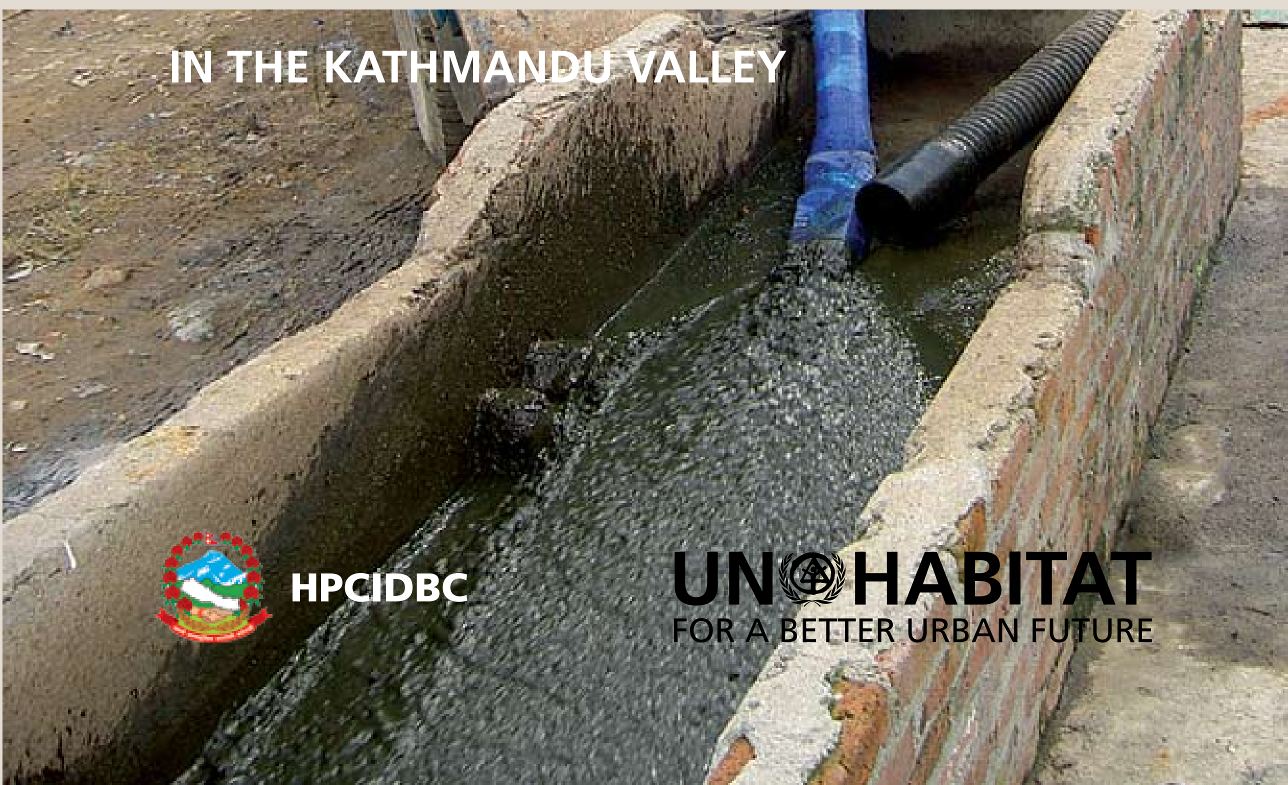
STATUS AND STRATEGY FOR FAECAL SLUDGE MANAGEMENT

IN THE KATHMANDU VALLEY



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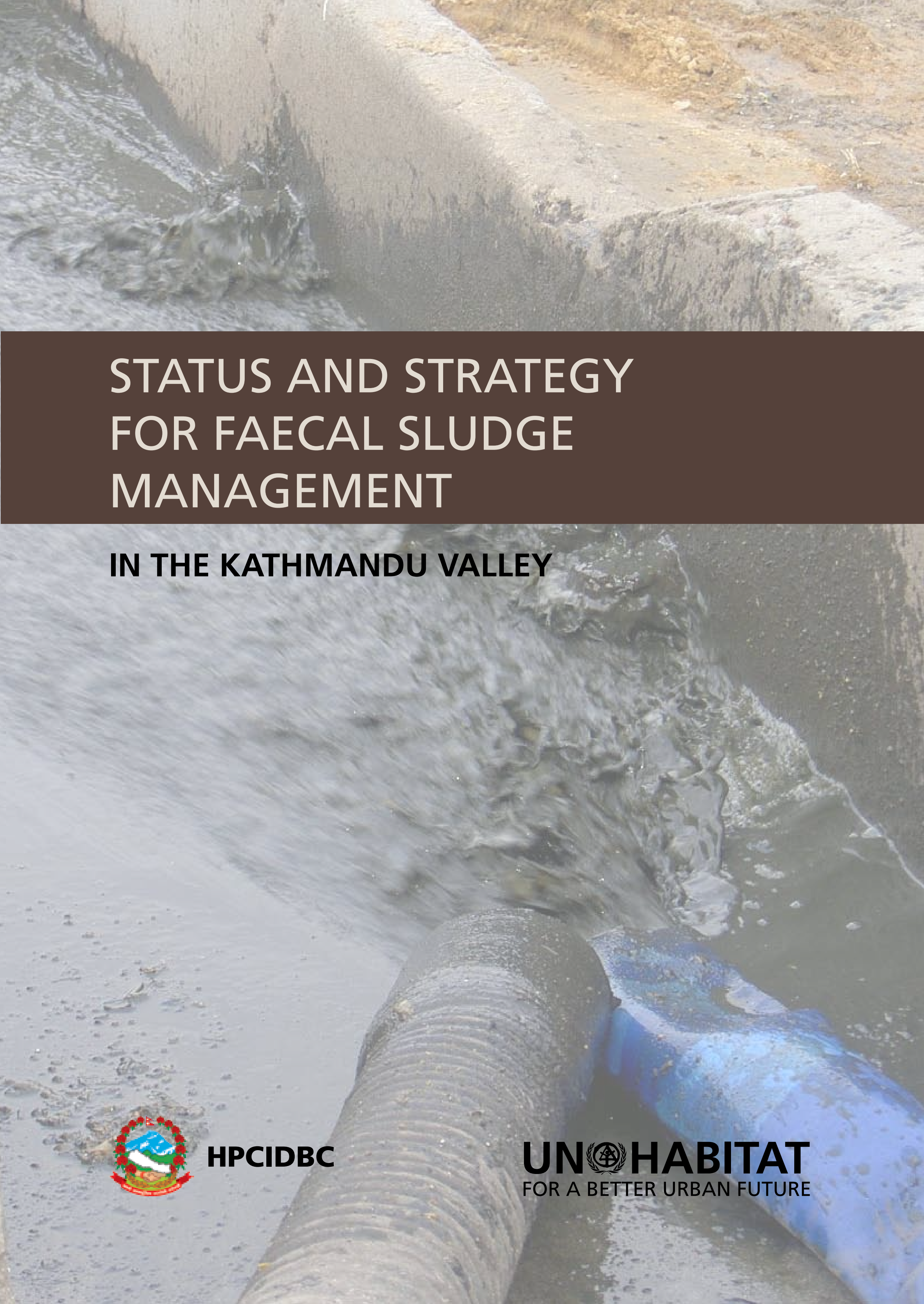

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Published by: High Powered Committee for Integrated Development of the Bagmati Civilization

Citation: HPCIDBC, 2011. *Status and Strategy for Faecal Sludge Management in the Kathmandu Valley*, High Powered Committee for Integrated Development of the Bagmati Civilization, Kathmandu, Nepal.

Cover photo: Mingma Gyalzen Sherpa

Design and Printproduction: WPS, eMail: printnepal@gmail.com

ISBN: 978-9937-2-3686-7

MESSAGE

It is a pleasure for the High Powered Committee for Integrated Development of Bagmati Civilization (HPCIDBC) to publish this study report on "Status and Strategy of Faecal Sludge Management in Kathmandu Valley" in collaboration with the Water for Asian Cities Programme, UN-Habitat, Nepal.

This publication has come up at the right time while, HPCIDBC is adapting to the Bagmati Action Plan (BAP) to improve the conditions of the Bagmati River. Haphazard disposal of feacal sludge from on-site system is one of the causes of pollution in the Bagmati River. Therefore, I expect that this publication will be instrumental in providing strategic directions and action oriented solutions for effective feacal sludge management in Kathmandu Valley.

I would like to thank Water for Asian Cities Programme, UN-Habitat, Nepal for executing this study and also thank all those people who provided their valuable inputs for the successful completion of the study.

Mr Prem Bahadur Singh
Chairperson
High Powered Committee for
Integrated Development of
Bagmati Civilization

PREFACE

Pollution of water bodies, mainly the rivers of rapidly growing urban centres, in the developing world is a major environmental concern. Discharge of untreated sewage including faecal sludge generated from on-site sanitation systems, indiscriminate disposal of solid waste are some of the main causes. In addition, lack of adequate infrastructures, institutional capacities and resources further exacerbates the problems.

Kathmandu Metropolitan City and the neighbouring Municipalities of the Valley face similar urban environmental challenges among which pollution of the River Bagmati and its tributaries is a serious environmental problem. By addressing the issue of faecal sludge management in the Kathmandu Valley, it is expected to control indiscriminate dumping of feacal sludge into the rivers and minimize river pollution. I believe this study will be a useful guiding document for all concerned stakeholders to efficiently manage faecal sludge in the Kathmandu Valley and other similar emerging small towns and cities in Nepal.

