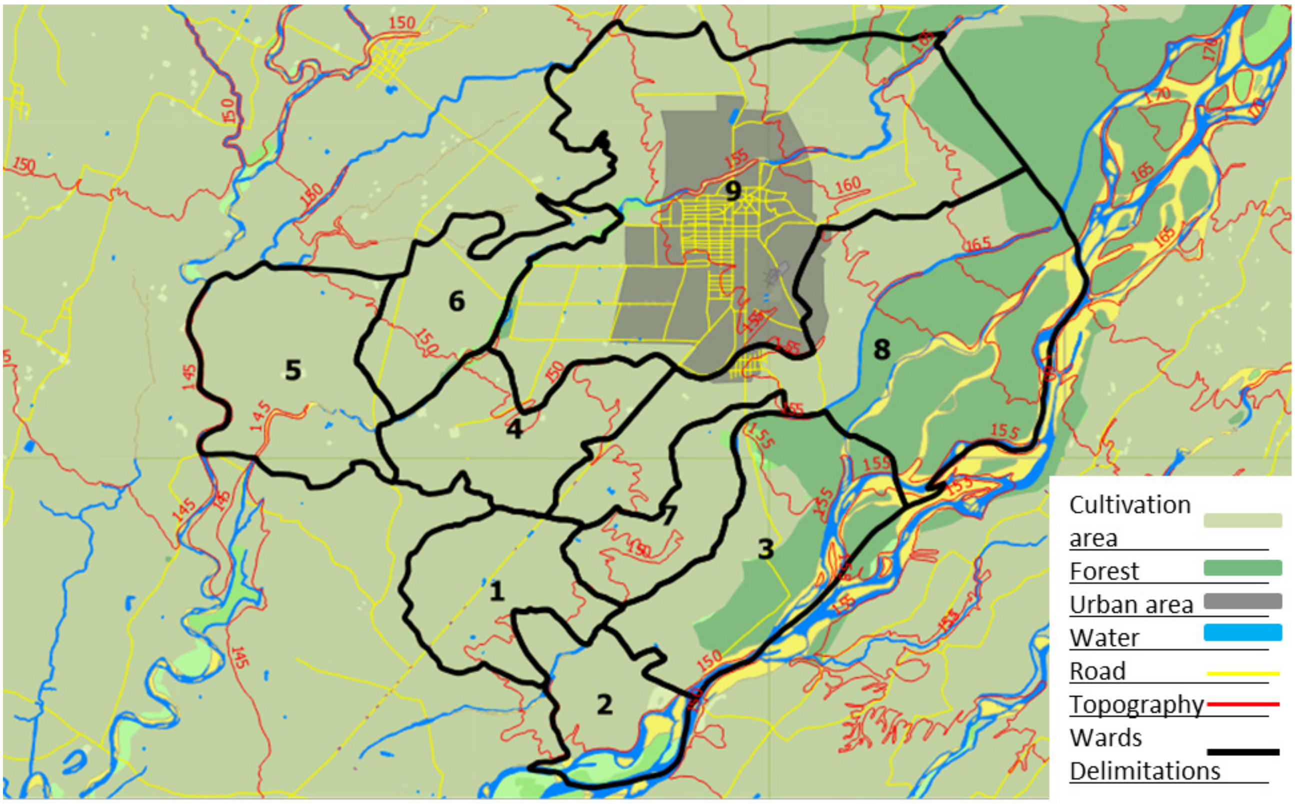


Figure 1: Map of the project area with the municipal boundaries

The CSP planning process covered the entire municipality, except for the informal settlements, based on the decision of the CSP task force and the municipality.

Table 1 provides a summary of the demographics.

Table 1: Demographics of Tikapur

Total municipal surface	67.2 km^2
Population of the municipality	56,127 (as per 2011 census)
Population growth rate	2.35% (Ward 9: 6.98%)
Population density	400-1600 persons/km^2
Residents per household	6.3 (average)

Population density

In Tikapur Municipality the peri-urban settlement covers a large portion both in surface (94 % of total surface) and population (63-65% of total population). It has a low population density of 5.32 p/ha. Main source of income for people here is agriculture and livestock.

The densely populated urban core area has a population density of 16.2 p/ha (Figure 2). The main source of income for people living in the urban part are services and business. The core area also has access to a piped water supply network. Parts of Ward 9, which is the largest ward, falls in the urban core of the Municipality with an estimated population of 16,000. The rest of the Ward 9 and all the other wards are considered as peripheral peri-urban settlement areas with a population of 34,000 people.

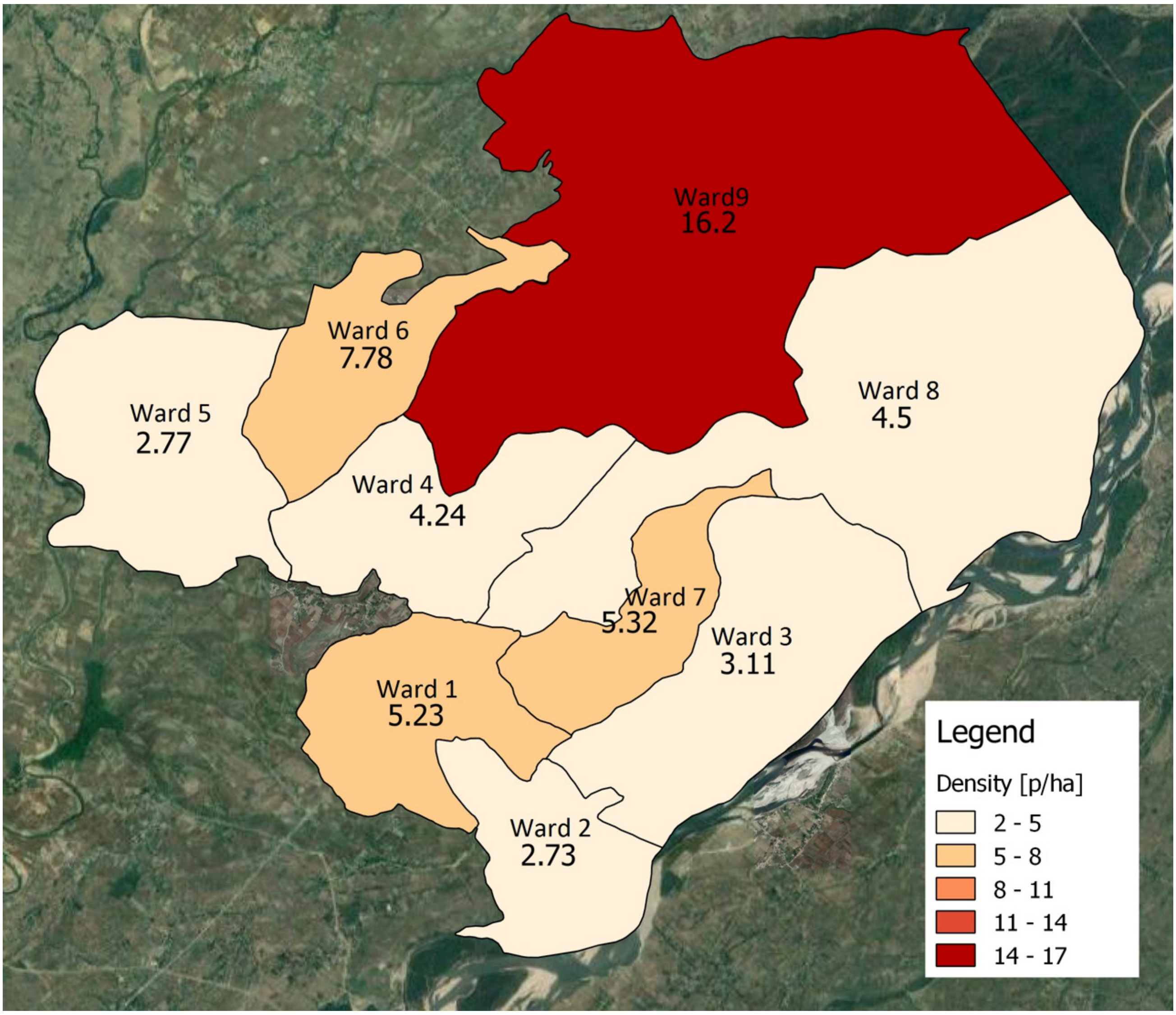


Figure 2: Ward wise population density distribution, Tikapur Municipality

1.4 Planning framework

In the context of Nepal, following a massive success under the open defecation free (ODF) campaign, access to sanitation has increased significantly. It is likely that the national target of achieving 100% sanitation coverage by 2017 will be achieved. However, the national ODF movement has a major focus on the user interface and providing basic access to sanitation. In an urban context, there is an urgent need to think beyond ODF and consider addressing the remaining sanitation chain components from containment, conveyance, treatment and end use along different waste streams. There is a need to look at different waste streams individually, integrate and address it through a holistic approach to address the growing urban sanitation problems such as wastewater management, faecal sludge management and solid waste among others.

Under this context, the Citywide Sanitation Planning (CSP) provides a structured planning framework to improve environmental sanitation situation of settlements. It follows a step-by-step guided approach to sanitation planning providing ample opportunities for stakeholder interaction and dialogue mainly through its different planning stages on: i) baseline assessment and prioritizing needs, ii) selection of appropriate solutions through a process of informed decision making and iii) preparation of a realistic implementable action plan to address the pressing needs.

The need for a new approach towards planning for improved sanitation services in low and middle-income countries like Nepal emerged as a response to the inadequacies of conventional master planning approaches, which have paid insufficient attention to:

- Equitable service delivery requirements for low-income and informal settlements, which often need arrangements that differ from the mainstream services for the rest of the city.
- The important role of the private sector in sanitation service provision, notably small-scale entrepreneurs (both informal and formal).
- The potential benefits of alternative, innovative approaches for service delivery to overcome physical, financial or institutional constraints.
- The need to ensure that there is sufficient demand to pay for services and cost recovery to pay for operation and maintenance costs.
- Capacity building requirements required for ensuring that facilities and infrastructure are adequately managed and maintained.

City wide sanitation planning guidelines such as Sanitation21, serve as a city-wide planning tool to develop an equitable city-wide sanitation service delivery plan; guiding recommendations for upgrading services which are realistic within the local capacity for implementation and the availability of funding and resources. It encourages decision-making based on sound information and suggests improvements wherever information is missing to prepare the city for the next planning step. Complementing Sanitation 21, other planning tools such as the Community Led Urban Environmental Sanitation (CLUES), also tested and validated in Nepal, provides a step by step approach to sanitation planning at the neighbourhood and community level.

Likewise, the book on Faecal Sludge Management, Systems Approach for Operation and Implementation, published by IWA (2014) is also a valuable guideline for the integrated planning of FSM systems.

2. Methodology

2.1 Launching workshop

Following an understanding with the Project Management Office (PMO), TSTWSSSP and the Tikapur WUSC to conduct the CSP, a launching workshop was organized in Tikapur to orient the different stakeholders about the objective of the planning process, methodology, timeline and the tentative outcomes. The intent of the workshop was also to gather local momentum on the process and garner support from the stakeholders during the planning process.

2.2 Assessment of baseline situation

Baseline data was collected in Tikapur through a randomized sample household survey during April, May 2016. The main objective of the survey was to understand the environmental sanitation status of Tikapur Municipality, particularly on access to toilet facilities, faecal sludge management, wastewater management status and solid waste management.

2.3 Need prioritizations workshops

During the assessment period, several focus group discussions and workshops were also conducted to collect issues and concerns of the users and identifying key needs and priorities with respect to environmental sanitation. In addition, potential stakeholders were also identified who would be influential in the process of developing and implementing the Citywide Sanitation Plan.

The information and data generated from the survey was analysed using multiple analysis tools and a concise situational analysis report was produced. The assessment was done in close collaboration with the Regional Project Management Office of the Third STWSSSP, Design and Supervision Consultant team, Water and Sanitation Users Committee and the Municipality.

2.4 Experts' workshop

An experts' workshop was organized in September 2016 in Kathmandu with an objective to discuss on the environmental sanitation situation, priorities and needs identified in the baseline situation assessment exercise. The expected outcome of the workshop was to identify potential solutions and implementation modalities. The participants were grouped into three thematic groups viz. sanitation and black water management, solid waste management and flood and storm water management. The outcomes from these discussions were discussed with the community and incorporated in the environmental sanitation plan.

2.5 Analysis of service options and combinations

Following the experts workshop, further technical analysis was conducted to draw out the service combinations for the prioritized needs. A group of components experts worked on the specific components. Likewise, an ETH Master's thesis was also in-built which specifically analysed the service options and combination for black water management. The identified options and service combinations were consolidated and discussed further with the town level stakeholders before the plan was finalized.

3. Situational analysis

The environmental sanitation situation assessment was based on two mains tools: (a) randomized sample household survey and (b) the *Sanipath* health risk assessment tool. A total of 400 households were surveyed covering all the wards of the Tikapur Municipality. The questionnaire imcluded 140 questions on different aspects of environmental sanitation. The survey took 14 days to complete and was conducted by nine local enumerators. The mobile data collection application, *Kobocollect* based on ODK coding language, was used for data collection.

3.1 Drinking water supply

In the survey, 99.3% of the survey population responded that they had enough water for their sanitation needs. 71% of the respondents took 5 minutes or less to get water and only about 5% took more than 10 minutes. Concerning the connection to the new water supply network being built at the time of the survey, 54% thought they would be connected to it, 17% thought they would not and 29% did not know.

3.2 Faecal sludge management

3.2.1 Toilet access and status

Toilet coverage was found to be high in Tikapur Municipality (92%) with lowest coverage in Ward 6 (66%) and highest in the urban-core area (100%). 2% of the Municipality population were found to be practicing open defecation while the figure was 8% in Ward 6. Out of the population without a toilet, 33% practiced open defecation and 65% shared toilets with neighbours and family (Figure 3).

The surveyed toilets were either five years old or less (63%) or 10 years old or less (85%). On average, one toilet was used by 5.6 persons. The cleansing material was water for everyone (100%) and nobody disposed waste into the toilet. The toilets were found to be well maintained (99.5% of functional toilets) and used (99%). 63% of the toilets were considered to be clean during visual inspection by the enumerators. The main reason for not constructing a toilet for households was the high construction cost (64%) (Figure 4). Respondents were willing to pay an average of NPR 1,690 for toilet construction.

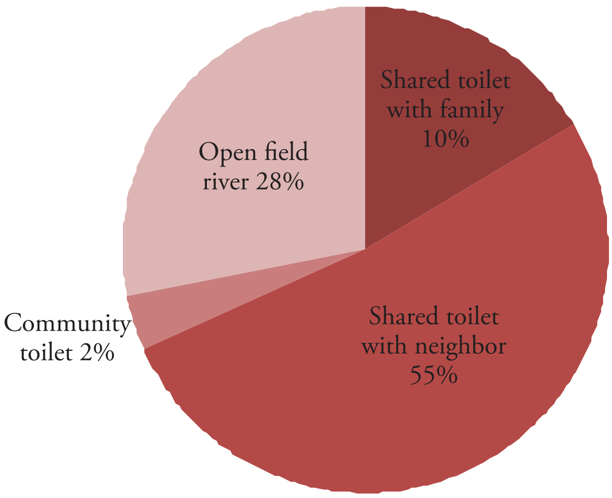


Figure 3: Defeacation site for household without toilets

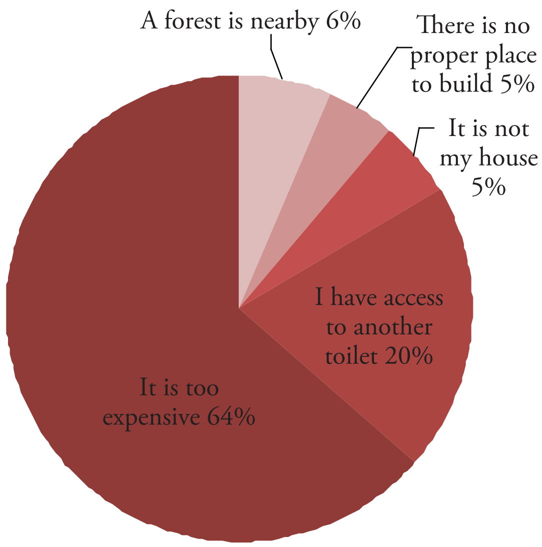


Figure 4: Reasons for absence of toilets

3.2.2 User interface

The predominant type of user interface was the squatting pour flush toilet (83%) followed by dry toilets (15%). This percentage was homogenous all over the municipality.

3.2.3 Storage/containment

Containment technology consisted of single pits (71%) and biogas digesters (18%) in the peripheral area and septic tanks (42%) and single pits (42%) in the urban core area.

Figure 5 shows the containment types at the municipal level.

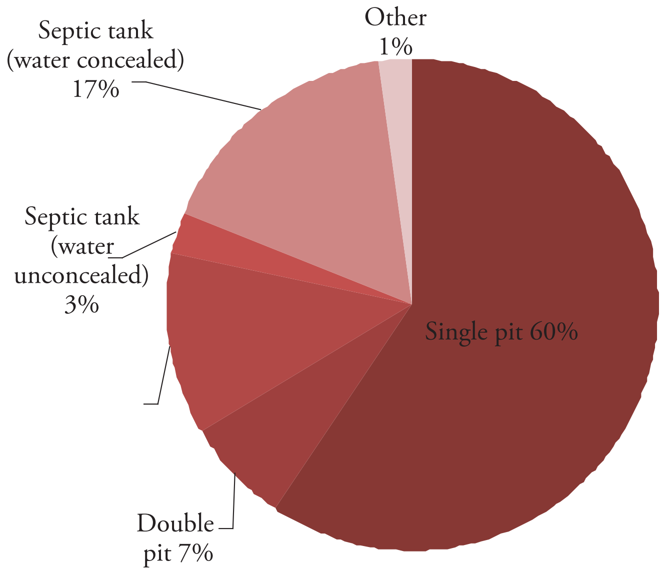


Figure 5: Municipality wide containment technologies

3.2.4 Conveyance

44% of the households had not emptied their septic tanks or pits as a majority of them were not yet full. One reason for this could be that the majority of toilets were only between 1-5 years old. Another reason could be the construction of the septic tanks/pits with an unlined bottom. 62% of the surveyed population hired manual emptiers to empty their septic tanks or pits (95% in the core-urban area and 50% in the peripheral area) while in 38% of the population, a family member emptied them. In 61% cases of emptying, no protective gear was used whereas in about 33% of the cases, at least gloves, boots or masks were used.

More than 50% of the respondents were paying the emptier between NPR 500 -1000/visit, while about 15% were paying between NPR 1000 – 2000 and a small percent of the population were paying more than NPR 2000/visit.

3.2.5 Sludge volume estimation and characteristics

Two methods of estimation have been considered for estimation of sludge volumes. The first method is based on a theoretical sludge production rate (Table 2) and the second is based on the results of the household sample survey (Table 3).

Table 2: Sludge volume estimation based on theoretical production calculation

Literature	Sludge prod L/ cap/day	Proportion of technology	Production rate L/day	Production rate m^3/d
Pit	0.2	0.6	6,600	6.6
Septic tank	1	0.21	11,550	11.55
Bio digester*	1	0.12	6,600	6.6
Twin pits	0	0.07	0	0
Total		**100%**	**24,750**	**24.8**

Table 3: sludge volume estimation based on household survey

Based on the survey results	Emptied systems (54% of tot.)	Mean estimated Volume [m^3]	Mean emptying frequency	Emptied sludge production estimate [m^3/d]	Production rate [m^3/d]
Pit	3240	1	1.6	14.2	22.8
Septic tank	1134	3	0.4	3.7	
Bio digester*	648	3	0.8	4.3	
Twin pits	378	1	0.6	0.6	

Among the two methods of estimation, the result of the survey-based method was considered closer to the field reality. It is estimated that around 23m^3 of sludge is generated in Tikapur per day. Considering a population growth rate of around 2.3%, it is estimated that the sludge generation rate will be 29 m^3/day in the year 2026 and 36 m^3/day in the year 2036.

Faecal sludge characteristics, could not be analysed during the situational assessment in Tikapur. The average total solids value of FS measured in 42 different samples in Kathmandu was found to be 27 g/L (Sherpa, 2005). 65% of the TS consisted of Total Volatile Solids (TVS). These values could serve as reference while designing treatment systems.

3.2.6 Treatment and end use/disposal

Emptied sludge is nearly always discharged directly into the environment (85%) without any further treatment, the rest being put into an alternative pit (14%). Figure 6 and 7 provides details on the emptying frequency and the end use disposal practices respectively.

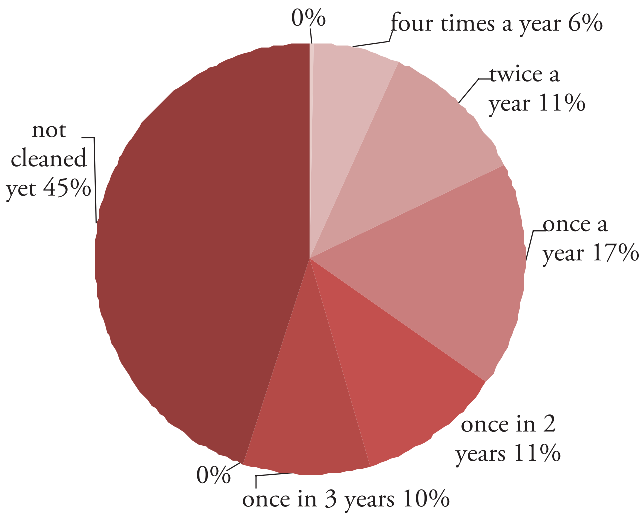


Figure 6: Emptying frequency

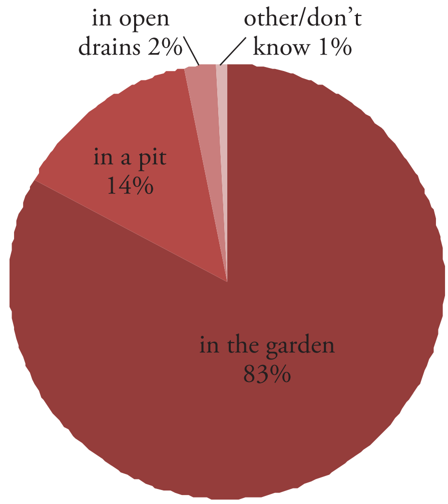


Figure 7: End use/disposal of emptied faecal sludge

3.2.7 Shit flow diagram

A shit flow diagram (SFD) was developed for Tikapur to communicate and visualize how excreta flows through the town. The main purposed of the SFD was for advocacy to communicate the status with non-experts and decision makers.

The shit flow diagram was developed for Tikapur (Figure 8) based on the information collected from the baseline survey and from other sources. The following SFD is a good estimation, but not an exact situation in the Municipality. While developing the SFD, the sludge contained in the single and twin pits at a safe distance from the drinking water sources were considered as safely disposed sludge. This accounted to 30%, marked in green in the SFD. Faecal sludge from septic tanks and slurry from biogas digester outlets did not undergo further treatment. The major intervention required is the faecal sludge management (FSM) after emptying of pit/septic tanks. With a high percent of the sludge from septic tanks/pits going directly into the environment without any treatment, a good emptying, conveyance and treatment system could improve the present sanitation situation in the Municipality.

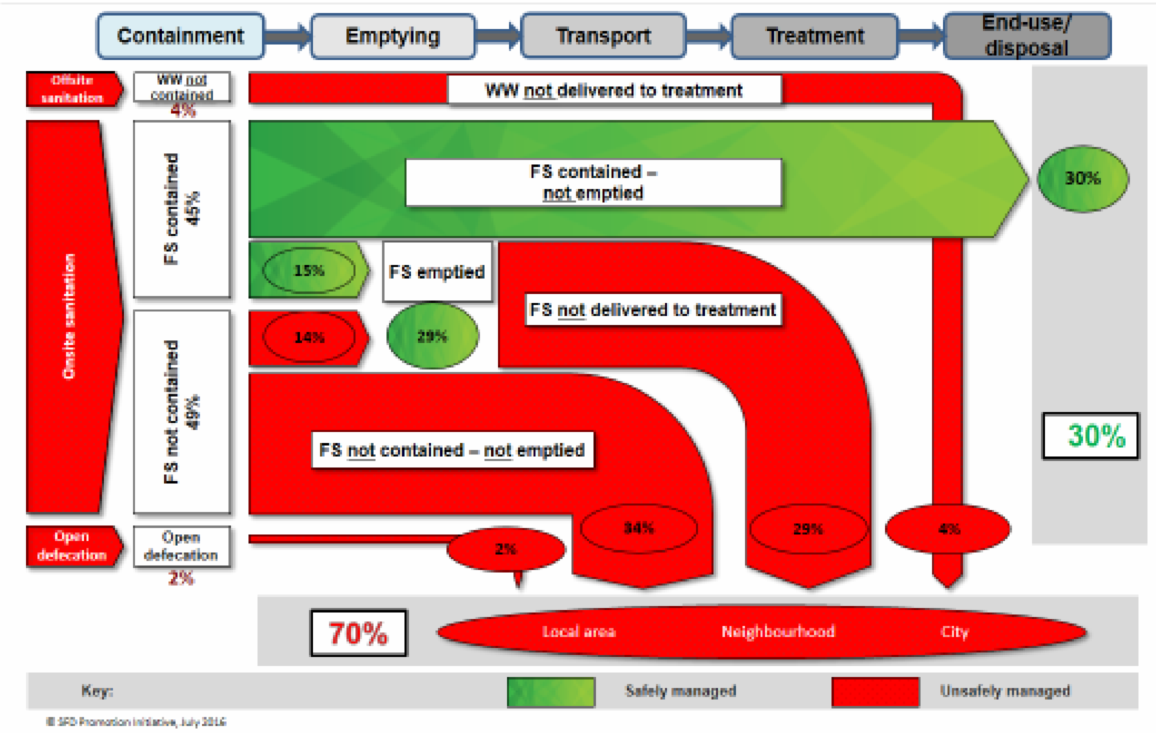


Figure 8: SFD for Tikapur

3.3 Grey water

The results showed that almost 70% of the greywater generated from the kitchen was being managed within the household premises either by sending it into a pit (47%) or allowed to flow into the garden (23%) while, around 20% discharged it into open drains and 10% into no specific place. As observed during the transect walk, some of the core low lying areas in Wards 9, had water logging conditions at the backyard of the house. As part of the urban development planning, space has been left for building storm water drainage lines in these areas.

3.4 Storm water and flooding

On average, at the Municipality level, only few people indicated of experiencing problems related to flooding. In the core-urban area, only 2% of the household surveyed mentioned having experienced flood related problems. In these areas, the flood induced problems were found to be localised, eg. ponding effect in specific localities. 84% of the respondents had never experienced flooding events. Figure 8 shows the flood prone areas in the Municipality. The core area in Ward 9 is the "low zone"with lack of drainage system. The pink shaded area receives flood water from the Karnali river. Wards 1,2,3 and 7 are the lowest area in Tikapur. These wards also do not have drainage facility, receives flood water from the river and also the washout from the rest of the Municipal area.

73% of the toilets were mentioned to be unaffected by flooding events. Those affected mentioned that the toilets (12.2%) and /or the septic tank/pit (3.8%) overflowed or/and were flooded (17.2% of the toilet and 4.2% of the septic tank/pit). Only 24% and 8% of the households reported septic tank/pit overflow or flooding respectively. In the flood prone Wards, the toilets overflowed in 59% of the households and/or were flooded in 55% of the cases (Figure 9). Of the population whose toilets were affected during flooding, 44% went for open defection whereas the rest either continued using the household toilets (31%) or found another toilet to use (25%).