Andre Dzikus
Chief
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ABBREVIATIONS AND ACRONYMS

AIT	Asian Institute of Technology
BOD	Biological Oxygen Demand
BSMC	Bhaktapur Sub Metropolitan City
DWSS	Department of Water Supply and Sewerage
ENPHO	Environment and Public Health Organization
FS	Feacal Sludge
FSM	Feacal Sludge Management
HPCIDBC	High Powered Committee for Integrated Development of the Bagmati Civilization
HFCW	Horizontal Flow Constructed Wetland
KMC	Kathmandu Municipality
KUKL	Kathmandu Upatyaka Khanepani Limited
LSMC	Lalitpur Sub-Metropolitan City
MLD	Million Litres per Day
NGO	Non Governmental Organization
NGOFUWS	NGO Forum for Urban Water and Sanitation
NWSC	Nepal Water Supply Corporation
OSS	On-site Sanitation System
PPPUE	Public Private Partnership for Urban Environment
SDB	Sludge Drying Bed
TCOD	Total Chemical Oxygen Demand
TS	Total Solids
TSS	Total Suspended Solids
TSTP	Teku Septage Treatment Plant
UNDP	United Nations Development Programme
VDC	Village Development Committee

SUMMARY

In the Kathmandu Valley, around 70% of the households dispose their excreta directly into the sewer line while remaining 30% of the households still depend on onsite systems such as pit latrines and septic tanks. The practice of using onsite system is found to be more environmentally friendly in the present context of Kathmandu compared to direct discharge of wastewater into the sewer lines. Currently, due to lack of adequate wastewater treatment facilities, more than 95% of the sewerage ends up into the rivers without any form of treatment. Disposal of untreated sewerage and haphazard dumping of solid waste are seen as the two major contributors of river pollution in the Valley, evident from the deteriorating water quality of River Bagmati and its tributaries.

Onsite sanitation systems are prevalent mostly in the outskirts or peri-urban areas of the Valley. The study shows that 30% of households in urban areas of Lalitpur, 8% in Bhaktapur and 18% in Kathmandu District still use septic tanks for disposal of excreta while in the peri-urban areas more than 50% of the households use such onsite systems. There are around 68,000 septic tanks in the Valley. These onsite systems need regular emptying due to accumulation of faecal sludge (FS). Sludge emptying is done either mechanically or manually. Currently, a group of entrepreneurs provide mechanical FS cleaning services while many individuals are associated with manual pit emptying. On average a household empties a septic tank at an interval of 3 to 3.5 years. However, due to the absence of a proper faecal sludge management (FSM) system almost all the collected sludge is directly discharged into rivers. Thus, there is an urgent need for a proper FSM system in the Valley. Establishing a FS treatment system under a responsible institution/authority is seen as the foremost and integral component as other essential amenities for FSM i.e. sludge collection and transportation are already in place. The entire FSM system could be operated through a public private partnership approach as there is an enormous potential of benefiting multiple stakeholders in this process. Establishment of a FSM system in Kathmandu will be a good demonstration for other urban or peri-urban areas in the country which faces similar sanitation problems.

CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND

Rapid urbanization characterized by sharp population growth and unplanned settlements has been posing serious challenges on the environmental status of the Kathmandu Valley. The negative impacts due to this rising pressure can be witnessed by the deteriorating environmental sanitation quality of the Valley. One of the severe impacts is pollution of the major rivers flowing through the Valley due to direct discharge of untreated domestic wastewater and dumping of solid waste.

The Valley comprises of 5 municipalities and 114 Village Development Committees (VDCs) located in the three districts of Kathmandu, Bhaktapur and Lalitpur. Based on the 2001 census, the projected population in 2010 is estimated at 2.3 million with an annual growth rate of 4.9%. Figures show that more than 90% of the total population in the Valley has access to toilet facilities i.e. 93% in Kathmandu, 91% Bhaktapur and 81% Lalitpur districts (Gautam *et al*, 2004). However, due to lack of appropriate and adequate treatment systems almost all wastewater is directly discharged into the rivers. The present sanitation system in the Valley is based on a combination of onsite and offsite systems. Most of the houses in the urban areas of the Valley have cistern-flush or pour-flush type toilets connected to the sewerage system or to open drains. The peri-urban areas which do not have access to the sewerage connection have toilets connected either to pits or septic tanks.

At present there is only one large scale wastewater treatment facility and a few community based wastewater treatment system that is operational in the Valley which treat less than 5% of the total wastewater generated. Therefore, wastewater management has become very urgent and important on one hand while on the other hand equally important is the management of faecal sludge generated from onsite systems. Past studies show that most households in the Valley have their toilets connected to the sewer system. A survey carried out by Nippon Koei (1999) in the five municipalities of the Valley also shows that sewerage system is the main form of excreta disposal for majority of the population. Around 74% of the population directly discharge wastewater from toilets into the sewers, 21% use septic tanks and 4% use pit latrine. Open defecation in open land, riverside accounts to 1%. Similarly, a study by NGO Forum for Urban Water and Sanitation in 2003 in five municipalities of the Valley showed that 74% of the households were discharging their night soil into the sewer, 9% of the households drained their night soil into the sewers through septic tanks and 15% used only septic tank to discharge night soil (Joshi *et al*, 2003). From these studies it is observed that the trend of discharging night soil directly into sewers remains the same over the years. Similarly, the percentage of population using septic tanks has also remained more or less the same, which is between 21 to 24%. Due to absence of a FSM system in the Valley, most of the sludge collected both manually and mechanically ends up in the rivers, untreated. There is an urgent need to improve the FSM problem to avoid potential environmental pollution and associated health risks resulting from improper sludge handling and disposal practices. Therefore, this study by UN-Habitat has been conducted to understand the status of FSM and to recommend measures to improve FSM practices in the Valley.

Wastewater disposal from household into open drains

1.2 OBJECTIVE

The main objective of the study was to review the existing practices, problems of FSM and to devise an action oriented strategy for FSM in the the Valley.

1.3 METHODOLOGY

1.3.1 LITERATURE REVIEW

Project completion reports, documents, wastewater master plans of the Valley, thesis of PhD and Master's students were reviewed to collect information on the sanitation situation of the Valley.

1.3.2 HOUSEHOLD SAMPLE SURVEY

A sample survey was conducted in the Valley to understand the current sanitation practices at the household level. Information relating to emptying practices, frequency of pit emptying, type of sanitation facilities, payment for services was collected from the households. In addition, information from the sample survey was used to estimate the number and distribution of septic tanks and the total sludge volume in the Valley.

The sampling design was based on stratified two stage sampling technique. The required sample size for this study was estimated to be 1750 households around the Valley. Primary sample units (PSUs) were taken as wards and sub-wards of Village Development Committee (VDC)/ Municipality. In the Valley, due to the heterogeneous nature of the household sizes, the wards were split into sub-wards of 5000 or more than 5000 household sizes.

In the first stage, PSUs were selected by using probability proportional to size selection method from their corresponding strata. The frame for selecting sample for the survey was the list of wards/sub-wards with corresponding number of households from Population Census 2001. Altogether 70 PSUs were selected and from each selected PSUs 25 households were selected for the study.

In the second stage, random selection procedure of households was adopted. 5 sampled households were selected from the center of the PSU and 20 sampled households from four corners of the PSU. A dwelling may contain more than one household, but only one household was selected from a single dwelling. The logic behind this was that all the households within a dwelling were using the same type of waste water management facility. In this approach, the sample households are more representative due to its scattered nature of sample allocation. The sample PSUs were spread over all the 26 wards/sub-wards of Kathmandu Metropolitan City (KMC) (East, West, North, City Core North & South, and City Centre), two wards in the Kirtipur Municipality (KM), 6 wards in the Lalitpur Sub-Metropolitan City (LSMC), 3 wards in the Bhaktapur Municipality (BM), 2 wards in the Madhyapur Thimi Municipality (MTM) and 31 wards in the rural areas of the Valley. Since the sample design was not self-weighting, weighting factor was applied to estimate indicators in aggregate level.

1.3.3 CONSULTATION WITH EXPERTS AND STAKEHOLDERS

Local as well as international experts were consulted to find out current problems and practices relating to FSM and to seek for possible strategies for long term FSM. Potential stakeholders on FSM like High Powered Committee for Integrated Development of the Bagmati Civilisation (HPCIDBC) was consulted seeking for options to manage FS within their wastewater treatment premises. Private sludge entrepreneurs and their association were consulted to understand current problems faced during sludge emptying, transportation and its disposal. Also suggestions were sought from the private entrepreneurs to find solutions for sustainable FSM in the Valley.

1.3.4 PLANNING WORKSHOP

As part of devising appropriate solution for FSM, a planning workshop was carried out in Kathmandu on 18 July 2007. The participants of the workshop were private sludge emptier, HPCIDBC, UN-Habitat and representatives from various organizations.

2.0 OVERVIEW ON FS MANAGEMENT, QUALITY AND TREATMENT

In most urbanized areas in developing countries, excreta are disposed off in facilities located on the housing plot itself. Whether these facilities are septic tanks, dry latrines, bucket latrines, communal toilets or other types, they all accumulate FS, which needs to be removed periodically. The owners are little concerned about the problems with FS removal and management. FSM is usually limited to a de-sludging service that is provided by municipal agencies or the private sector, but proper sludge disposal and subsequent treatment or management are generally lacking. It is observed that every day thousands of tons of sludge from onsite sanitation installations are disposed off untreated into lanes, drainage ditches, open urban spaces and into water bodies such as rivers and sea. FS disposed off or used untreated in agriculture creates enormous health risks and environmental pollution. The impacts and types of risk associated due to indiscriminate dumping and disposal practices are provided in Table 2.1. In order to reduce or eliminate potential health and environmental risks and impacts it is necessary to manage FS effectively.