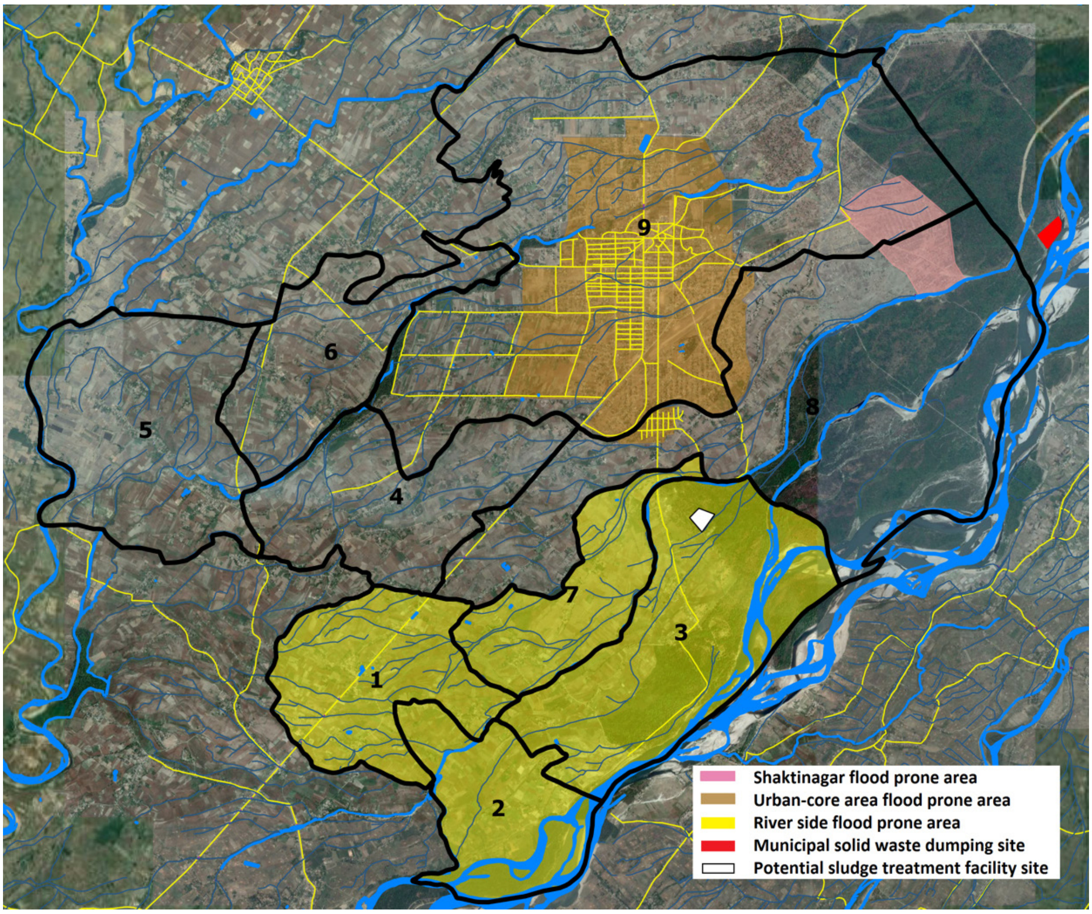


Figure 9: Flood prone areas in Tikapur municipality

3.5 Solid waste

From a previous study (ICON, 2015), the solid waste production in Tikapur was estimated at 11 tons/day. The municipal waste was estimated to compose of 39% organic waste, 7% plastic waste, 12% paper waste, 2% medical and 30% others, including glass, metal, sand/ dust.

During the baseline survey, most of the surveyed population said they segregated organic and inorganic waste (93%). The organic waste was managed at the household level either by burying in pits (65%) or by making compost (23%) (Figure 10). The inorganic waste was found to be burned (91%), sold (27%) or disposed into the river (22%). For the inorganic waste disposal, the respondents had the possibility to choose more than one answer (Figure 11). The municipality had assigned eight staff for solid waste management activities, which consisted mainly of sweeping the streets and transporting the wastes to two dumping sites.

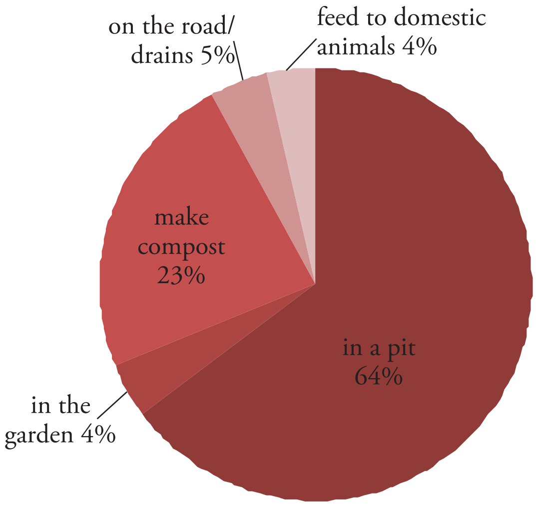


Figure 10: Organic waste disposal

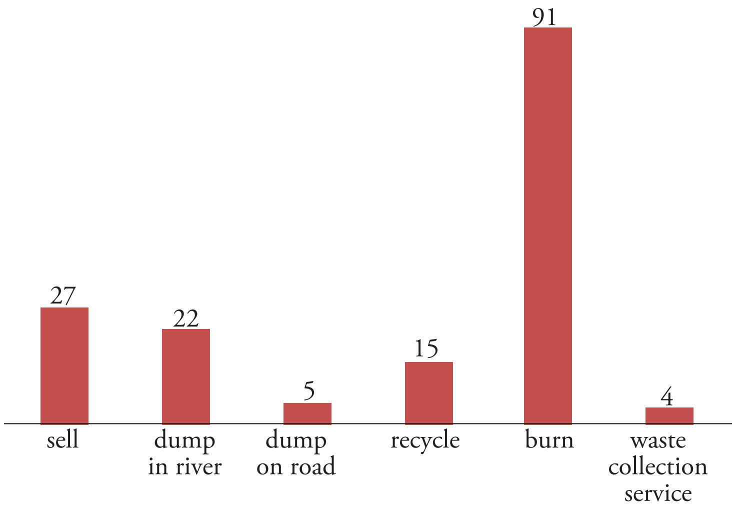


Figure 11: Inorganic waste disposal

3.6 Institutional and stakeholder analysis

The following section provides the details of the different stakeholders both at the local and national level. The stakeholder has been divided into process, primary and secondary stakeholders.

3.6.1 Process stakeholders

Department of water supply and sewerage

In the case of the TSTWSSSP, the Ministry of Water Supply and Sanitation (MoWSS) is the executing agency while Department of Water Supply and Sewerage (DWSS) is the implementing agency for the project. The Ministry is responsible for formulating and guiding the sector activities to meet the objectives and targets outlined in the national development plans while DWSS, as the lead agency in the sector, implements the project.

As part of the implementation arrangement, DWSS has a Project Management Office (PMO) at the centre to oversee day to day activities. There are two regional office for the East and Western part of Nepal. For Tikapur, the western regional office based in Nepalgunj oversees the project implementation and day to execution and coordination of the project activities.

Design and supervision consultant

Building Design Authority (BDA), the design and supervision consultant, was providing technical supervision of the ongoing water supply system implementation work in Tikapur. Besides, water supply, BDA was responsible for community mobilization, implementation of Output Based Aid (OBA) in sanitation and construction of selected number of public toilets in Tikapur. It also had a mandate to assist the Water User and Sanitation Committee (WUSC) to prepare the project implementation plan and schedule and advise technically during the project implementation period.

3.6.2 Primary stakeholders

Town development fund
The Town Development Fund (TDF) established in 1989 is governed under the Town Development Fund Act 1997. The legislation established the TDF as a government-owned autonomous body to provide financial, technical and institutional support and research to organizations involved in the construction and development of municipalities and urban centres. TDF is one of the major investors in the Tikapur Water Supply and Sanitation Sub-Project. Based on a financial appraisal, it has provided 30% of the total project cost as a loan to the WSCS and local government institutions.

Tikapur water users' and sanitation committee
The Tikapur Water Users and Sanitation Committee (WUSC) is a representative body established on behalf of the water and sanitation users in Tikapur. There are 11 elected members in the committee. The WSUC is responsible for the overall execution of the TSTWSSSP components, mainly on establishment of the water supply systems and proposed sanitation improvement interventions. The CSP process was executed with WUSC as the lead agency in close coordination with the local authority.

Tikapur municipality
Tikapur Municipality is the local governing body whose responsibility is to provide initial information necessary for the town project initiation. It also has a role to ensure that the WUSC formation takes place in the service area in a fair manner. Following the initial assessments and preparation of the project document and after endorsement by the District Development Committee (DDC), the local authority and the WSUC jointly submits the proposal to the Project Management Office at DWSS. In addition to these provisions, as per the project framework, 20% of the sanitation improvement component must be financed by the local authority while remaining 80% is funded by the project (ADB, 2000).

3.6.3 Secondary stakeholders

Community based organisations and institutions
There are many local institutions in the town project area such as schools, hospitals, health posts, college, offices, factories, restaurants, cinema halls and local youth clubs. These institutions were consulted as beneficiaries to calculate local water demand during the design, collect local information and to gather support for the programme. These institutions which are only beneficiaries of the project have been considered as secondary stakeholders.

District water supply office
Likewise, District Water Supply Office (DWSO) which is the district level office of the DWSS has also been categorized under the secondary stakeholder. Its role in the project is minimal as most of the work is executed through Town Project Officer (TPO), who is a government official appointed by the PMO, at each sub-project site. However, the DWSO has a coordination role to play between the centre and district level activities.

3.7 Needs and priorities on sanitation

Based on analysis of the baseline situation involving a series of assessment methods and techniques such as household survey, FGDs, interaction with local stakeholders, following were identified as the key issues and concerns in Tikapur:

Access to toilets:
- Even though toilet coverage was found to be high and open defecation rate very low at the Municipality level, toilet coverage was still very low in some wards like 5 and 6.
- A high percent of households without a toilet were using shared toilets.
- Need was felt for increasing access to private toilets to ensure 100% toilet coverage in the Municipality.

Awareness on public health:
- Prevalent faecal sludge handling practices are very poor leading to high environmental and public health risks
- A need of awareness raising campaigns to bring awareness among the public on the various environmental and public health risks issues

Faecal sludge management:
- A need to improve the containment units for reduced environmental pollution and public health risks
- Address the changing settlement pattern in the Municipality while developing sanitation systems. For example, there could be an increased demand for faecal sludge management services due to high proportion of septic tanks in newly built up areas
- Safe emptying and management of sludge from pits and the effluent from existing biogas digesters.

Storm water management:
- Prioritised concrete actions against flooding events in wards 2, 3 and 7.
- Detailed study on the need and opportunity of developing a storm water drainage system

Solid waste management:
- Presently, solid waste management is not considered a priority issue
- Identification of a landfill site for integrated management of solid waste and faecal sludge
- Development of a business plan by the Municipality for managing solid waste and faecal sludge management

4. Environmental sanitation improvement plan

This section proposes potential solutions for the different waste streams to improve the environmental sanitation situation of Tikapur. It also recommends an institutional framework for the operation and maintenance of the proposed options. Similarly, a capacity building component has been recommended as a cross-cutting theme to complement proposed interventions.

4.1 Faecal sludge management

4.1.1 Analysis of service options for faecal sludge management

A technical analysis conducted for Tikapur, showed that a centralised wastewater treatment plant connected to a conventional sewer system is not feasible for Tikapur due to the reasons below (Kraft, 2017):
- the low gradient in the Municipality,
- need of pumping stations every couple of 100m,
- long sewer network requirement, particularly to connect the scattered peripheral area. The capital expenditure (CAPEX) and operating expense (OPEX) will be huge for Tikapur if they opt for the conventional system due to a low population density. For peripheral areas, the best sanitation option is the on-site systems like twin pits, septic tanks and bio-gas digester.

Likewise, for the dense core-urban area, several sanitation options are possible which could be implemented in combination or as independent systems. Two service options: i) onsite system and ii) off site sewer-based options were compared for the dense urban area (Figure 12).

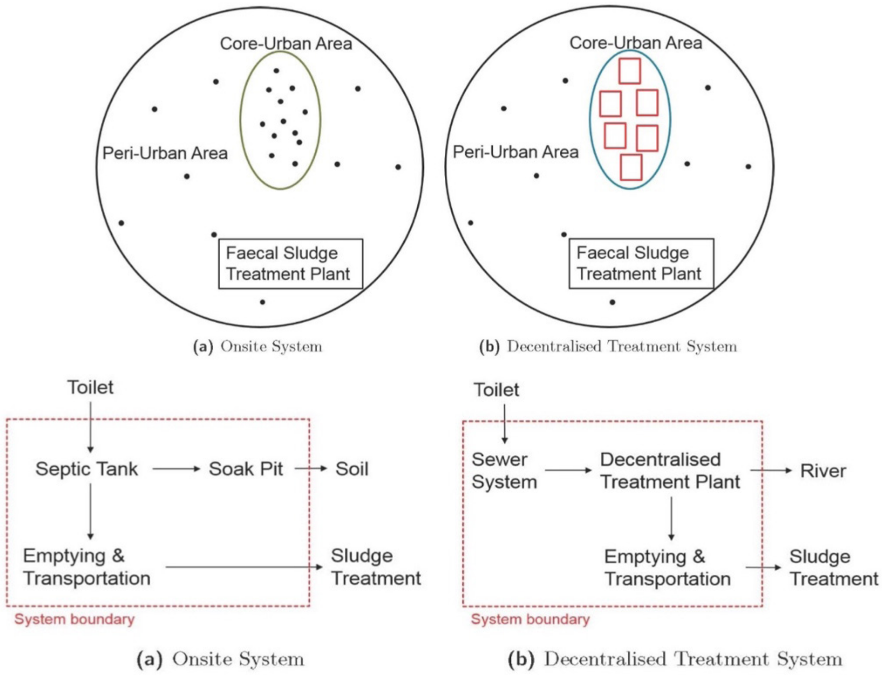


Figure 12: Schematic representation of the treatment systems

Comparative analysis of the service combinations showed that the decentralised wastewater treatment systems (Dewats) is cheaper than the onsite system over a planning horizon of 20 years and a population growth rate of 7% for the current situation in the core-urban area of Tikapur. The capital expenditure which includes the construction of proper septic tanks and soak pits for each household in the core-urban area are more expensive than building a simplified sewer system and decentralised treatment plant for a neighbourhood consisting of around 200 households. The total capital and operational expenditure of the Dewats for a design wastewater flow of 120 *lp*–1*d*–1 is even less expensive than the total capital and operational expenditure of the Onsite System for a design wastewater flow of 15 *lp*–1*d*–1. The simulations have shown that as soon as the population density per hectare of a neighbourhood in the core-urban area is greater than 50 cap/ha, the total capital and operational expenditure of the Dewats are less expensive than the onsite system. This is an important finding especially for emerging neighbourhoods at the fringe of the core-urban area.

However, existing population density in the core urban area of Tikpaur (Ward 9) is around 16.2 inhabitants per hectare. This makes Dewats financially unviable. Besides, there are several factors that challenge the feasibility of establishing such a system. Some of the important ones are:

- No natural gradient hence difficult to establish a sewerage network without using a pumping device
- Although CAPEX and OPEX, over a 20 years life span is low, the upfront cost requirement to install the sewerage and Dewats is high as compared to upgrading on-site systems connected to a faecal sludge treatment plant (FSTP). In the latter, responsibility of septic tank upgrading lies mainly with the household and hence, external support will not be required for upgrading on-site system. The cost required is for the construction of FSTP and its maintenance. Municipality can introduce an incentive mechanism for the upgradation and attract private sector to provide emptying and transportation services
- Likewise, identifying appropriate land and building consensus among household to establish a number of Dewats is not easy and can pose numerous social challenges and
- Operational aspect requires overseeing a large number of Dewats which is also challenging.