TABLE 2.1: Impacts and risks caused by disposal of FS in nature

Impact	Type of risk
Surface and groundwater pollution	Actual surface water pollution; potential for groundwater pollution
Transmission of excreta-related infections; occurrence of a high level of pathogens in the urban environment	Potential risk of increased levels of disease prevalence; scientific proof of actual risks attributable to the disposal of untreated FS and to high levels of pathogens "floating" within the urban environment may be obtained on the basis of extensive epidemiological studies, only
Unpleasant odours and eyesore	Impact felt by those dwelling near the disposal sites and by those passing by

Source: EAWAG/SANDEC, 1998

2.1 FS QUALITY

FS contains sludge of various consistency accumulated in and evacuated from on-site sanitation systems such as septic tanks, aqua privies, family latrines, and unsewered public toilets (Strauss, 2002).

FS characteristics vary highly with the storage duration, temperature, intrusion of groundwater in septic tanks, performance of septic tanks, tank emptying technology and pattern. A basic distinction can usually be made between sludge which, upon collection, are still relatively fresh or contain a fair amount of recently deposited excreta (e.g. sludge from frequently emptied or unsewered public toilets) and sludge which have been retained in on-plot pits or vaults for months or years and which have undergone a biochemical degradation to a variable degree (e.g. sludge from septic tanks, septage). FS is often associated with one of two broad categories i.e. high and low-strength sludge. Table 2.2 shows typical FS characteristics along with the characteristics of typical municipal wastewater.

FS with high water content being disposed at Teku Septage Treatment Plant, Kathmandu

FS characteristics also differ widely by locality. Table 2.3 shows the FS characteristics in major cities of Thailand, Philippines, Ghana and Nepal. Sherpa (2005) indicates that such high total solids

TABLE 2.2: FS from on-site sanitation systems in tropical countries: characteristics, classification and comparison with tropical sewage

Item	Type "A" (High-strength)	Type "B" (Low-strength)	Sewage - for comparison's sake
Example	Public toilet or bucket latrine sludge	Septage	Tropical sewage
Characterization	Highly concentrated, mostly fresh FS; stored for days or weeks only	FS of low concentration; usually stored for several years; more stabilized than Type "A"	
COD mg/l	20, - 50,000	< 15,000	500 - 2,500
COD/BOD	5: 1.... 10: 1		2 : 1
NH_4-N mg/l	2, - 5,000	< 1,000	30 - 70
TS mg/l	≥ 3.5 %	< 3 %	< 1 %
SS mg/l	≥ 30,000	↵ 7,000	200 - 700
Helm. eggs, no./l	20, - 60,000	↵ 4,000	300 - 2,000

Source: Montangero & Strauss (2004)

TABLE 2.3: Septage quality in Bangkok, Manila, Accra and Kathmandu

Locations	COD [g/L]	BOD /COD	TS [g/L]	TVS (% of TS)
Bangkok[1] (256 samples)	15.7	1:7	15.4	69
Manila[2]	37	1:10	72	76
Accra/ Ghana[3] (68 samples)	230	-	12	60
Kathmandu[4]	-	-	27	65

[1] Based on AIT (1997-2003).
[2] Based on University of Philippines (1997)
[3] Based on 4 years field monitoring of Achimota Faecal Sludge Treatment Plant, Accra, Ghana (1998)
[4] Based on analysis results of Kathmandu. TS (N=42) and TVS (N=28)

Source: Sherpa (2005)

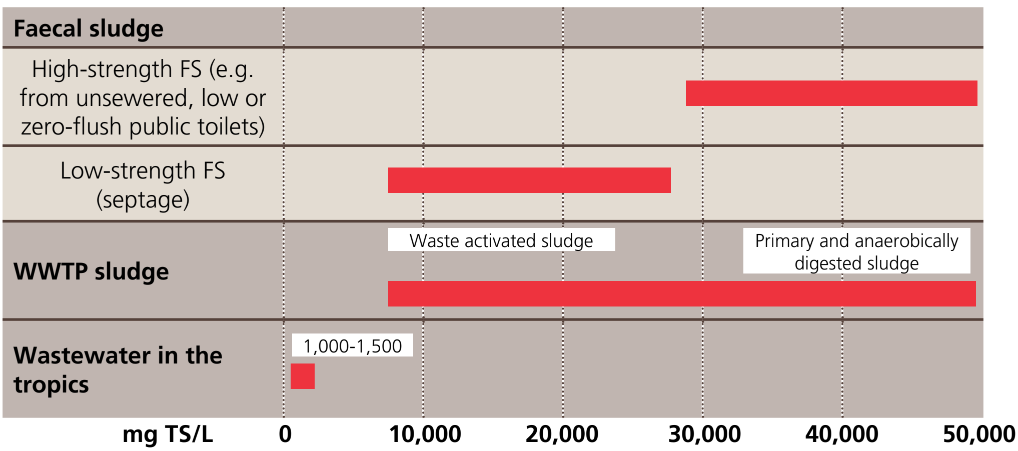
content in the FS of Kathmandu compared to Bangkok and Ghana could be due to the differences in the emptying practices, the construction nature of septic tanks and the differences in the dietary habits. The average total solids value of FS measured in 42 different samples in Kathmandu was found to be 27 g/L.

FS from septic tanks are bio-chemically more stable due to long storage periods and are in more diluted form than from installations which are emptied regularly at shorter intervals (eg. public toilet vaults), which results in variation of pollutant concentrations. The pollutant concentrations in FS are by a factor of 10 to 100 times higher than in municipal wastewater as presented in Figure 2.1 which compares the total solids content of FS, sludge from a wastewater treatment facility and wastewater.

2.2 FS TREATMENT

Unlike digested sludge produced in mechanized biological wastewater treatment facilities or in other types of wastewater treatment works (e.g. waste stabilization ponds, oxidation ditches), the organic stability of FS attains varying levels. This variability is due to the fact that the anaerobic degradation process, which takes

FIGURE 2.1: Total solids concentration



Source: Koottatep et al (2003)

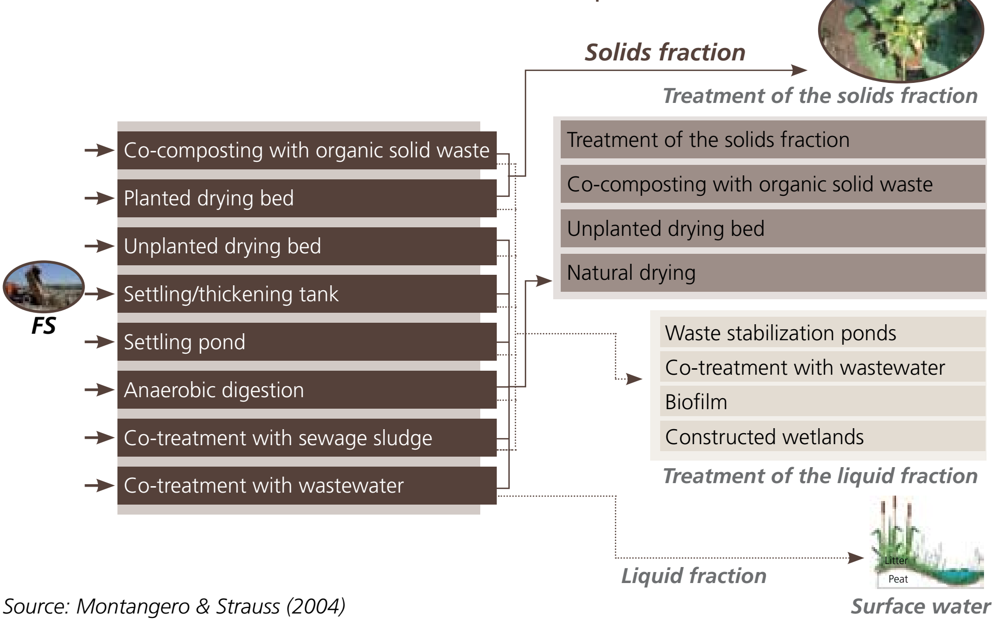
place in onsite sanitation systems, depends on several factors like ambient temperature, retention period and the presence of inhibiting substances. As the faecal matter is not being mixed or stirred, this impairs the degradation process (Koottatep *et al.*, 2003).

The choice of a FS treatment option depends primarily on the characteristics of the FS generated in a particular town or city, budget availability, land availability and on the treatment objectives (Montangero and Strauss, 2004). The widely varying quality and quantity of FS requires a careful selection of appropriate treatment options. Primary treatment may encompass solids-liquid separation or biochemical stabilization if the FS is still fresh but has undergone partial degradation during on-plot storage and prior to collection.