A comparative analysis of the feasibility of sanitation systems is provided in Table 4 below. Hence, based on the analysis it is recommended that System 1 is practically more feasible in the context of core urban area of Tikapur.

Table 4: Feasibility analysis of sanitation systems in the core area of Tikapur

Variables	System 1: Septic tanks with soak pit and a centralized FSTP	System 2: Simplified sewer system with Dewats (ABR and HFCW) and a FSTP
Technical feasibility	• Upgrading of existing system to septic tank is possible • Considering 16,000 inhabitants (approx. 3200 households) at the core area, assuming each household has one toilet and considering 42% * already have a septic tank, around 1856 units of septic tanks need to be upgraded.	• Low gradient poses challenge to construct simplified sewers • Considering approximately 16,000 inhabitants (approx. 3200 households) in the core area and taking 200 households per Dewats, around 16 Dewats needs to be built.
Capex & Opex	• The Capex for installation and upgradation of onsite systems is normally borne by households. Municipality provides incentives for onsite systems • Capex for transportation to be covered by Municipality or need to introduce a private sector • Capex treatment to be borne by Municipality or external source • O&M of onsite systems taken care by households while transport + treatment component by Municipality/private	• The total Capex and Opex of the Dewats for a design wastewater flow of 120 *lpcd* is less expensive the total Capex and Opex of onsite system for a design wastewater flow of 15 *lpcd* over a 20-year horizon and in areas where density is >50 p/ha • O&M by Municipality or outsourced to private sector. Sewerage fees to be collected from households for system operation • The scale of O&M requirement will be significantly high as compared to on-site systems.
Land requirement	• Existing household space can be used for upgrading septic tanks. • New space need to be allocated for establishing FSTP	• Space need to be identified allocated for building simplified sewers, Dewats and FSTP • Finding appropriate space for establishing Dewats in urban core is a challenge
Land availability	• Land is available within the Municipality boundary, away from the settlements for establishing FSTP	• Land is available within the Municipality boundary, away from the settlements for establishing FSTP
Social acceptability	• High (since the systems requires upgrading, social acceptance is not an issue)	• Medium (although public spaces are available, establishing Dewats in core pat of the settlement may not be easily acceptable)
Financing mechanism	• Household investment can be channeled for upgrading existing containments systems to septic tanks. However, incentives and enforcement from the local authority will be required • External support required to establish FSTP	• Compared to on-site, the upfront capital cost requirement is very high. • External source will be required to establish all components including FSTP
Institutional aspects and management requirements	• As per the FSM Institutional & Regulatory Framework, FSTP management should be taken care of by the Municipality/local authority	• User groups to takes care of each Dewats or could be outsourced to a private entity • Municipality responsible for overall monitoring and management of the system

4.1.2 Proposed option for the short and medium term

Although a decentralized service combination shows viability, investment is the main bottleneck to implement the service option. Hence, for the short and medium term based on analysis of the baseline conditions, user needs and priorities, five key interventions are proposed below in order of priority:

- Ensure access to private toilets to those households without toilets and are currently sharing toilets, particularly in Wards 5 and 6. The households should be informed about the different technological options, costs and the possible financing mechanisms
- Upgrade temporary/poor on-site sanitation facilities to reduce environmental pollution, particularly in areas with high ground water table and areas prone to regular flooding
- Ensure right selection of technology and proper design for new toilet constructions
- Develop and implement faecal sludge management system
- Complement the intervention through capacity building and awareness raising of communities and other concerned stakeholders.

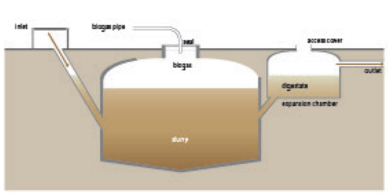
The above action points have been further elaborated with analysis and description of the options and services in the preceding sections. As part of establishing a FSM system, section 4.1.3 provides options for safe containment, section 4.1.4 on emptying and conveyance and finally section 4.1.5 on treatment and end use.

Increasing access, upgrading and managing faecal sludge were the first priority issue as identified during the community consultations. Therefore, these aspects are analysed and provided in greater details as compared to management of other waste streams.

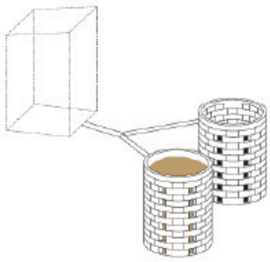
4.1.3 Proposed FSM system – containment options

This section provides details on the first three action points recommended under Section 4.1.2 concerning increasing access and upgrading current containment options to safer options.

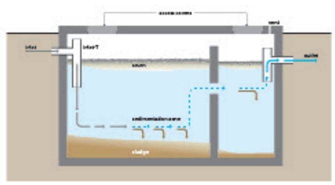
To achieve 100% toilet coverage in the households without access or to upgrade systems in the near future, three safe containment options are proposed at the household level. The three options (Figure 13) take into account technical and economic feasibility, social acceptance and the available local skills to build and maintain them in the long term. An overview of the different sanitation options and provides background information, including the implementation costs.



Opt 1: Biogas digester with flush toilet



Opt 2: Twin pit flush latrine



Opt 3: Septic tank with flush toilet

Figure 13: Overview of the three sanitation systems proposed for Tikapur

Option 1: Biogas digester with flush toilet

The Government of Nepal (GoN) has been promoting biogas digesters of different capacity (2m^3, 4m^3, 6m^3 and 8m^3) for which the biogas digester model GGC 2047 and its modified design are being implemented (AEPC, 2016). This system is based on the use of a biogas digester to collect, store and treat excreta. The biogas which is produced, can be used as energy for cooking or lighting purposes. Inputs for this system include urine, faeces including flush water and cleansing wastewater/material and available animal waste. This system can be used together with a pour/ cistern flush or a urine diverting flush toilet.

This system is best suited in the peripheral settlements where there is adequate space for its installation and where many households are rearing animals. The 12% of the households in Tikapur with toilets attached to a biogas digester are predominantly located in peripheral areas. The focus group discussion (FGD) outcomes also showed marked interest and demand for this system in the peripheral areas. Ward 5, with low toilet coverage, is also located in the peripheral area and toilets attached to biogas digester could become a popular choice here.

Cost of system and financing mechanism

Table 5 provides the estimated capital cost of different sized biogas plants and corresponding subsidies provided by the GoN. As per the policy, almost 30% of the total capital cost is covered by a national subsidy, while the remaining 70% needs to be invested by the household.

Table 5: Estimated cost for household biogas and government subsidies

Size of biogas digester	Estimated cost (NPR)		Subsidy policy (2016)[c]
	2011 [a]	2016 [b]	
$2m^3$	34,100	49,000	16,000 (33%)[d]
$4m^3$	46,900	68,000	20,000 (29%)
$6m^3$	55,200	80,000	24,000 (30%)
$8m^3$	65,000	94,000	24,000 (26%)

Note: a. Approved quotations of biogas plants in Terai region, BSP (2011)
b. Cost extrapolated for year 2016 with 10% annual increments
c. Renewable Energy Policy (MOPE, 2016)
d. In parenthesis: subsidy as a percentage of capital cost for year 2016 Source: MOPE (2016)

In addition to the above, as per the government policy, an additional 10% of the subsidy amount specified above per plant per household is provided to "targeted beneficiary groups". These beneficiaries refer to households that are underprivileged or economically deprived. Likewise, biogas plants using kitchen waste and other household biodegradable waste, receive a subsidy of up to 50% of the total cost but not exceeding NPR. 10,000 for capacity of $4m^3$ or less with the objective to improve the urban environment and reduce the consumption of imported fuel.

GoN also has a policy to support implementation of large-scale biogas plants for commercial, institutional, community and municipal scale waste-to-energy plants. Table 6 provides the subsidy categories for the different plants.

Table 6: Subsidy scheme for large biogas plants

<table>
<tr><th rowspan="3">Biogas plants</th><th colspan="7">Subsidy amount in NPR</th></tr>
<tr><th colspan="6">Thermal application per m³ of biogas produced/ day at normal temperature and pressure</th><th rowspan="2">Additional subsidy for electricity generation per kW (baseload for 24 hrs)</th></tr>
<tr><th colspan="3">Terai</th><th colspan="3">Hills</th></tr>
<tr><td rowspan="2">Commercial biogas plants</td><td>Small</td><td>Medium</td><td>Large</td><td>Small</td><td>Medium</td><td>Large</td><td rowspan="2">65,000</td></tr>
<tr><td>20,000</td><td>25,000</td><td>30,000</td><td>24,000</td><td>30,000</td><td>36,000</td></tr>
<tr><td>Institutional biogas plants for public institutions</td><td colspan="3">57,000</td><td colspan="3">68,000</td><td>185,000</td></tr>
<tr><td>Community biogas plants</td><td colspan="3">45,000</td><td colspan="3">54,000</td><td>150,000</td></tr>
<tr><td>Municipal scale waste to biogas energy systems</td><td colspan="3">40% of the total cost but not exceeding NPR 200,000</td><td colspan="3">40% of the total cost but not exceeding NPR 240,000</td><td>40% of the total electrification cost but not exceeding NPR 400,000</td></tr>
</table>

Pre-conditions for implementation

The capital cost of installing a biogas digester is quite high for an average income household. Thus, establishing a revolving fund will be a crucial step to support households interested to install such a system. The revolving fund can be managed either by the Tikapur WUSC or the Municipality in collaboration with local financing institutions such as the cooperatives. Toilets connected to biogas should be promoted in households that fulfil the following conditions:

- Do not have toilets and are interested to install toilets connected to a biogas digester
- Households have adequate space for installation
- Possess at least one cattle and are willing to use animal dung or food waste to generate and use biogas
- Willing to invest to install a biogas system and participate in the subsidy modality set up by the government
- Willing to properly manage the biogas slurry as per the set guidelines
- Willing to participate in a revolving fund scheme in case financial assistance is required
- Households fulfil criteria b, c, d & e and are interested to upgrade their simple pit latrines to biogas systems

Option 2: Twin pit flush latrine

The double pit system consists of two alternating offset pits connected to a pour flush toilet. The blackwater and in some cases greywater, is collected in the pits and allowed to slowly infiltrate into the surrounding soil. Over time, the solids are sufficiently dewatered and can be manually removed with a shovel.

This system is also suitable in the peripheral area. However, pit system must not be promoted in the flood prone areas of Wards 1, 2, 3 and 7. In the other peripheral areas where people already have a single pit system, households must be encouraged to upgrade to a double pit system. For households without a toilet and with a preference for a pit system, priority choice should be the double pit system.

Cost of system and financing mechanism

The tentative cost of a double pit latrine ranges from NPR 40,000 to 50,000. In Tikapur, the cost can be reduced if the materials used for manufacturing the concrete rings is produced at mass scale. The revolving fund concept proposed for promotion of System 1 is also feasible for this system.

As part of the nationwide open defaecation free (ODF) campaign, toilet construction subsidies are only provided to households that are economically deprived and whose status must be endorsed by the local community and authority. Adhering to the ODF principles, subsidy should be provided only to needy households.

A cost sharing modality with the households should be developed. Such a mechanism should include:

- For households that are identified as economically deprived and designated for subsidy, households provide all the unskilled labour and construct the toilet superstructure using their own investment. External support organizations (e.g. NGOs) provide skilled labour and material support required for the construction of the toilet sub structure.
- For normal or non-poor households who do not have toilets, the project provides the required design, technical assistance and facilitates a financing mechanism whereby households can access micro-loans to build the system.

Pre-conditions for implementation

This system is specifically recommended for households that fulfil the following conditions:

- Do not have private toilets and are interested to install a double pit system
- Have adequate space for construction of the proposed toilet
- Do not fulfil the criteria to install a biogas attached toilet (Option 1)
- There is no drinking water source nearby and the threat of ground water contamination is minimal
- Have a toilet with a single pit and are willing to upgrade to double pits
- This is not an option for areas with high groundwater table (< 2 metres)

Option 3: Septic tank with pour flush toilet

A septic tank is a watertight chamber made of concrete, fiberglass, polyvinyl chloride (PVC) or plastic through which blackwater and greywater flows for primary treatment. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate(effluent and sludge require further treatment).

As per the national building code of Nepal, it is mandatory to construct a septic tank system in buildings located in urban areas without access to sewerage provisions. The Ministry of Federal Affairs and Local Development (MoFALD) also issued a circular in mid-2016 to all the municipalities to make septic tank construction mandatory. DWSS is in the process of approving standard septic tanks designs along with the institutional and regulatory framework for FSM in urban areas. The draft of the framework is in the approval stage at the MoWSS.

In Tikapur, the core urban area is densely settled and is expected to expand. Houses located in these areas do not have access to sewerage. There are no plans from the government to lay out sewerage networks in the near future. Double pit latrines and biogas digesters are not feasible options for the densely populated area due to space constrains. Additionally, preference assessment indicated that household in the market area do not prefer to use biogas as they do not rear animals and thus animal waste is not easily available to feed the digester. Therefore, for household in the urban core area septic tank is a viable sanitation alternative and new construction must be encouraged to install septic tank. Apart from the urban core, this is also a feasible option for the peripheral area if the household's preference is a septic tank.

Cost of system and financing mechanism

The cost of constructing a standard septic tank for an average 5- member household is above NRs. 80,000. Since the upfront capital investment is quite high and there is no subsidy mechanism tied up to this system, households are reluctant to build such systems in urban areas. However, with the enforcement of the FSM institutional and regulatory framework, households must comply to design and build standards septic tanks. Together with the regulatory framework, establishment of a financing mechanism will be essential to support households interested to build septic tanks. As proposed for sanitation systems 1 and 2, the revolving fund mechanism can be used for establishing such a system.

Pre-conditions for implementation

The septic tank system is recommended for households which fulfil the following conditions:

- Households where both biogas and double pit systems are not feasible
- First preference to households that do not have toilets and are located in the urban market area of the settlement
- Households willing to invest all capital cost for construction or are willing to invest only 50% of the upfront cost themselves and take a loan for the remaining 50% of the cost through a revolving fund set up by the project
- Project provides technical designs and strategic support during construction.

4.1.4 Proposed FSM system – emptying & conveyance

This section provides further details to establish a FSM system for the emptying and conveyance. Along the FSM value chain, emptying and transportation of faecal sludge constitutes one of the most important aspects. In Tikapur, these service components are not available and need to be established. The current FS emptying practice is carried out manually either using a manual pit emptier or self-emptying by the household themselves. Manual emptying should be replaced by mechanical options such that the risk from sludge handling is minimized. The following options can be used to establish the emptying and conveyance system.

Establishing a local entrepreneur

In many small towns of Nepal similar to Tikapur, private entrepreneurs providing FS emptying services have sprung up on their own due to the demand for emptying. It is likely that once there is significant demand for FS emptying, private entrepreneurs will develop automatically. However, to speed up the process in Tikapur, current manual pit emptiers can be identified and supported by the Municipality to provide regular mechanical emptying services. The FS vehicle cost can be partially subsidized by the Municipality or through external support so that the upfront cost burden for the entrepreneur is reduced.

A locally assembled, tractor mounted FS collection vehicle can be in the range of 1.2 – 1.8 million rupees. Additional details on the FS collection vehicle is provided in Annex 2.

Municipal initiative

To establish a mechanical FS emptying system, Tikapur Municipality should ideally invest in the FS collection vehicle and provide sludge emptying and transportation services to the households. The municipality has a legal mandate to provide such public sanitation services to the general population. As part of the service delivery, the Municipality could either provide the service itself or lease out the vehicle to a private entrepreneur through a Service Level Agreement (SLA) to provide FS emptying and transportation services within the municipality.

The alternate option for the Municipality would be to make an open call for private sector to provide mechanical FS collection services. In this arrangement modality, the Municipality agrees with the private sector on a service fee to be charged, issues a licence to operate within the municipal boundaries and assures of minimum demand for FS services. The latter can be created using a regulatory framework, where Municipality controls illegal disposal via compliance, charging fines and penalties and other control mechanisms, and creating awareness on mechanical emptying service provisions.

WUSC initiative

The mechanical emptying service could also be established through the Tikapur WUSC. The WUSC is currently providing drinking water to the households covering most parts of the municipality. WUSC is also responsible for implementing the Third Small Towns Water Supply and Sanitation Sector Project to augment the current water demand. In addition to providing water supply services, it has a mandate to provide sanitation services. Thus, FS emptying, and conveyance services could also be taken up by the WUSC based on an understanding reached with the Municipality. Internal or external investments could be sought to procure the FS collection vehicle.

4.1.5 Proposed FSM system - treatment and end use

As part of the proposed FSM system, following emptying and conveyance, this section proposes options for the FS treatment and end use. The learnings and experiences from similar treatment systems in Nepal and India have been taken as references to propose treatment options and to propose tentative investments for Tikapur. The proposed treatment plant can be constructed in one of the potential sites in Tikapur. Preliminary site visits were carried out to these locations together with the Municipality staff during the planning phase. It is proposed that these locations should be studied in greater detail during the detailed design phase and should fulfil the site selection criteria presented in Annex 3.

Potential FSTP locations:

The first site is located at the Southern part of the Municipality on the way to Tikapur Park. It is almost half way between the Airport and the Park, after the Polytech institute. The proposed land belongs to the Municipality and is close to the forest area.

The second site is further South after the Tikapur Park in the forest area. It is quite close the banks of the Karnali River. Dykes have been built in the recent years. Previously it was a flood prone area. A location map is provided in Annex 4.

The section below provides analysis of the proposed FS treatment options:

System 1: Combination of unplanted drying beds, horizontal flow constructed wetlands and sludge stabilization

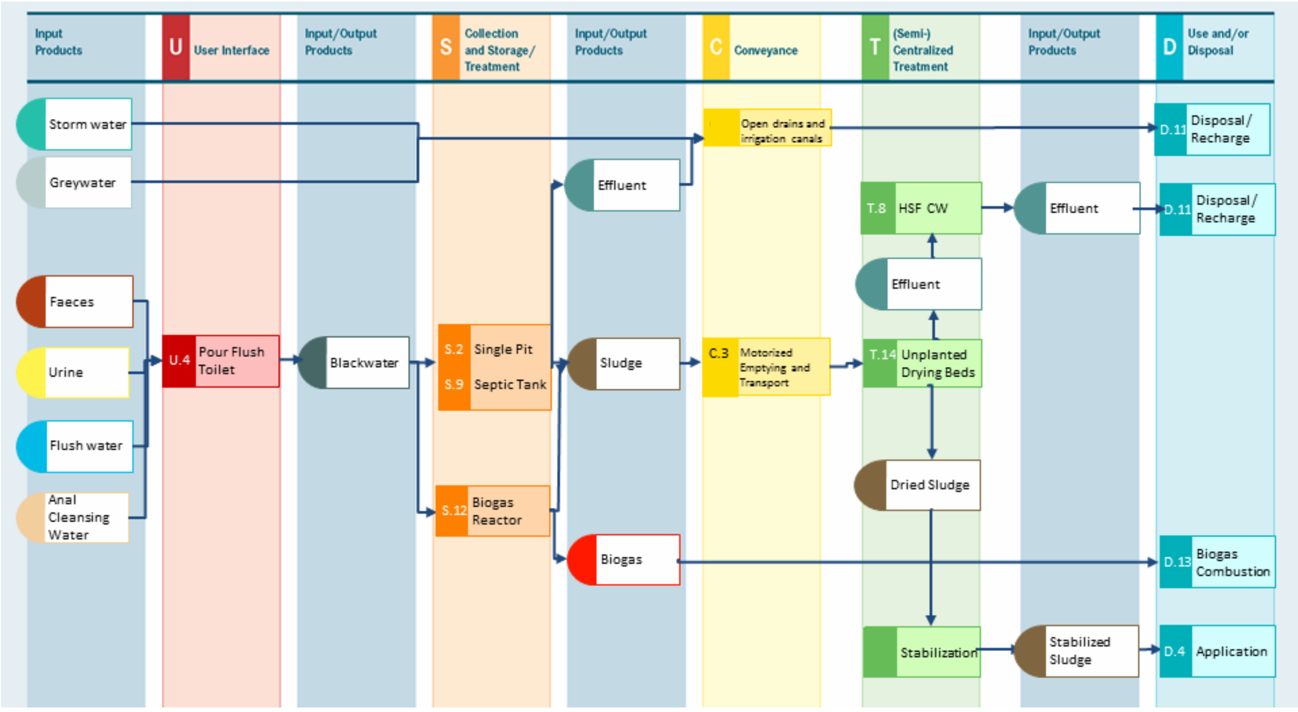


Figure 14: Schematic diagram of FS treatment system 1

The schematic representation of this system is presented in Figure 14. The concept of the unplanted drying bed is separation by gravity, drainage and evaporation, of solid and liquid in the faecal sludge. The sludge is brought and disposed onto the drying beds with a recommended loading rate of 100 to 200 kg TS/m^2/year (IWA, 2014). A full cycle of loading, drying and removing can take between 10-20 days. The resulting dried sludge can have its volume reduced by 90% and the moisture content between 50 and 70%. The dried sludge is scraped out and allowed further drying or co-composted in sludge stabilisation units for further treatment and stabilisation of the dried sludge. About 80-85% of the sludge volume is separated by gravity in the drying beds as effluents. The effluent from these beds are treated in a horizontal subsurface flow constructed wetland. The effluent can then be discharged into irrigation canals.

This system is easy to operate and maintain. In landscapes with adequate gradient, the system can be operated without electricity. Table 7 provides an estimated land footprint requirement for this system. The estimation for the footprint is based on a tentative calculation of the different treatment components. The calculations are provided in Annex 6a.

Table 7: Estimated land footprint

SN	Specifications	Area in m^2	Remarks
1	Unplanted sludge drying beds	2,000	Based on calculations Annex 6a, Table 1
2	Stabilizing units for dried sludge	500	Based on estimates of similar systems
3	Horizontal constructed wetlands for effluent treatment after SDB	700	Based on calculations Annex 6a, Tables 2, 3, 4
4	Access road and additional space	2,000	Space for vehicle unloading, landscaping, etc.
	TOTAL	**5,500 m^2**	

A similar treatment system constructed in Gulariya Municipality with a capacity to treat 3m^3 of FS per day, the total land requirement was around 1200 m^2 and the total cost of the system was around 3.2 million rupees. The Gulariya system comprises of drying beds for solids and a combination of anaerobic baffled reactor (ABR) + anaerobic filter (AF) and a horizontal flow constructed wetland (HFCW) for the effluent of the drying beds.

Taking the Gulariya cost as a yardstick (1.1 million per m^3 of FS) and topping up additional costs, the proposed system for Tikapur for with a capacity of 23 m^3/day would cost around NRs. 30 million. The estimated land requirement is from 5500 m^2 (equivalent to around 11 *ropanis* of land) and above.

System 2: Combination of planted drying beds and effluent treatment (ABR+AF+CW)

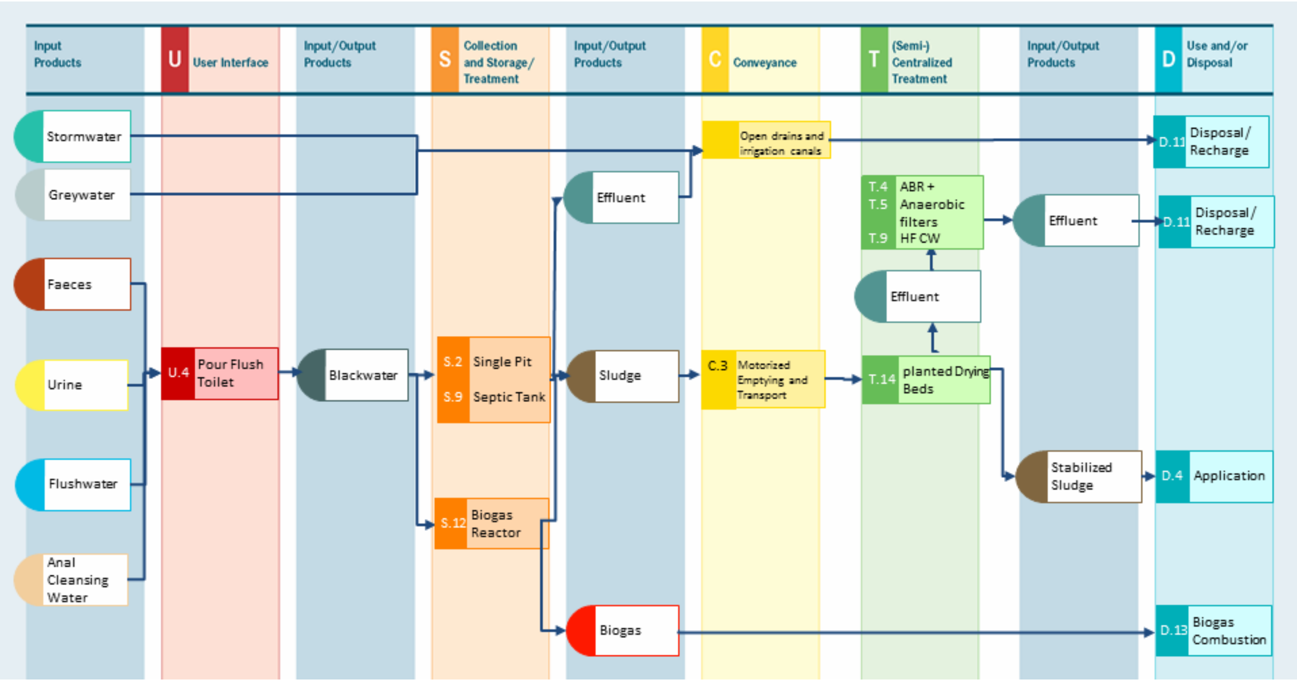


Figure 15: Schematic representation of system 2

The schematic of the proposed system is provided in Figure 15. The system consists of planted drying beds followed by an ABR and AF. The main advantage of the planted drying beds over the unplanted one is the low desludging frequency (once in 3 to 5 years against twice per month), however this option needs continuous feeding so that the plants do not dry out. The reduction of sludge volume can reach up to 99%. The plants in the sludge drying beds allow a much bigger volume reduction through extended retention time and a better stabilization of the sludge as compared to the unplanted drying beds. The resulting stabilized sludge can be used as soil conditioner.

Effluent from the sludge drying beds is treated through a combination of ABR and AFs. The effluent from these units is further polished through a horizontal subsurface flow constructed wetland before final disposal into the environment. The ABR and AFs reduce the total solid and biological oxygen demand (BOD) content of the wastewater and the constructed wetland helps in reducing the pathogens. This system is easy to operate and maintain. In a topography with adequate gradient, the system can be operated without electricity.

Table 8 provides an estimated land footprint requirement for this system. The estimation for the footprint is based on a tentative calculation of the different treatment components. The calculations are provided in Annex 6B.

Table 8: Estimated land footprint for system 2

SN	Specifications	Area in m	Remarks
1	Planted sludge drying beds	1,000	Based on calculations Annex 6b
2	ABR+AFs	50	Same as above
3	Horizontal constructed wetlands	700	Same as above
4	Stabilizing unit for dried sludge	500	Based on designs from similar systems
5	Access road and additional space	2,000	Space for vehicle movement for unloading, landscaping, etc.
	TOTAL	**4,250 m^2**	

Based on a similar type of system proposed for Charali with a capacity to treat 27m^3 of FS/day, the land requirement was estimated to be about 7,500m^2. For the proposed system, the land requirement can range from 4250 m^2 and above. The tentative estimated cost for the proposed system in Tikapur with a capacity of 23m^3/day would cost around NRs. 40 million. This is in reference to the Charali system. With system optimization, the cost can be reduced significantly.

Based on the two systems provided above, the second system using planted drying beds is recommended for Tikapur. The key reason behind is the low maintenance requirements compared to the first. However, both the designs are new for the Nepalese context and the performance of these treatment systems need to be evaluated over time.

4.1.6 FSM service model and institutional arrangements

This section proposes some of the service models to be considered to operate and maintain the FSM system. Currently, most of the FS generated in Tikapur is discharged in the environment without any form of treatment. In addition, there is also an absence of local private entrepreneurs providing formal mechanised emptying service in the Municipality. The proposed FSM service model is necessary for establishing and operationalising the overall system. This section highlights two types of service models for developing a sustainable FSM system in Tikapur Municipality.

i. The demand-based model

Under this service model, FS emptying at households, institutions and public toilets are carried out as per demand from the public. Service fees are paid as per volume of FS emptied and collected at individual households and institutions.

The baseline assessment showed that 78% of the respondents preferred a demand based emptying service as opposed to other service models.