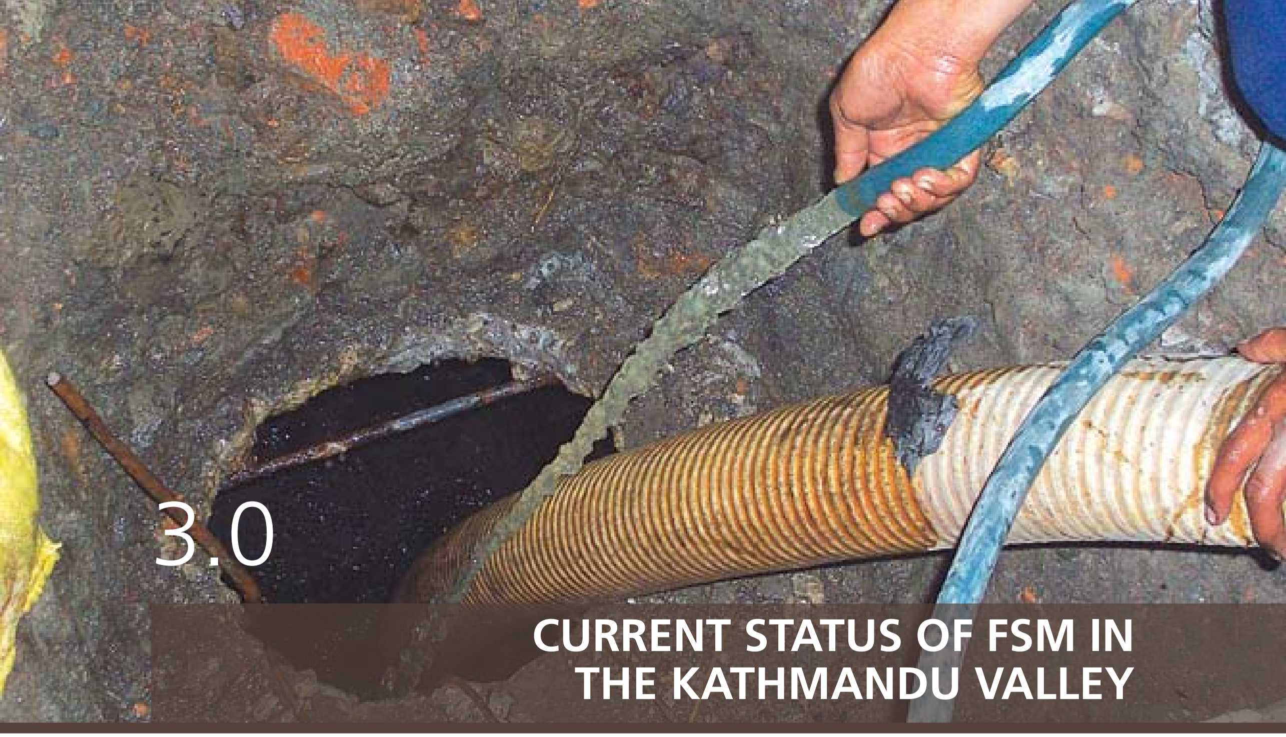
An overview of the potential modest treatment options and several combinations of options is provided in Figure 2.2. The first stage of FS treatment mostly involves separation of solids from the liquid. The liquid part can be treated using different wastewater treatment options while the solids can undergo co-composting or natural drying process for agricultural reuse or land filling. Depending on the treatment objectives and the prevailing conditions the best options can be chosen for a selected area. Some of the treatment options with the pros and cons and FS treatment options that have been used in different countries is provided under Appendix A for reference.

In developing countries like Nepal, to prevent haphazard disposal and pollution of water bodies as well as to minimize total management cost, decentralized or semi centralized FS treatment units are recommended. As per experience, using small to medium size FS treatment systems can help to minimize FS haulage volumes and thus reduce the treatment cost borne by the operators of FS emptying facilities (Montangero and Strauss, 2004)

FIGURE 2.2: Overview of modest FS treatment options



Source: Montangero & Strauss (2004)



3.0 CURRENT STATUS OF FSM IN THE KATHMANDU VALLEY

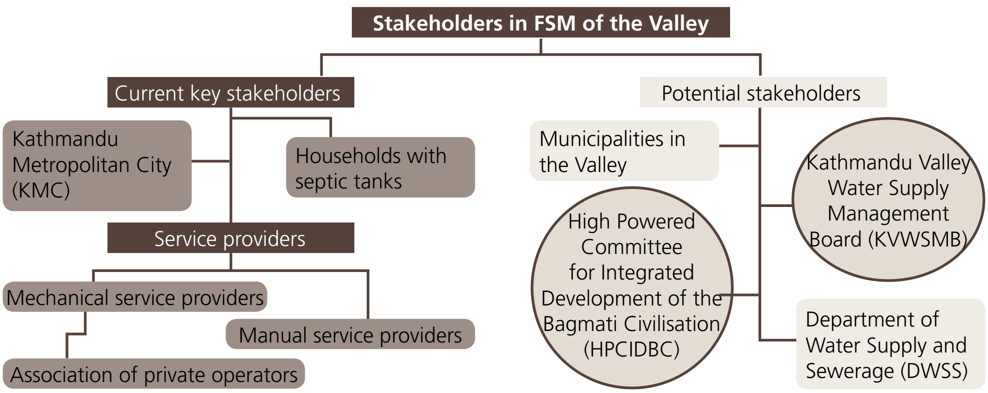
3.1 STAKEHOLDERS IN FSM

Based on consultations with experts, relevant departments/agencies and assessing the current status, stakeholders have been identified and categorized as key stakeholders and potential stakeholders. Categorization of the stakeholders is based on the following definitions:

Key stakeholders: refers to the ones who are currently involved in FSM of the Valley either formally or informally.

Potential stakeholders: refers to the ones who by their assigned responsibilities, legal mandates or by their existing operations such as provision of certain facilities, project objectives/activities, existing future plans and strategies can be closely linked to or collaborated for FSM of the Valley. Figure 3.1 provides an overview of different stakeholders involved in FSM.

Figure 3.1: Stakeholders in FSM of the Valley



3.1.1 KEY STAKEHOLDERS

3.1.1.1 FS SERVICE PROVIDERS

Service provider refers to those private and public individuals and institutions which provide FS cleaning services. The private service providers are either entrepreneur providing mechanical cleaning services or individual/groups who provide manual cleaning services. A public service provider refers to the municipalities such as the KMC.

PRIVATE OPERATORS

There were between five to eight private entrepreneurs who were providing FS cleaning services in 2005. Currently, there are 10 private operators, nine are associated with a group called *Phohar Maila Sankalan Sewa Sangh* (Association of Private FS Collectors) while 1 private operator provides its services under *Kathmandu Mahanagarpalika Phohar Maila Byawasthapan Sewa* (Kathmandu Municipality Waste Management Services).

MANUAL SERVICE PROVIDERS

Manual service providers work as a group in several locations in the Valley. The total number of manual service providers could not be quantified as this job could be performed by anyone working on a daily wage basis. In some areas local sweepers were also involved in cleaning septic tanks.

3.1.1.2 HOUSEHOLDS WITH SEPTIC TANKS

Households are the main source of FS generation. As part of regular operation and maintenance septic tanks or pits are de-sludged regularly to avoid overflow and leakages. The national building code and municipal bylaws mandates each house/building to install septic tanks in areas where sewerage is not accessible. Past studies and figures from the present study shows that around 30% of the households in the Valley, mostly from the peri-urban areas where sewerage network is low, use septic tanks. See section 3.3 for details.

3.1.1.3 KATHMANDU METROPOLITAN CITY

KMC has been one of the major stakeholders involved in FSM in the Valley. KMC established the Teku Septage Treatment Facility in 1998 and the Urban Environment Section was providing FS emptying and treatment services till 2004. The private operators were also allowed to use the facility with a tipping fee. Since 2005, the facility has been out of operation, due to management and technical problems, and is providing only FS emptying services.

3.1.2 POTENTIAL STAKEHOLDERS

Based on the current roles, responsibilities and their potential capacities, the following institutions have been identified as potential stakeholders for FSM in the Valley.

Private sector's ad for FS emptying service

3.1.2.1 HIGH POWERED COMMITTEE FOR INTEGRATED DEVELOPMENT OF THE BAGMATI CIVILIZATION

Under HPCIDBC, the Gujeshowri Wastewater Treatment facility has been providing wastewater treatment services for households upstream of the Pashupatinath temple. The treatment facility comprises of oxidation ditch combined with sludge drying beds.

As per the discussion with HPCIDBC authorities, field visits and observations it was found that the sludge drying beds have not been optimally used. In addition, there is space available for construction of additional sludge drying beds if required. Therefore, a high possibility was seen to utilize the existing sludge drying beds to treat FS while the effluent could be co-treated with the domestic wastewater in the oxidation ditch. This could be done considerably at a low cost on one hand while on the hand by providing FS treatment services, HPCIDBC could generate revenue through collection of tipping fee from private FS operators. As of present, HPCIDBC faces financial burden due to high operation and maintenance cost for operation of the wastewater treatment facility. Thus keeping in view of the potential benefits, HPCIDBC was identified as a potential stakeholder for FS management of the Valley.

3.1.2.2 METROPOLIS AND MUNICIPALITIES IN THE VALLEY

The LSMC and three other municipalities i.e. BM, MTM and KM of the Valley have also been identified as potential stakeholders for FS management in the Valley.

The Local Self Governance Act of Nepal mandates individual municipalities to provide its residents with proper water and sanitation provisions. Thus under this mandate, these institutions in the long run could have potential role of providing FS management services. However in the present context none of these institutions are involved in FSM. It was found that LSMC does not have immediate plans to develop FS management services. Households within LSMC take FS cleaning services from private operators as well as from KMC.

BM is also not involved in any FSM activities. Under GTZ assistance in 1994, the municipality had established its own wastewater management system. Waste stabilization ponds were constructed at Hanumanghat and Sallaghari. Currently both the treatment facilities are out of operation due to technical problems. In the past, local sweepers were providing FS emptying services to households. The municipality has one collection vehicle and about a decade ago it was providing FS emptying services. The collected FS was disposed at the Sallaghari treatment facility. After four years of operation, it was discontinued when Nepal Water Supply Corporation restricted FS disposal. Currently, BM provides emptying services under the condition that individual household provides their own space for FS disposal. Besides, households from BM also take up services of private operators for FS cleaning. BM does not have any future plans regarding FSM.

Similarly, MTM also does not have any FS management related facilities. However, wastewater management plans have been developed for the municipality. A community based wastewater treatment facility has been successfully operating in Sunga since 2005. Most households

have been connected to the municipal sewer line, a part of which is treated in the community wastewater treatment facility. Households with septic tanks are taking emptying services of private operators when needed.
Household at the core area are connected to sewers while those in the peripheral areas use septic tanks. The municipality has strict monitoring mechanism to check the construction of new buildings. Therefore as compared to other municipalities septic tanks are in place even in the newly constructed houses. There is no FSM service in the municipality. Like in other municipalities, households take up private cleaning services when required.