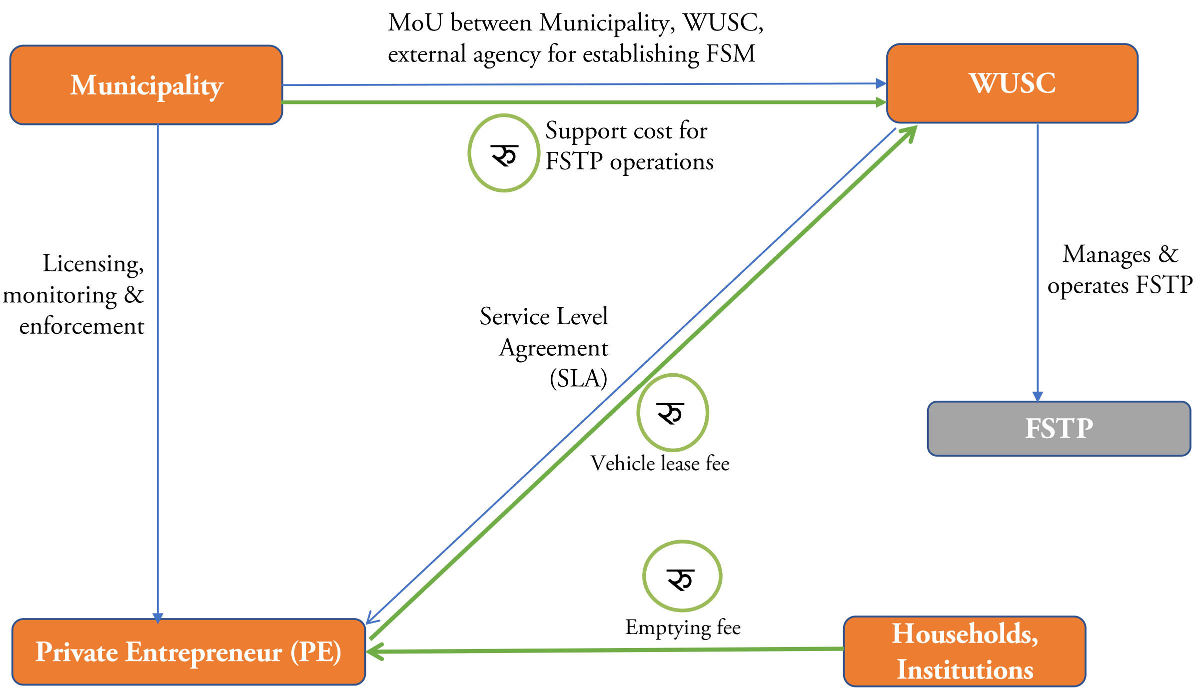
The schematic representation of a demand-based service model is provided in Figure 16. Under this service model, the municipality is the regulator. As Tikapur Municipality has limited capacity and resources to provide FSM services, as a medium-term arrangement and until the Municipality is fully capacitated, this demand-based service model proposes to outsource the FSM service to the WUSC. The municipality subsidizes the overall operation through annual budget support to run the operations.

The main reason for proposing the WUSC is because:

- WUSC is a well-established local institution for water and sanitation. It has the capacity and a mandate to provide such services. In 2015, the Municipality also handed over the management responsibility of the old water supply system to the WUSC. It is also implementing the GoN/ADB funded TSTWSSP project to augment local water demand.
- WUSC has a team of skilled experts and technicians for providing water supply services. Ideally, the technical team can also assist in the operation of the FSM services.

To operationalize this service model, first, a Memorandum of Understanding (MoU) is signed between the Municipality and WUSC whereby Municipality agrees to outsource FSM responsibilities to WUSC.

Second, as there are no private entrepreneurs (PE) in Tikapur that provide mechanical FS emptying services, the capacity of PE needs to be gradually built up. PE can take the overall responsibility for providing emptying and transportation services once capacitated. Under this scenario, where WUSC takes full responsibility of FSM, WUSC procures a FS collection vehicle, builds a team (driver plus assistant) by utilizing the current manual pit emptier/s to provide emptying and transportation services. Through a SLA, the WUSC should outsource the emptying and transportation service operations to the PE. In return, the PE pays a vehicle lease fee and is responsible for providing FS emptying and collection services. Both parties agree to set an appropriate local service tariff. The FSTP should be managed and operated by the WUSC.



Key features:

- Municipality as regulator, PE provides FS collection + transport services
- WUSC oversees FSTP operations

Figure 16: Schematic representation of demand responsive service model

Roles and responsibilities of stakeholders

Under the above service model, the envisioned institutional roles and responsibilities of the different stakeholders are provided below.

Municipality

- Undertake overall responsibility of planning, management and regulation of FSM based on the preparation and approval of FSM policy, institutional and regulatory framework and the necessary guidelines.
- Develop, approve and disseminate the FSTP design, institutional and regulatory framework, business models and operational guidelines for FSM in Tikapur.
- Provide annual subsidy to support HR cost of the FSTP operator and necessary operation and maintenance (O&M) cost to the WUSCs, until the FSTP can be financially sustained through revenue earned.

- Provide land required to establish the FSTP in the municipality, based on the approved land selection criteria as given in the approved FSM institutional and regulatory framework, and contribute 15% of the total capital cost required to establish the system.
- Establish FSM Committee with selected experts to steer and provide oversight in the effective implementation of FSM under the Environmental Management section of the Municipality.
- Delegate the responsibility of FSTP operation and maintenance to the local WUSC until Municipality builds upits internal institutional and management capacity
- Issue license to private entrepreneur for faecal sludge collection, transport and disposal at the specified FSTP. Review the performance of the PEs on annual basis and renew license subject to satisfactory performance
- In cases where neighbouring Municipalities and Rural Municipalities do not have a FSTP in place, and there is a possibility to uptake additional volume in the FSTP, coordinate with these authorities for possible disposal of sludge at the designated treatment plant.
- Link and coordinate with local water, sanitation and hygiene (WASH) committees on sanitation promotion particularly regular FS emptying.
- Ensure FS collected from individual households, institutions, public toilets are brought to the designated FSTP for disposal
- Monitor effective implementation of FSM and ensuring regulation compliance and instituting improvements, as per the approved FSM Institutional and Regulatory Framework.
- Collect and analyse information from the FS Private Entrepreneurs (PEs) and FSTP operators to monitor operations and make informed decision for effective FSM.

Water users and sanitation committees

- Ensure effective operation and maintenance of the FSTP as the plant operator as per the operation and maintenance guidelines of the FSTP.
- Facilitate cooperation between the Municipality, citizens and private entrepreneur on FSM collection, transportation, treatment and disposal/end use
- Put in place dedicated human resources as operator(s) for the FSM treatment plant operation and ensure that the annual HR cost of the operator and the O&M costs of the plant is deposited in the WUSCs account by the Municipality
- Based on experience of FSM operations, seek support required from Municipality and DWSS to address challenges encountered and support Municipality in the effective regulation and institutionalizing improvements, as appropriate
- Enhance market promotion of end products while considering social, economic and cultural factors
- Collect tipping fees based on the volume discharged from designated vehicles bringing FS into the treatment plant
- Secure operation and maintenance fund, plus O&M costs, mainly to support the Plant Operators cost from the Municipality for initial years until operations can be sustained from service charge collected
- Maintain an information base of FS operations of the treatment plant, including a log of FS brought/disposed into the treatment plant by the FS vehicles
- Identify a private entrepreneur for providing the FS collection service

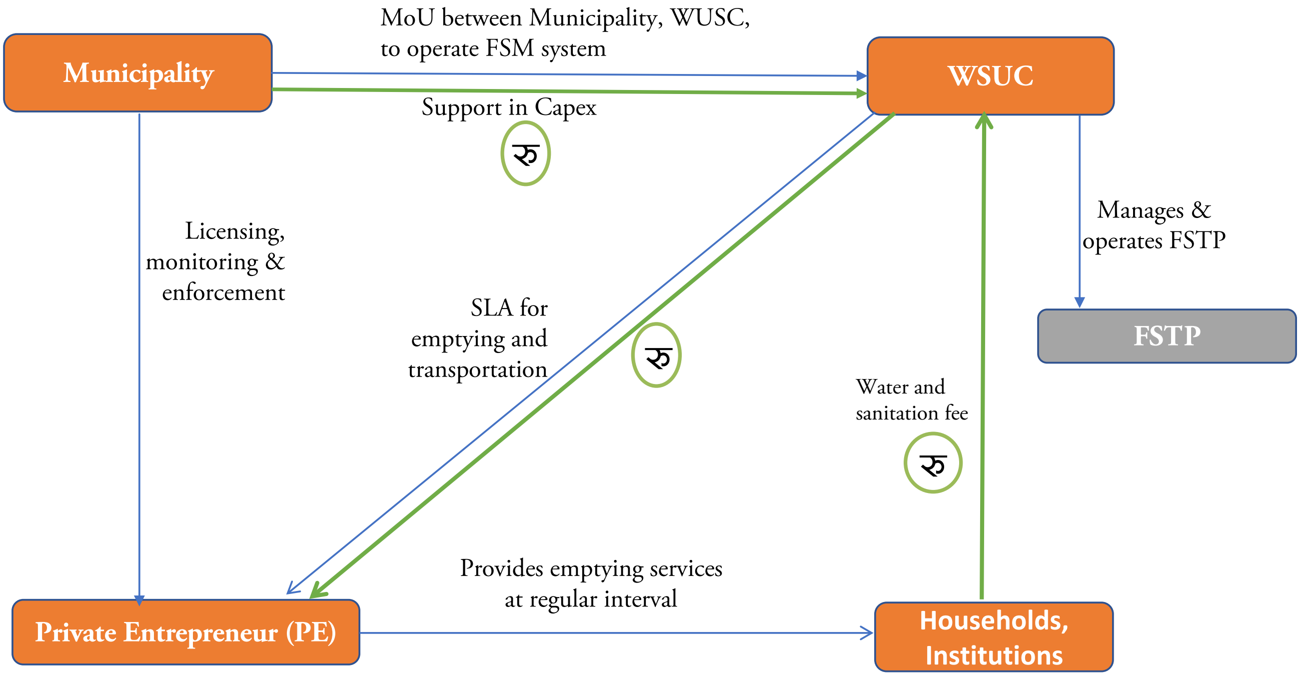
Private entrepreneur

- Partner with local bodies and WUSCs in the effective operation of FSM service
- Provide safe FS collection, transportation and disposal services
- Ensure that only domestic FS generated by households and institutions is brought to the FSTP
- Provide effective customer service.
- Establish a call centre to receive demand for FS emptying from households and institutions
- Ensure that all collected FS is brought to the designated FSTP so that there is no illegal disposal of FS to safeguard public health and environment

- Pay and deposit treatment fee (10% of the emptying cost) per volume (m^3) of sludge discharged into the FSTP
- Ensure that the truck operators and assistant are fully trained on occupational health and safety protocols as provided in the O&M guideline.
- Obtain a valid license from the Municipality to operate FS services in the designated service area
- Fill and report operational information to the Municipality and use this information to improve operational performance

ii. The regularised model

Regularised emptying refers to a service where FS from onsite sanitation systems are emptied at regular pre-determined intervals. The key feature of this model is the emptying of septic tanks at fixed intervals irrespective of the filling of the tanks. The fees of septic tank emptying, and transportation is inbuilt in the water tariff. The schematic representation of this model is provided in Figure 17. As in the demand-based model, the Municipality is the key regulator in this model. A MoU is signed between the Municipality and the WUSC and the responsibility of operationalizing a FSM is outsourced to the WUSC by the Municipality. To optimize services, WSUC can lease out emptying and collection services to the private entrepreneur/s.



Key features:
- Service level agreement (SLA) with private entrepreneur for emptying, transport & treatment
- WUSC collect water and sanitation fee and provide regular FS emptying and treatment services

Figure 17: Schematic representation of the regularized emptying model

In this model, the upfront payment amount for FS emptying service is low as it is inbuilt in the water supply tariff. A fixed amount of FS can be expected at the treatment plant on a regular basis and hence assurance for financial security for operation and maintenance of the system.

This service model is only applicable for households with septic tanks. For household without septic tanks, a different set of tariffs needs to be defined.

iii. Financial analysis of service models

Financial analysis of the demand-based business model from similar towns like Tikapur shows that subsidy will be required during the initial years of operation until the business generates sufficient revenue to finance its operation. The main source of revenue stream is the tipping fees collected from the FS trucks and (minimal) revenue generated from sale of compost. Likewise, the main operational costs are the salary of the FSTP operator, regular maintenance costs such as periodic cleaning of the drying beds and consumables such as water, electricity and fittings.

Various financing mechanisms are possible within the different service models. Some of the key ones are provided below with the pros and cons in Table 9.

Table 9: Comparison of financing mechanisms for operation of FSM services

No	Feature of financing mechanisms	Pros	Cons
1	**Subsidy driven model:** - Annual support is provided by the Municipality to cover the human resource cost of the treatment plant operator. - Other sources of potential revenue streams are from tipping fees and co-composting	- Constant source of revenue sustains the operation of the plant - Emptying and transport costs are met through emptying fees collected from households	- For Tikapur as the sludge generation is small, not much bio-solids are produced - Sourcing of organic waste is a challenge
2	**Built-in sanitation fee in the water tariff for regularized emptying:** - Since Tikapur WUSC already has a good user base, within the set water tariff it can add a certain percentage of the water fee as sanitation fee. - Provide regular emptying of septic tanks (eg. every 3 years)	- Provides a continuous source of revenue stream and does not need to rely on external sources - Regularized emptying guarantees a continuous waste input at the treatment plant. Facilitates to plan for a production of compost	- Users who already have septic tanks that can accommodate large sludge volumes may not be eager to participate
3	**Built-in sanitation fee in water tariff for demand-based emptying:** - Sanitation fee is only collected from the water supply users in form of a water tariff. In return, when there is a demand for septic tank emptying, the service fees are subsidized. - Emptying fees are higher for households that are not registered as a water user	- Upfront emptying fee to households is less as it is subsidized - A continuous source of revenue is collected to support operations of the FSTP without external support	- WUSC needs to convince the households thoroughly of the benefits of such a fee mechanism

It is recommended that a detailed business plan should be prepared for Tikapur to analyse the financing mechanisms and type of treatment system to be adopted. Both the business plan preparation and the treatment plant design should go hand in hand and not one after the other. This will help in system optimization and selecting the most appropriate system.

4.2 Solid waste management

Solid waste management was not identified as a priority issue during community consultations. However, inorganic waste handling has been identified as a major problem in Tikapur. Burning and haphazard disposal of inorganic waste creates nuisance and poses both environmental and public health hazards. Furthermore, burying organic waste in pits is not a sustainable solution.

The following guiding principle should be considered while developing a solid waste management strategy for Tikapur. Some action points can be implemented immediately, while others will have to be integrated in the solid waste management strategy. The strategy should be developed in line with the provisions made in the Solid Waste Management Act 2011 by the Government of Nepal.