3.1.2.3 KATHMANDU VALLEY WATER SUPPLY MANAGEMENT BOARD

Kathmandu Valley Water Supply Management Board (KVWSMB) is an autonomous corporate entity established in 2006 under Water Supply Management Board Act (2006) for operation of water and wastewater services in the Valley. It acquired ownership of all facilities within the Valley previously owned by erstwhile operator Nepal Water Supply Cooperation (NWSC) in February 2010. It is the asset owner of water supply and wastewater facilities and responsible for providing wastewater related services to the population within its geographical areas in the Valley through a service provider. It is also responsible for preparing plans, formulation of service policies, mobilizing financial resources and managing implementation of capital investment plans.

Recently as per the Nepal Government's Company Act (2063), the Kathmandu Upathyaka Khanepani Limited (KUKL) (Kathmandu Valley Water Utility), which is a public company, has taken over the responsibility of overall management of water supply and sanitation services under a license and lease agreement for 30 years with KVWSMB. KUKL is responsible for maintenance of all assets received on lease. The sewerage department within KUKL is responsible for construction of new sewer lines, its operation and maintenance. Although KUKL is the responsible authority, the only existing centralized Gujeshwori Wastewater Treatment facility is under the jurisdiction of HPCIDBC. KUKL at present collects water supply and sewerage fee from its customers who are connected to its water supply network. Although KUKL collects the sewerage fee there are no immediate plans and programmes related to FSM in the Valley.

3.1.2.4 DEPARTMENT OF WATER SUPPLY AND SEWERAGE

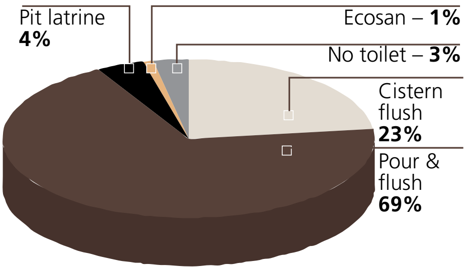
Department of Water Supply and Sewerage (DWSS) is responsible for implementation of water and sanitation services in all areas except municipal areas, ie. all VDCs which are peri-urban type settlements are under the mandate of DWSS. As most peri-urban areas are served with septic tanks, role of DWSS in principle is important for FSM of the Valley. DWSS has specific technical sections to carry out water supply and sanitation related activities such as the environmental sanitation, sewerage management, appropriate technology development section, etc. However, it was found that there were no immediate plans of FSM for the Valley.

3.2 HOUSEHOLD SANITATION PRACTICES

3.2.1 TYPES OF SANITATION SYSTEMS

The Valley has the highest sanitation coverage as compared to other parts of Nepal. Different types of sanitation facilities are adopted by the city dwellers of the Valley. Some of the common types of toilets are the flush and discharge type, pour flush toilets with or without drainage facilities, closed pit latrines etc. The study found that 69% of the households in the Valley were using pour flush type toilets while 23% used cistern flush type and only 4% used pit latrines while around 3% did not have access to toilets (Figure 3.2).

FIGURE 3.2: Type of sanitation facilities at households



3.2.2 WASTEWATER DISPOSAL PRACTICES

The wastewater from toilet or black water disposal practices varies in the urban and rural areas. As per the survey it was found that majority of the households in the urban areas dispose black water directly to open drains or sewers while only few percentage of the households used onsite facilities like septic tanks. 30% of the households in urban areas of Lalitpur, 8% in Bhaktapur and 18% in Kathmandu used septic tanks for disposal of black water (Table 3.1). Majority of these tanks are simple lined pits which cannot be considered as "septic tanks", although it is the terminology used locally. Essentially it is a larger sized pit, lined with a brick wall and covered with a concrete slab.

The rural areas as indicated in this survey mainly comprises of peri-urban type settlements, have toilets connected to septic tanks. Out of the three districts in the Valley the peri-urban areas of Lalitpur has the highest number of septic tank coverage.

TABLE 3.1: Percentage of households using septic tanks

District	Urban/Rural	
	Urban (%)	Rural (%)
Lalitpur	30	61
Bhaktapur	8	50
Kathmandu	18	45

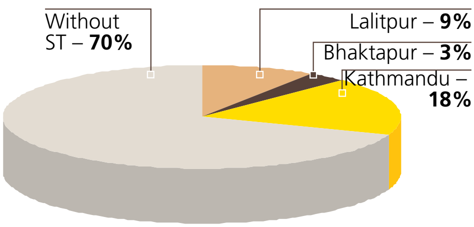
Among the 1750 households surveyed in the three districts, only 30% were using septic tanks while remaining 70% of households were disposing black water into sewers or municipal drains. This shows that a majority of the households in the Valley do not use septic tanks for wastewater disposal from toilets.

3.2.3 SEPTIC TANK DESIGN, MAINTENANCE AND PERCEPTIONS

SEPTIC TANK DESIGN

As part of assessing the household sanitation practices, this study also looked into the design quality aspects of septic tanks. It was found that majority of the households do not follow the standard design guideline for construction. While assessing the type of materials used in septic tank construction, it was found that 76% of the septic tank walls were made out of brick cement mortar, 11% with brick mud mortar and only 13%

FIGURE 3.3: Septic tank coverage in Kathmandu Valley

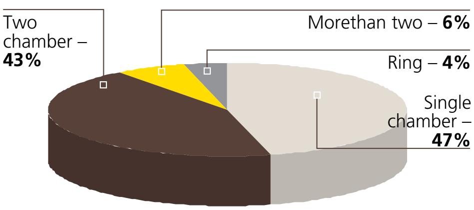


A single chambered tank with no provisions for FS emptying

Poorly designed septic tank in a new house

were reinforcement cement concrete walls. Likewise, only 60% of inner walls of the septic tanks were plastered with cement. These result indicates that majority of the septic tanks are poorly constructed. In terms of the design considerations, only 6% of the tanks had more than 2 chambers, 43% were two chambered, 47% were single chambered while 4% of the septic tanks were of the concrete ring type (Figure 3.4). The later cannot be considered as a septic tank but in most peri-urban areas the households understood this type of installation as septic tanks.

FIGURE 3.4: Design of septic tanks



OPERATION, MAINTENANCE AND TREATMENT PERCEPTION

Majority of the households are not concerned about routine maintenance of the septic tanks. According to the survey, 57% of the households clean/empty septic tanks when it is completely full and start overflowing, 22% empty due to the blockage and only 16% empty septic tanks as a part of routine operation and maintenance.

A well designed septic tank acts as a pre-treatment of household wastewater. However, analysis of household's preference level on wastewater disposal shows that most households prefer to connect to sewer lines instead of constructing septic tanks. Those who use septic tank is either due to the absence of sewerage system or due to technical difficulty in connecting to sewers. The survey also showed that 80% of the sampled household did not know where the sludge was disposed once it was emptied mechanically. This indicates that in general households are not aware on environmental conservation; there is clearly no ownership on the overall process of sludge management, and as there is no legal mandate and enforcement mechanisms households are less concerned on the fate of FS.

3.3 FS GENERATION IN KATHMANDU VALLEY

For the estimation of the FS generated in the Valley first the number of septic tanks in the Valley was estimated as follows:

3.3.1 NUMBER OF SEPTIC TANKS

The following figures have been taken into consideration for estimation of septic tanks:

- Based on the census data of 2001, the total population and total households in the Valley were calculated for the year 2010.
- As found from the household survey, the average family size for the Valley was 4.05 and the average household size in each dwelling was 2.17, which have been considered in the estimation of the number of septic tanks.
- Based on the household survey, the percentage coverage of septic tanks in urban and rural areas of Kathmandu, Bhaktapur and Lalitpur have been taken into consideration (see Table 3.1)
- Average household growth rate was taken as 5%

Based on the above figures the number of septic tanks in the Valley is presented in Table 3.2. As per the calculations, the number of septic tank in the Valley was estimated as 68,000 units.

TABLE 3.2: Number of septic tanks in the Valley

Districts	VDC/ Municipalities	Projected Population 2010	Projected households 2010 (i)	Share of households using septic tanks (ii)	Estimated No. Septic Tanks (No. of HH in each dwelling 2.17)
Laltipur	Lalitpur Sub-metropolitan City	207701	44596	13379	6165
	VDCs and Institutions	222742	43232	26372	12153
Bhaktapur	Bhaktapur Municipality	91796	15772	1262	581
	Madhyapur Thimi Municipality	60424	12415	993	458
	VDCs and Institutions	133079	24015	12008	5533
Kathmandu	Kathmandu Metropolitan City	1016631	230239	41443	19098
	Kirtipur NP	61791	14356	2584	1191
	VDCs and Institutions	558615	111590	50216	23141
Total		2352779	496215	148255	68,320

Note: (i) Projected household based on Census 2001 (ISRC, 2010)
(ii) Share of septic tanks based on sample survey (Table 4)

3.3.2 FS GENERATION

The following assumptions and figures have been taken into consideration for estimation of total FS generation in the Valley:

- Average volume of septic tank from survey was found to be 5.31 ± 0.39 m^3 with a standard deviation of 4.67 at 95% confidence level;
- The average emptying frequency of septic tanks was (3.77 ± 0.4);
- While cleaning, only 82% of the FS from septic tanks are emptied (based on the data from the households which say the emptying is incompletely done).

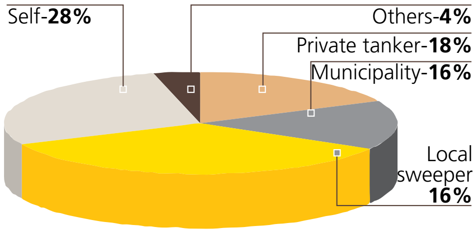
From the above data the average volume of the FS generated per year in the Valley is 76,600 m^3/year.