- **Public participation**: Public awareness is necessary to ensure their partnership in managing solid waste and keeping the environment clean. Awareness and relevant knowledge on issues like waste minimization, reduction on use of hazardous waste like plastics, composting can facilitate the long-term sustainable waste management in the Municipality.
- **Waste reduction and segregation at source**: People must be made aware about the 3R principle of reduce, reuse and recycle to minimise the waste generation and to promote reuse and recycle of waste generated. Promotion of waste segregation at the household level improves management of the different streams of waste. Wherever possible, people must be encouraged to practice household scale composting or to mix their organic waste into the bio-gas digester. Such household level management will substantially reduce the amount of organic waste transportation to landfill site or to the dumping area.
- **Stakeholder participation**: Involving private sector entrepreneurs and other community-based organisations not only reduces the work -load of the local authority but also creates job and entrepreneurial opportunities in the solid waste management business. These organisations can establish door-to-door waste collection system and establish decentralised collection and transportation depots for recyclables. They can also initiate community level composting and marketing of organic waste. However, in order to establish a sound service system, the private entrepreneurs must receive training and have well trained work force on the ground. Capacity building is also necessary at the Municipal level to be able to monitor the operations of the private sector.
- **Sustainable market development**: The local authority must be responsible for determining the service charges for households, commercial and non-commercial institutions using the solid waste collection service. In addition, the local authority must also oversee the recycling market and the operations must be incentivised for sustainable operation by the private sector. Supporting these entrepreneurs to develop business plans to deliver financially viable services will also ensure sustainable operation by these private entities.
- **Establishment of integrated waste management facility**: As a long-term plan, the local authority must identify a suitable location to establish an integrated waste management facility to manage both the solid waste and the faecal sludge generated in the Municipality. The current location at the river bank where waste is being dumped is not an appropriate location to establish a permanent facility. An alternate site could be the location identified by the community to establish a faecal sludge management facility in the community forest area in Ward 3. However, a feasibility study in collaboration with the Solid Waste Mobilisation Resource Centre would help in identifying a suitable site.

4.3 Grey water and storm water management

The first priority for storm water management interventions should be the built-up areas of the Municipality. One of the main challenges for drainage construction in Tikapur is the low gradient (>0.1%). Grey water generation is high in Tikapur (200L/person/day), particularly in the summer season which must be taken into consideration if the drainage system is designed to receive grey water stream.

Planning and construction of storm water drains must be done through coordination among concerned agencies. The major agencies who must be involved are the TSTWSSSP, TDF, the Municipality and the WUSC and the irrigation project.

The last Masterplan developed in 1971 for managing both storm water and grey water should be referred to and updated to prepare the storm water drainage plan. During the preparation of this plan, TDF showed keen interest to work together with the Tikapur Municipality and the WUSC provided there was local demand for such a task. There is even a possibility to carry out a detail design and estimate for the storm water drainage through TDF financing.

It is recommended that the local users and the municipality pursue a keen interest on this potential collaboration and continue dialogue with TDF to work out a plan of action for storm water management.

4.4 Capacity building

During the consultative meetings, a major issue raised was the need to generate awareness on environmental sanitation in Tikapur. Since this is a cross-cutting issue touching upon all environmental sanitation components, it is recommended as one of the key interventions that should be taken up during the implementation phase. The awareness should focus on achieving total sanitation and hygiene behavioural change. Some of the key capacity building activities to improve the current environmental sanitation situation are provided below:

- Capacity enhancement for the Municipality on environmental sanitation issues
- Awareness campaigns on the need for safe sanitation practices
- Awareness on proper management of inorganic waste
- Door to door awareness campaigns for sanitation behavioral change through use of female community health volunteers (FCHVs), schools, mother's group, etc.
- Training on household level composting by using better equipment or by improving the present pit composting to improve the composting practices and the quality of compost. Trainings on safe emptying and disposal of sludge from pits/septic tanks both to households and potential entrepreneurs
- Identify and build capacity of local entrepreneur to provide safe faecal sludge emptying and transportation services
- Training sessions to operationalize the FSM service plan and financing mechanism

5. Tentative investments

The total budget estimated for sanitation improvement as a first phase initiative is around 47 million Nepali rupees. The key investments are in the area of: sanitation upgrading and increasing access (NPR 7 million), establishment of a FSM system (NPR 36.5 million), capacity building activities (NPR 1 million) and development of a storm water drainage design (NPR 3 million). The details are presented in Table 10.

Table 10: Sanitation investment plan

No	Headings and Activities	No of units	Unit cost	Tentative Investments requirement (NPR) in million	Remarks
1	***Sanitation access and upgrading***				
1.1	Seed money to set up a revolving fund for providing access and upgrading sanitation systems	LS	30,000	7	Based on the assumption that around 5% of the population upgrade their system either to biogas or septic tank systems i.e, 241 households per year
2	***Faecal sludge management***				
2.1	Procurement of customized sludge collection vehicle	LS		1.5	
2.2	Design and establishment of a FS treatment facility using planted drying beds			35	Based on projections from similar treatment units designed elsewhere
3	***Capacity building and awareness***				
3.1	Awareness raising activities in the environmental sanitation	30	20,000	0.6	
3.2	Specific customized training on sanitation, business model operationalization	5	75,000	0.4	
3.3	Exposure and cross learnings	LS		0.5	
4	***Storm water drainage study and design***	LS		3	A tentative lump sum figure provided based on consultation with local experts.
	Total investment requirement (NPR)			**48**	

6. Operationalizing the CSP

This section provides a stepwise recommendation for operationalizing the CSP in Tikapur.

i. Working on a priority basis

The environmental sanitation plan should be implemented on a priority basis. As per the plan, the first priority, is the establishment of a FSM system. Subsequent priorities should be implemented in a phase wise manner.

ii. Financing and collaboration

The Municipality and WUSC should partner with potential stakeholders to implement the overall plan. Some of the potential partners for partnerships are:

- The Government of Nepal and the ADB-funded Small Towns Project
- USAID project on Water, Sanitation and Hygiene Finance (WASH-FIN) Nepal
- ISAU under the STWSSSP, DWSS
- Town Development Fund
- NGOs and private sector partners

The Municipality and Tikapur WUSC, should collaborate with relevant stakeholders to develop the detail technical design and identify the financing mechanism to support implementation.

iii. Technical assistance and facilitation of implementation process

Key stakeholders participated in some of the strategic decision-making process as part of preparing this plan which enabled them to be familiar with the planning processes. However, during the implementation phase, external facilitation and technical assistance will be required mainly to support: i) preparation of technical designs for FSM with detail project report, ii) preparation of business plans, iii) building capacity of stakeholders on system improvements, operation and maintenance and sensitization

The above tasks should be performed by relevant development organizations or consulting firms with expertise in urban sanitation and experience in establishing FSM systems.

iv. Development of design for storm water management

Discussions were ongoing between the WUSC, Municipality and the TDF to finance the study on storm water management during the preparation of this plan. The talks between the stakeholders should be expedited. This was one of the priorities identified and should go in parallel to establishment of the FSM system.

Annex 1: FGD summary in Tikapur

SN	Issues	Bijayanagar and Shaktinagar	Wards 1, 2, 3 and 7	Wards 4, 5, 6 and 9
1	Toilet and FSM	**Issues:** 1. quick filling of single and twin pits, especially in the rainy season 2. absence of FSM system 3. manual (bucket) emptying 4. haphazard disposal of FS in the environment **Potential solutions:** 1. incentivise household biogas through financing mechanism 2. construct raised twin pits to avoid flooding to some extent 3. find emptying solutions at the community level 4. develop a FSM system	**Issues:** 1. no rings in pits 2. pits fill up quickly due to water intrusion from nearby canals and river **Potential solutions:** 1. incentivise household biogas through financing mechanism 2. upgrade single pit system to twin pit system with rings 3. mechanical emptying of pits 4. promote FS treatment options that can generate manure and/or gas	**Issues:** 1. water pumps and septic tanks are closely located creating potential risk of cross contamination 2. disposal of FS within household premises creates environmental hazard 3. lack of proper FSM system **Potential solutions:** 1. upgrade single pit system to twin pit system with rings 2. incentivse household biogas through financing mechanism
2	Solid waste management	**Issues:** 1. burning of inorganic waste 2. litter due to wrappers of chocolates and tobacco 3. inadequate concrete bins constructed by the Municipality 4. absence of collection mechanism of the waste from concrete bins **Potential solutions:** 1. construct more concreate bins 2. develop waste collection mechanism by the Municipality	**Issues:** 1. haphazard disposal of inorganic waste, especially wrappers 2. lack of awareness and management **Potential solutions:** 1. establish designated place for disposal and collection 2. promote the principle of reduce, reuse and recycle	**Issues:** 1. plastic, glass and wrappers create a nuisance 2. need to address medical waste, especially from private clinics 3. waste segregation is not practised 4. Tikapur lacks an ideal location for landfill site **Potential solutions:** 1. follow the principle of reduce, reuse and recycle 2. involve private sector in solid waste management with the Municipality taking the lead 3. establish a sound solid waste management system 4. identify a good landfill site location through stakeholder consultation
3	Storm water management	**Issues:** 1. stagnant water during rainy season 2. absence of storm water drainage **Potential solutions:** 1. laying of storm water drainage with proper outlet 2. explore possibility of using irrigation canal as outlet	**Issues:** 1. lack of drainage system 2. frequent flooding **Potential solutions:** 1. laying of storm water drainage with proper outlet	**Issues:** lack of proper drainage system **Potential solutions:** 1. establish combined drainage system with priority for blocks 3,6 and 14 that are flooded during the rainy season
4	Grey water management		**Issues:** 1. no drainage system for grey water management **Potential solutions:** 1. laying of drainage for grey water	
5	Awareness	**Issues:** 1. inadequate awareness on environmental sanitation issues **Potential solutions:** 1. conduct awareness raising activities on personal health and hygiene, health impact of plastic waste, benefits of grey water recycling and solid waste management through sanitation committees and sub-committees	**Issues:** 1. inadequate awareness on environmental sanitation issues **Potential solutions:** 1. conduct awareness raising activities on personal health and hygiene, health impact of plastic waste, benefits of grey water recycling and solid waste management through sanitation committees and sub-committees	**Issues:** 1. inadequate awareness on environmental sanitation issues **Potential solutions:** 1. conduct awareness raising activities on personal health and hygiene, health impact of plastic waste, benefits of grey water recycling and solid waste management through sanitation committees and sub-committees
	Priority ranking	**3, 2, 1, 5, 4**	**1, 5, 2, 3, 4**	**1, 2, 3, 4, 5**

Annex 2: Customized faecal sludge collection vehicle costs and accessories

No	Details costs of customized suction vehicle	Estimated cost (NPR)	Operation and maintenance task	Repair and maintenance costs (every 2-3 years)	Remarks
1	Vehicle chassis (tripper truck 16 tonne)	25,00,000	Can operate for 9-10 years		Can carry up to 18 tonnes
2	Compressor	1,50,000	Requires replacement every 2-3 years	1,50,000	
3	Collection tank	1,00,000	Requires replacement every 2-3 years	1,00,000	
4	Generator	50,000	Requires replacement or maintenance every 2-3 years	50,000	
5	Accessories (pipes, bends, valves)	50,000	Pipe replacement	50,000	
	Total Cost	**28,50,000**		**350,000**	

Note: all estimates are based on the costs provided by local FS entrepreneurs from other small towns. The price may vary as per the type of company, location of purchase and time.

Cost of FS trucks in India

Financials	**Vacuum truck without jetting pump (USD)**
Capital Expenditures	
Truck (New)	$13,159
Body	$4,112
Hose	$247
Vacuum Pump	$3,290
Total Capital Expenditures	**$20,808**

Source: India Market Findings for OI and OP Technologies – Phase I Interim Report, 2013

Note: The above cost USD 20,808 is equivalent to around NPR. 22,26,000 (Twenty-two lakhs, twenty-six thousand.

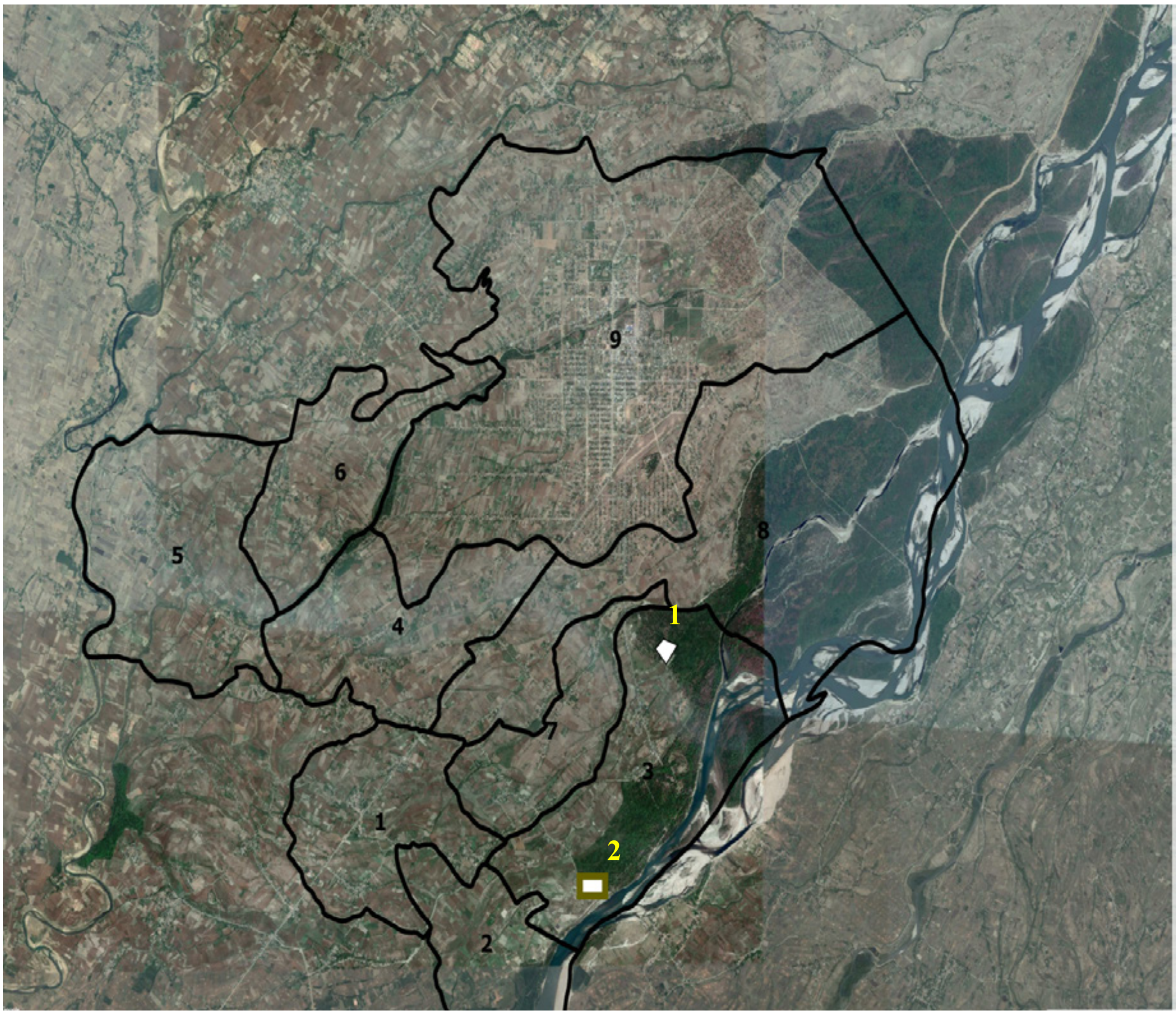
Annex 3: Criteria for selection of FSM treatment site

- Land allocation should be done either through land use planning as per the Land Act or through coordinated efforts among stakeholders at the local level;
- The treatment site should be established away from dense settlement areas, agricultural land, and other sensitive areas like water body, hospitals or schools to avoid potential social opposition arising from problems of foul odour or other aesthetic reasons;
- The site can be established in a community forest or woodland that is not declared as a protected area;
- The site should be at least 300m away from the nearest dwelling, 30m downstream from any drinking water source, not in a protected or religious area, and in relatively flat land with no more than 8% slope;
- Public or WUSC land with ownership certificate and without adverse social and environmental impacts for construction;
- The ideal location for establishing a faecal sludge treatment is within a solid waste management or a wastewater treatment facility where such system already exists; or that the treatment should be integrated when such system is being planned.