The calculated estimation provides an overview of the FS generation in the Valley under average condition. However, the estimation on the total FS generation can vary due to several factors such as changes in the emptying frequency, volume of the tanks, emptying practices, type of the toilet system and awareness among the septic tank users.

3.3.3 FS COLLECTION AND TRANSPORT

FS collection in the Valley is a combination of mechanical and manual emptying. Households opt for both types of services while some clean it themselves. Survey results show that the share of manual emptying is quite large. Among the households with septic tanks 34% empty manually by hiring local sweeper while, an equal percentage of households empty mechanically using private (18%) and public (16%) cleaning services. It was also observed that 28% of the households were self cleaning (Figure 3.5). This practice was common in the farming communities where FS was used as manure. Some households were also discharging FS directly into storm water drains during monsoon season. Due to increased sewerage coverage it was reported that over the years the volume of FS cleaning services required has decreased considerably.

FIGURE 3.5: FS emptying practices at households



3.4 FS SERVICE PROVIDERS

FS collection starts with demand from households. Households demand for FS cleaning services once septic tanks or pits are filled and require emptying services. FS is either emptied mechanically or manually by the service providers. The collected FS

Private FS collection truck.

KMC's FS collection vehicle

is then transported by service providers for final disposal.

3.4.1 MECHANICAL AND MANUAL EMPTYING

Currently, there are ten private operators providing FS cleaning services, among which nine private operators are associated with a group called *Phohar Maila Sankalan Sewa Sangh* while one operator provides its services under *Kathmandu Mahanagarpalika Phohar Maila Byawasthapan Sewa*. Mechanical FS collection or emptying is done with the help of vehicles.

The *Phohar Maila Sankalan Sewa Sangh* has 3 de-sludging trucks, 3 drivers and 7 assistants while the *Kathmandu Mahanagarpalika Phohar Maila Byawasthapan Sewa* has 1 de-sludging truck and 1 driver and 2 helpers. The vehicles are equipped with a generator, pipes and a suction pump. In case of KMC, the FS vehicle has a suction pump mounted internally. KMC has 2 suction vehicles with a storage capacity of $3m^3$ used for FS cleaning services. KMC employs 3 drivers and 3 assistants for sludge collection.

Manual service providers work as a group in several locations in the Valley. The numbers could not be quantified as this job could be performed by anyone working on a daily wage basis. The manual cleaning is done using a bucket, rope or shovel. The collected FS is then buried in land if the client has sufficient space or disposed into municipal sewers or rivers. According to interviews with a group of manual service providers, a decade back they were emptying between 225 to 365 houses annually but now they empty only between 2-4 houses annually. Over the years, manual emptying has decreased as households are increasingly connecting to sewer lines.

3.4.2 FS EMPTYING CHARGE AND COVERAGE AREA

FS emptying or cleaning charges are levied based on the type of institutions by the

Locally assembled device for FS pumping.

Manual emptying of FS.

service providers. For hotels and diplomatic missions the charge is higher whereas for households it is lower. The cost also varies depending on the haulage distance. However, there is no logical calculation on the emptying charge levied by the private service providers corresponding to the haulage distance. Emptying charge is also negotiated based on the economic status of the client. The emptying charges of KMC are classified into more categories than the private operators. In addition to FS emptying services, KMC is also responsible for cleaning septic tank and blocked manholes. It covers wide range of area within the Valley.

Table 3.3 provides the FS emptying costs charges by the private operators and KMC and the coverage areas.

With regards to manual emptying, the service providers are contacted either personally or through networks. The service fee ranges from Rs. 2000 and above per emptying depending upon tank size and client's economic status.

TABLE 3.3: FS cleaning costs

Clients	Association of Private FS Operators (NRs/trip)	KMC, Waste Management Section (NRs/trip)
Households inside ring road	1500 to 2000	1800
Households outside ring road	1500 to 2000 (depending on distance travelled)	2100-2500 (depending on distance travelled)
Government Office and Institutions	-	2400
School, NGOs, hospital and social organization		1500
Five Star Hotels	1500 to 2000	3000-5000
Diplomatic Agency (Embassy)	4250	6300
Balmandir, Govt. Schools, Agencies for disabled	1500	Minimum charge
Coverage Area	Kathmandu, Bhaktapur, Lalitpur (Lele, Godavari), Manthali (Ramechhap), Tatopani, Dhading, Butwal	Bhaktapur, Lalitpur (Kusunti, Chapagaun, Siddhipur), Kathmandu – Chabahil, Bouddha, Kapan, Budhanilkantha, Tinthana (Thankot) and Madhyapur Thimi

Note: USD 1 = Approx. NPR 70

Source: Private FS operators and KMC (2007)

3.4.2 VOLUME COLLECTED MECHANICALLY

The percentage of mechanical emptying was 64% (N=36) in 2003 as per the study conducted by NGO Forum (Joshi *et al*, 2003). The current survey shows that only 34% (N=533) of the household opt for mechanical emptying among other emptying practices. There is a reduction in the number of households opting for mechanical services as compared to previous years. The reason for this decline could be due to the increasing number of households discharging wastewater into sewer lines constructed by municipality or the households themselves. The later type of construction is considered illegal but it is common in numerous new built up areas. In addition, many households and settlements prefer disposing waste into sewers as compared to septic tanks due to the low investment cost.

Although there is a potential to collect around 76,600 m^3/year of FS as per current estimates, all are not collected mechanically. However, considering the present share of mechanical emptying as 34% of the different emptying practices, there is a potential to collect 26,000 m^3 of FS mechanically per year.

With a monthly average of 233 trips, around 10,000m^3 of FS was collected annually by the mechanical service providers during 2005 (Table 3.4). Likewise, an estimated 2965 trips were made by the private service providers and KMC during 2007. With a truck volume of 3.5 m^3 around 10,200 m^3 of FS was collected in that year. In an average around 10 trips of FS were collected in a day.

3.5 FS DISPOSAL AND TREATMENT

There is no FS disposal and treatment site at the moment. FS collected manually is disposed into pits where land is available but in areas where land is not available it is disposed into nearby steams and ditches. Some farming communities use the emptied sludge as manure in agriculture.

All mechanically collected FS is disposed off illegally into sewers or storm water drains which finally ends up in the rivers. In the absence of a disposal and treatment site the private operators have been facing many operational challenges. The personals involved with FS collection face public

TABLE 3.4: Estimated volume of FS collected mechanically

Name of collection companies	No of trips/ year (2005)	No of trips/ year (2007)	No of working days in a month
Total trips made by 5 FS operators	2004		20 -25 days
KMC	792	763	17 days
Kathmandu Municipality Waste Management Services (1 operator)		360	-
Association of Private FS Collectors (9 operators)		1800	(9 working months
Total	2796	2923	

opposition everyday. Under such conditions, they are compelled to dispose the FS behind closed doors into drains and sewers.
The only FS treatment plant which was operated by KMC, know as the Teku Septage Treatment Plant (TSTP) has not being functional for a long time due to operational and management problems. Financial constrain within KMC to timely address O&M issues of the plant was another major cause of the failure of the plant. The TSTP was constructed in 1998 by KMC and came into operation beginning of 1999. The plant was successfully operational for 6 years. The design capacity of the plant was 40 m3 of FS per day. The plant consisted of a pretreatment unit with a settlement tank and vertical flow constructed wetland (CW) system for treatment of the effluent (Shrestha, 1999). The CW type system was used to treat domestic wastewater, grey water in many institutions and also community based systems that have been successfully demonstrated by UN-Habitat and its partners (UN-Habitat, 2008).

Teku septage treatment plant (non operational).

3.6 STAKEHOLDER'S ISSUES ON CURRENT FS MANAGEMENT

A stakeholder interaction workshop was conducted on 18th July 2007 titled "Comprehensive Faecal Sludge Management in Kathmandu Valley" organized in Kathmandu. The key objective was to discuss practices and problems on FS management in the Valley and find means to solve problems. All key stakeholders and potential stakeholders were invited. The workshop provided a common platform to share views, ideas and suggestion between different groups regarding FSM. The major issues and recommendations from the workshop were as follows:

- Private operators providing FS collection services were found very interested in FS management of the Valley. They were very conscious on the negative impacts due to haphazard disposal of FS into water bodies.
- The private operators, due to lack of proper FS disposal facilities in Kathmandu, were compelled to dispose FS in the open. The private operators at their own initiatives had even bought a piece of land in Bhaktapur for FS disposal but could not use it due to public pressure and oppositions.
- It was reported that if a FS treatment facility was provided the private FS operators were ready to pay a tipping fee and dispose FS regularly. Apart from the tipping fee, they were also willing to bear additional costs of operation and maintenance of the treatment facility if required.
- As per Kathmnadu Valley Town Development Committee, a new policy has been formulated, which enforces mandatory construction of septic tank

in all the houses to be built. Housing complexes to be built are required to have proper septic tank with soak pits. The new policy has already been put into action from 15 May 2007.

- The FS treatment plant operated by KMC was not operational at all. It was reported that KMC still charges penalties if the private operators were found disposing FS illegally into open areas.
- The key issue of the discussion was that, FS collection and haulage system is already in place in the Valley, as this is provided by the private sector. The major gap for a proper FS management was the absence of FS treatment system. If HPCIDBC or any other institution provided such a treatment facility, the private FS operators association were willing to dispose FS in the facility with a tipping fee.

The workshop came up with the following recommendations:

- The workshop recommended that policy should be established to enforce household to construct separate drainage systems for black water and grey water.
- Septic tanks should be promoted and the laws should be made more stringent that promotes septic tanks in the Valley.
- A proper FS disposal and treatment facility should be immediately built. Using the treatment plant of HPCIDBC could be a viable option.
- The government should take full responsibility of the private FS collectors to operate its services and provide a working environment.