Source: *FSM Institutional Regulatory Framework (MoWSS, 2017)*

Annex 4: Proposed locations for establishment of FSTP

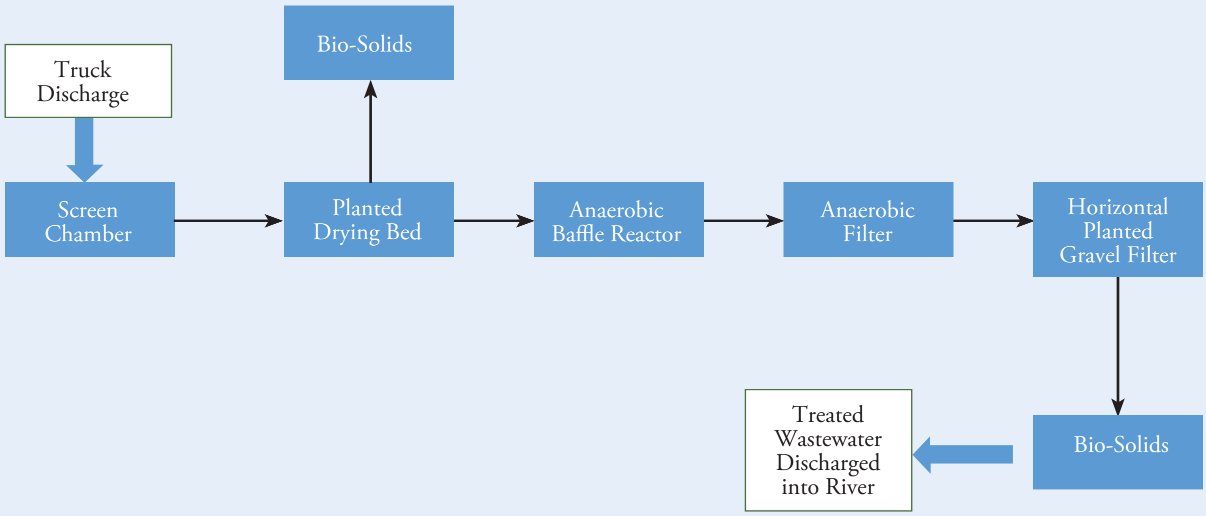
Site 1: Open space adjacent to the forest (approx. 3 km from the centre)
Site 2: Located in the forest area, further south of Tikapur Park (approx. 6 km from centre)



Annex 5a: A brief overview of the Charali FSTP

Charali FSTP

The plant is connected in series from one treatment module to the other. First FS is passed through a screen chamber to remove solid debris and then to a planted drying bed where solids are retained. The resulting effluent from the drying bed then passes through an Anaerobic Baffle Reactor (ABR), Anaerobic filter (AF), planted gravel filter and finally to a polishing pond. The expected final BOD level at the outlet of the polishing pond is <30mg/L. The dewatered sludge from the planted drying bed undergoes stabilization in the bed and on complete filling of the drying beds with sludge, a retention time of 6 months is provided before it is removed.



Layout Plan of FSTP for Charali

The proposed treatment plant has been designed to treat 27 m3 of FS per day. The treatment plant was proposed based on the following rationale:

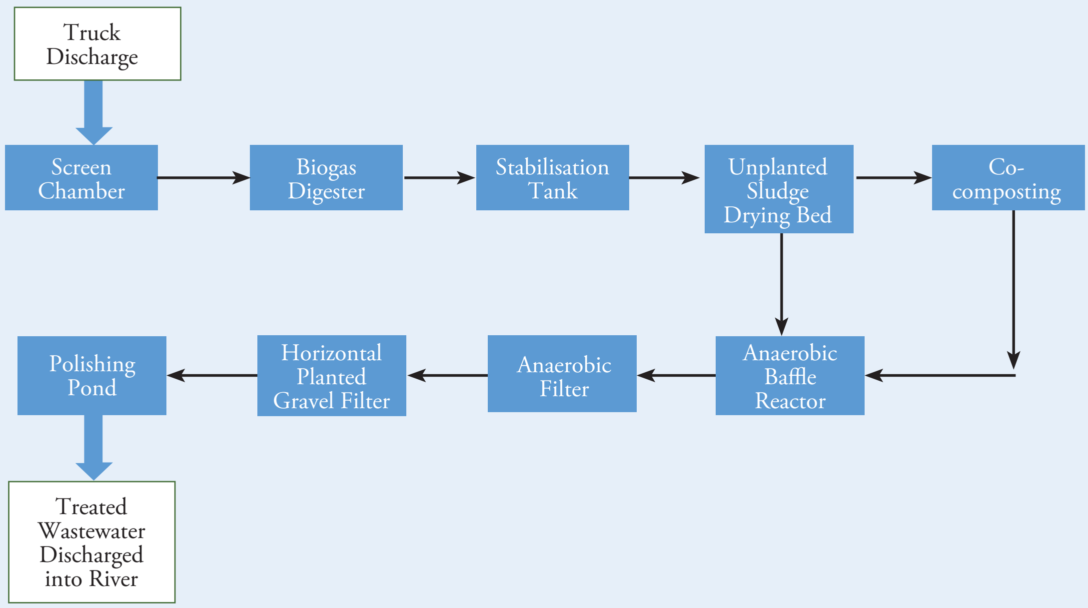
- Reduced odour during regular treatment plant operations
- Soil profile and water table at the site not conducive for heavy civil construction
- Expected fluctuation in input quantity of faecal sludge arriving at the treatment plant per day: Assuming the location of the site and cluster approach of integrating 4 local bodies into a single faecal sludge management plan.
- Expected fluctuation in quality of faecal sludge, as many containment systems from neighboring industries and factory establishments have low retention times and hence sludge has varying BOD and Total Suspended solids.
- Reduced operation and maintenance requirement
- Requirement for excess of treated water to be discharged in adjoining river

Source: Third Small Towns Water Supply and Sanitation Sector Project (TSTWSSSP), DWSS (2017)

Annex 5b: A brief overview of the Kakadvitta FSTP

Kakadvitta FSTP

The plant is connected in series from one treatment module to the other. First FS is passed through a screen chamber to remove solid debris and then to the biogas digester for anaerobic treatment. As a next step sludge undergoes stabilization and then discharged on the sludge drying bed. The dried sludge is composted while the liquid fraction undergoes a separate treatment process through an anaerobic baffle reactor (ABR), anaerobic filter (AF), planted gravel filter and finally to the polishing pond.



Layout Plan of FSTP for Kakadvitta

The proposed treatment plant has been designed to treat 12 m^3 of FS per day. The concept was decided based on the following objectives:

- Reduce odour during regular plant operations as there may be households in near vicinity to the treatment plant in the near future
- Reduce operation and maintenance requirement as skill for complex operations is not easily available.
- Requirement of sludge stabilization as there is a potential for reuse of dried bio-solids in farming.
- Organic load and pathogen reduction in treated water as excess of treated water is planned for discharge into Mechi river.

Source: Third Small Towns Water Supply and Sanitation Sector Project (TSTWSSSP), DWSS (2017)

Annex 6a: Estimation of surface area requirement for FSM system 1

Table 1: Calculation for *SDB*

Drying bed design variables	Variable name	Figures	Unit
Raw sludge production rate	a	23	m^3 per day
time of drying	b	15	days
sludge production during one cycle	c = a * b	342.2	m^3
thickness of sludge	e	0.2	meter
width of bed	f	6	meter
length of bed	g	15	meter
Bed volume	h = e * f * g	18	m^3
number of bed required	i = c / h	20	drying bed
surface area needed	=f x g x i	1800	m^2

Table 2: Estimation of leachate production following SDB

Leachate production	Variable name	Figures	Unit/reference values
Volume of leachate proportion	j	80%	(50-80%)
Volume of leachate production	k = a * j	18.3	m^3 per day

Table 3: Calculation of output volumes and masses

Variables	Variable name	Input wet sludge	Dried sludge	Leachate	Unit	Remarks
input	l	23			m^3/day	estimation
initial TS density	m	50			kg TS/m^3 of sludge	literature (30-50)
initial TS masse	n = l * m	1141			kg TS/day	
initial moisture content	o	95%				literature (90-95)
initial water masse	p = n / (1-o)	22813			kg/day	
volumetric removal	q		0.1		m^3 of dried S/ m^3 of wet S	literature
End volume of dried sludge	r = l * q		2.28		m^3/day	
Volume ratio ending drained	s			80%		literature (80-85)
Volume drained	t = l * s			18.2	m^3/day	
TS concentration in leachate	u			2.5	kg TS/m^3 leachate	literature
Masse of TS removed	v = t * u			45.6	kg TS/day	
Masse of TS in dried sludge	w =n - v		1095		kg TS/day	
TS concentration in dried S	x = w / r		480		kg TS/m^3 dried sludge	
Dried sludge moisture content	y		60%			literature (50-70)
masse of water in dried S	z = w / (1-y)		2738		kg water /day	
Masse of dried sludge	A = z + w		3833		kg/day	
density of dried sludge	B = A / r		1680		kg/m^3	
density of wet sludge	C = p / l	1050			kg/m^3	

Volume of dried sludge	2.3	m^3/day
Masse of dried sludge	3832.6	kg/day
Masse of TS	1095.0	kg/day
Volume of leachate	18.3	m^3/day

Table 4: Horizontal flow constructed wetland (HFCW) for leachate treatment

Variables considered for HFCW	Variable name	Values	Units
HRT		20	days
volume	HRT x leachate volume	365.0	m^3
no of units		4	
depth		0.6	m
width		4	m
length	Roundup (vol/no of unit/depth/width,0)	39	m
volume	no of units x depth x width x length	374.4	m^3
Surface area	no of units x width x length	624	m^2
flow rate		1.90	m/hour
flow rate		0.53	mm/sec
flow rate		0.21	L/sec

Considerations for HFCW	Values	Unit	References
BOD after DB	1350	mg BOD/L (max)	max at the beginning of drying cycle
ABR BOD removal efficiency	80%		
BOD of effluent	270	mg BOD/L	
BOD load per day	4927.6	g BOD / day	
BOD load per m^2	7.9	g BOD / m^2 / day	
limiting factor BOD load	10	gBOD/m^2 / day	Limit in cold climate
Hydraulic loading	29.2	mm/d	
limiting factor for WW	40	mm/d	for waste water

Annex 6b: Estimation of surface area requirement for FSM system 2

Volumes and masses	*Variable name*	*Input wet sludge*	*Units*
input	l	23	m^3/day
initial TS density	m	50	kg TS/m^3 of sludge
initial TS masse	n= l * m	1140.7	kg TS/day
initial moisture content	o	95%	
initial water masse	p = n / (1-o)	22813	kg/day

Drying beds design variables	*Variable name*	*Values*	*Units*
Raw sludge production rate	l	22.8	m^3 per day
feeding frequency	D	0.25	1/day
number of bed	E = 1 / D	4	
Bed filled per day	F	1	bed/day
Bed volume required	G = l * F	22.8	m^3
thickness of sludge	H	0.1	meter
width of bed	I	15	meter
length of bed	J = G / (H * I)	15	meter
Surface area needed	K = E * I * J	913	m^2

Leachate and sludge	*Variable name*	*Values*	*Units/references*
Volume of leachate proportion	j	80%	(50-80%)
Volume of leachate production	k = a * j	18	m^3 per day
Stabilized sludge production			
Volume reduction ratio	L	0.01	m^3 of dried S/m^3 of wet S
Sludge production	M = l * L	0.23	m^3 / day

ABR and Anaerobic Filter

Variables	*Variable name*	*Values*	*Units*
HRT	N	2	days
volume	M = k * N	36.5	m3
no of unit	O	2	
depth	P	1.5	m
width	Q	2	m
length	R = M / (O * P * Q)	7	m
volume	S = O * P * Q * R	42	m3
Surface area	T = O * Q * R	28	m2
settler length	U	1	m
filter unit length	V	0.8	m
number of Baffle/ filter unit	W = (R-U) / V	8	
Velocity in m/hr		0.2	m/hour
Velocity in mm/sec		0.1	mm/sec
Flow in l/sec		0.2	L/sec

Horizontal Flow Constructed Wetland (HFCW)

HRT for HFCW		20	days
volume	HRT x leachate volume	365.0	m3
no of units		4	
depth		0.6	m
width		4	m
length	Roundup (vol/no of unit/depth/width,0)	39	m
volume	no of units x depth x width x length	374.4	m3
surface	no of units x width x length	624	m2
flow rate		1.90	m/hour
flow rate		0.53	mm/sec
flow rate		0.21	L/sec

500B solutions

In collaboration with

eawag aquatic research