4.0 FS MANAGEMENT STRATEGY

This chapter outlines the FS management strategy for the Valley. Based on the current state of art practices and problems, a short term and long term strategy has been developed for FS management of the Valley. The short term strategy implies to immediate steps that can be taken to address FS management problem in the Valley while, the long term strategy targets for a more decentralized approach to FS service delivery. It aims for a wider coverage in the Valley.

4.1 SHORT TERM STRATEGY

In the short term following strategies should be adopted for effective FS management.

4.1.1 STRENGTHENING FS COLLECTION AND LEGALIZING OPERATIONS

As there are already private and public FS service providers in the Valley, it is recommended to coordinate and collaborate with these entities to further streamline and strengthen FS collection services. Major strengthening is needed in the following areas:

- Personal safety and hygiene during FS collection, disposal and treatment is a serious concern. Personnel handling FS are exposed to numerous pathogens and thus are at high health risk. Therefore, entrepreneurs and personnel handling FS during collection, disposal and treatment, should be trained on associated health risks and precaution measures.
- To create an enabling environment for FS collection, the services should be legal so that entrepreneurs do not face unnecessary harassment during operations.
- For smooth operation of the services, the FS collectors should be under the jurisdiction of a responsible institution or authority. The designated authority could be a department within a municipality or institutions like HPCIDBC or a monitoring group formed through stakeholder consensus

which oversees day to day operations. Also refer to section 4.1.5.
- Incentive through recognition and rewards, penalties in the form of fine should be developed to facilitate proper collection and disposal services.

4.1.2 ESTABLISHING A TREATMENT FACILITY

One of the key gaps identified under current FS management is the lack of a FS treatment facility. Therefore, establishment of a FS treatment facility should be prioritised. While developing the FS treatment system, the following points should be considered:

- The treatment system developed should treat the collected FS efficiently and effectively preferably through the use of a natural treatment system. Natural treatment system such as constructed wetland combined with other pre–treatment system could be a viable option mainly due to its easy operation and maintenance and the experiences of good performances in the context of Nepal.
- The system should be established such that it serves as a demonstration center for other urban, peri-urban and small towns in the country. So far, there are no such systems in operation in the country, therefore the lessons learned from it's operation could provide a good feedback for other similar systems that will be developed in future.
- The facility should be operated under a responsible authority or institution.

4.1.3 SELECTION OF FS TREATMENT LOCATION

Based on the stakeholder interactions and findings of this study, establishment of an appropriate FS treatment facility is one of the first tasks that need to be carried out for FS management.

Based on the consultations, the existing Gujeshwori Wastewater Treatment facility under HPCIDBC was found to be one of the ideal locations to treat FS. Since HPCIDBC is already providing wastewater treatment facility and is a well established institution with its own operational set up, it is convenient to establish FS treatment services. Establishing and working with a new institution is often a resource consuming process. Therefore with stability of the institution the sustainability aspect is also ensured. Moreover, there is less chances of public opposition to the system if established within the already existing wastewater treatment facility. Furthermore, it is willing to establish and offer FS treatment services.

4.1.4 FSM THROUGH PPP

The FS management model could follow the Public Private Partnership (PPP) approach to efficiently manage FS treatment operations. PPPUE/UNDP prepared a business plan for comprehensive FSM of the Valley. It has recommended fostering partnership between the public and private sector for managing FS in the Valley. The PPP dwells on the idea that both public and private sector have certain advantages relative to the other in the performance of specific tasks and can enable public services and infrastructure to be provided in the most economically efficient manner by allowing each sector to do what it does best. It also offers an opportunity to modernize the public service and local government, providing greater efficiency and effectiveness and ultimately a better quality customer service (Shrestha, 2007 as cited in Innovative, 2008). According to PPPUE, the term 'public' refers to the government, either central or local. For 'private' PPPUE applies a broad definition as follows (Innovative, 2008):

- Business (for profit): National and multinational, formal and informal enterprises
- Civil Society (not for-profit): NGOs, Community-based organizations (CBOs), user groups, individuals, academic institutions.

Public sector can work with the private sector following various models such as through i) Contracting, ii) Franchise, iii) Concession and iv) Open Competition

Tuladhar (1999) indicates that for an effective PPP in waste management, which could also be applicable for FSM, the following should be taken up as essential pre-requisites:

- Political commitment
- Confidence of all stakeholders in the process
- Carefully designed strategy and plans that are suitable to local conditions
- Municipality that is capable of planning, implementing and monitoring the entire process
- Private sector that is capable and willing to invest
- Fair and transparent process

Based on the stakeholder consultations, two models of partnership within PPP approach are recommended (Innovative, 2008).

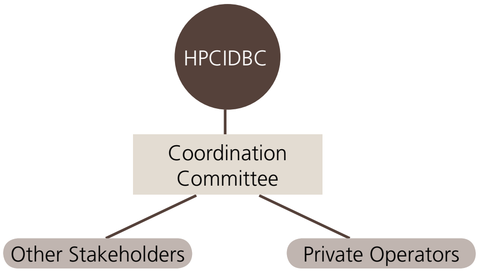
Under the first model, HPCIDBC takes a primary lead in the ownership. It invests for the construction of the treatment infrastructure. HPCIDBC will then

PPP MODEL ONE

- **Ownership & Initial Investment :** HPCIDBC
- **Operation Maintenance and Service Contract to :** Private Operators (PO)
- **Monitored by :** Coordination Committee

enter into an agreement with the private operators for operation, maintenance and service of the system. The rental fees will be standardized by the Coordination Committee which also monitors the contract and regulates the systems.

FIGURE 4.1 Coordination mechanism under PPP approach



PPP MODEL TWO

- **Ownership :** HPCIDBC
- **Initial Investment :** HPCIDBC/Donors/KMC/ Other stakeholders
- **Operation Maintenance and Service Contract to :** Private Operators
- **Monitored by :** Coordination Committee

Under second model, the investment for the system will be shared amongst the major stakeholder's viz. HPCIDBC, UN-Habitat, PPPUE, KMC and other potential donors. Under this model it is foreseen that an alliance is needed amongst the contributors and is recommended that the alliance be led by municipality.

The plant will be contracted out to the private operators under the supervision of the Coordination Committee. The Coordination Committee should have a representative from all major stakeholder including the investors, operators, users group, local government representatives and civic society.

Such an arrangement will ensure unique service to the households requiring FS cleaning services. The agreement will also ensure that the customers will be charged fair price.

4.1.5 MONITORING MECHANISM

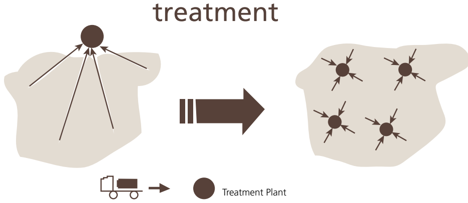
As mentioned under the PPP approach, a joint coordination committee should be formed comprising of representatives from each municipalities, relevant authorities such as the KVWSMB, KUKL, HPCIDBC, private FS service providers, civil society and households. The lead role could be taken up by HPCIDBC or any other institution depending upon mutual understanding. However, as HPCIDBC will be providing the treatment facility, it is appropriate that it takes the lead role in the process. The committee should develop policies, regulations, operation and monitoring procedures for FSM system.

In addition, municipal authorities could play a vital role in formulating and executing regulations which controls illegal disposal of FS meanwhile facilitating mandatory installations of septic tanks in households without access to sewer systems in the Valley.

4.2 LONG TERM STRATEGY

In the long run, based on experiences received from operations of FS treatment facility under HPCIDBC, the FS treatment systems should be expanded in other parts of the Valley. This would mean establishing additional decentralized FS treatment systems in the Valley. This would significantly reduce haulage costs which would decrease tipping fee for the FS operators as a result household individual households will have to pay less FS emptying costs.

FIGURE 4.2: From centralized to decentralized FS treatment



Each municipality should preferably have its own treatment system in place. However, if this is not feasible, municipalities should have a combined FS treatment system. For example, Kirtipur and Kathmandu or Madhyapur Thimi and Bhaktapur municipalities could share a treatment facility. The locations of the treatment facility should be positioned based on haulage distances and its costs such that all households receive similar benefits in terms of access and cost of emptying.

Septic tank cleaning and transportation services should be operated by private parties. The coordination committee as indicated under the short term strategy should still function as the main committee and provide its support. However, individual committees should be formed for management of decentralized FS treatment facility and its operations. There are ongoing efforts to develop wastewater management plan for the Valley. Recently an ADB PPTA was conducted to prepare a conceptual wastewater master plan for the Valley and submitted to the Government of Nepal (draft report ADB, 2010). The long term FSM strategy should thus coordinate with this plan to avoid duplication and foster partnerships to benefit mutually. For example the wastewater treatment plant locations as proposed in the master plan could be used as FS treatment sites. The master plan encourages the promotion of onsite systems such as septic tanks in the long run as well as large scale adoption of on site system. This basically relieves pressure on the centralized wastewater treatment systems. As septic tanks are privately funded by house owners, it reduces public funding on construction of large scale sewers as well.

4.3 DETAIL DESIGN OF DEMONSTRATION UNIT FOR FSM

4.3.1 TREATMENT OPTIONS

Considering the advantages and disadvantages of different treatment systems, three potential FS treatment options were explored at the existing Gujeshowori Wastewater Treatment facility operated by HPCIDBC. The options are:

- **Co-treatment with wastewater** – HPCIDBC is looking at possibilities to expand the existing wastewater treatment system to cater for increased flows. There is a potential opportunity to combine the wastewater and sludge treatment systems. Although this option would lower the cost of FS treatment and reduce overall space requirement, the highly fluctuating FS organic loading with a more stable wastewater loading rate will demand higher operational skills than currently available. In addition, the timing and financing of the proposed extension project is also not confirmed.
- **Anaerobic digester and dewatering unit** – The second option is to retain the FS in a digester for a certain period to reduce pathogens prior to discharge into a second stage dewatering facility. This option is similar to the Teku Septage treatment system. However, based on the learnings from the Teku system, the pre-treatment unit or the digester could face problems of solids retention due to solidification at the bottom of the tank. Additionally, through an anaerobic digestion process there is limited benefits of production of biogas as the sludge from septic tanks are already partially digested thus yielding low biogas production. Almost all FS that will be brought into the proposed treatment plant will be from onsite systems - mostly septic tanks.
- **Two stage constructed wetland system** – The third option is to construct a two stage constructed wetland system. The first wetland will assist in sludge dewatering i.e. separate the sludge and leachate. In the second stage the leachate will be treated further again in the horizontal constructed wetlands to attain the required discharge standards. This could be a viable option as this requires low maintenance skills, obtains expected sludge quality after treatment and more importantly uses the technologies already known in Nepal. However, the limitation of this option is the requirement of large area of land.

Based on consultations with international experts, local stakeholders and HPCIDBC, the two stage constructed wetland treatment system was proposed. The final effluent from the two stage treatment system could either be discharged into the existing wastewater treatment system discharge tunnel (depending on levels) or into ponds prior to discharge into the river.

4.3.2 PROPOSED FS TREATMENT SYSTEM

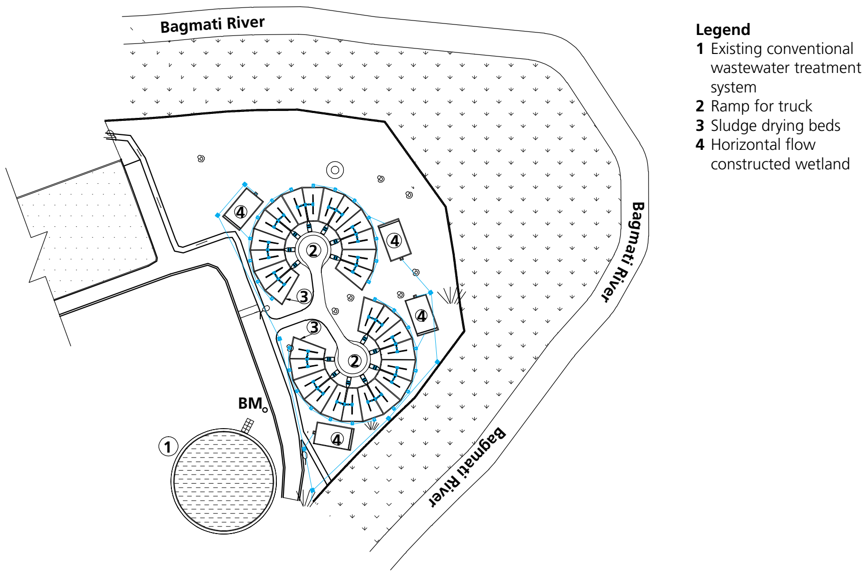
Design parameters: The following parameters were taken into consideration for designing the FS treatment system:

- **FS volume:** This study estimated that around 3000 trips of FS will be collected per year. For the FS treatment plant design the number of trips has been increased considering the fact that more FS will be collected by the operators once treatment system is in place. The discharge volume 30 m^3/day has been considered for the design. This is equivalent to around 10 trips of FS per day if truck volume is 3 m^3.
- **TS concentration:** The treatment design is solely based on the concentration of the Total Solids (TS) in the incoming sludge. Research at the Asian Institute of Technology, Bangkok during 1997-2003 found an average TS concentration of 15.4 g/L with a wide range from 2-67g/L (Table 3). A study shows that the TS concentration of the FS in the Valley was 27g/L (Sherpa, 2005). The results had a confidence range of 10 to 40g/L. Due to lack of other information, 27g/L was adopted as a conservative estimate for the TS concentration of FS in the Valley. However, it is expected that the TS from different tanks will vary.

COMPONENTS OF THE FS TREATMENT SYSTEM

The proposed FS treatment plant at the Gujeshowori Wastewater Treatment facility of HPCIDBC will be a two stage Constructed Wetland Treatment System

Figure 4.3 : Layout of proposed FS treatment plant



(Figure 4.3). Prior to the two stage CW system a bar screen is placed to block debris and large objects entering the system. Following the screen, the first part of the treatment system will consist of Sludge Drying Beds (SDB) while the second part will consist of Horizontal Flow Constructed Wetlands (HFCW). The detail design aspects of these components are described in the following sections individually.

BAR SCREEN

The purpose of the bar screen is to trap debris such as plastics, papers in the FS. The bar screen is placed just before the SDBs which helps to prevent debris from entering the beds thus avoiding clogging. A cross section of the bar screen is presented in Figure 4.4.

SLUDGE DRYING BEDS

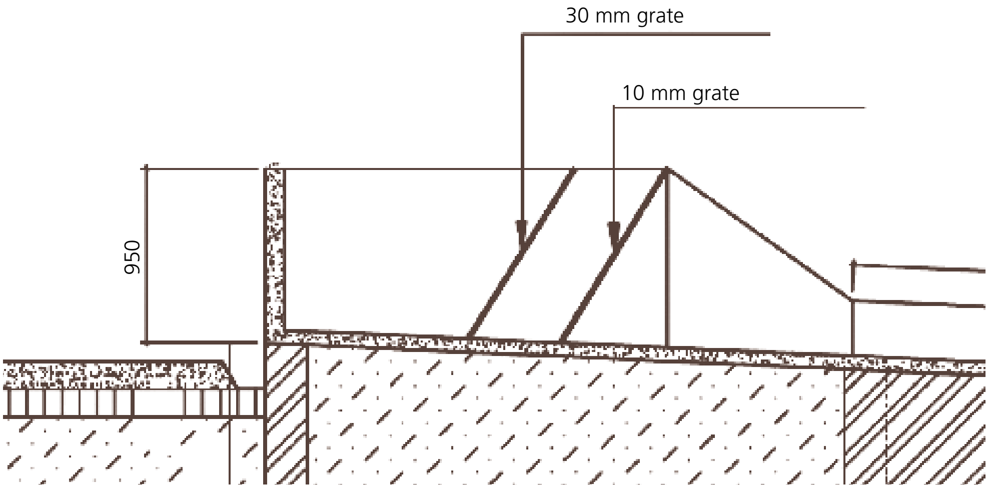
The SDBs is the primary treatment component of the system. The system will consist of 28 SDBs, placed in a circular position with 14 beds on each circle (Figure 4.3). Once FS is brought into the treatment plant, it passes through the bar screen and is discharged on the SDBs. Two adjoining SDBs will be connected through a single feeding inlet.

The main purpose of the SDBs is to separate the solids and the liquid fraction in the FS, a process known as dewatering. The SDBs combines sludge thickening, sludge stabilization, sludge dewatering and liquid clarification in one system. The filter media helps to retain the solid particles while the liquid percolates through the media. For stabilization of the solids, it is left to dry and then later scraped out to produce composting. The liquid effluent will undergo further treatment in the secondary stage.

Sizing of the SDBs is based on the following criteria:

- Sludge loading rate drying beds is 250kg TS/m^2/yr.

FIGURE 4.4: Cross section design of Bar



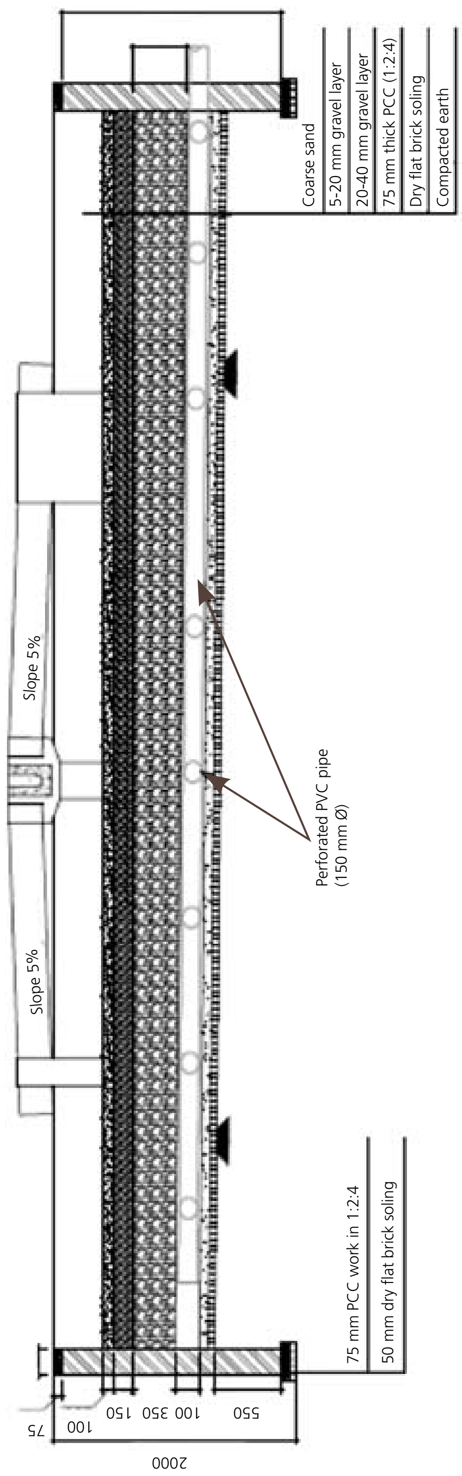


FIGURE 4.5: Cross section design of SDB

- Area requirement for SDBs is calculated by the maximum sludge application depth of 200 mm.
- Depth of SDB is taken as 1.2 m including the filter media and a free board of about 0.2 m.
- De-sludging period is 3 years.
- Feeding of each bed is over one day period with 6 days retention before discharging leachate and refilling.

The area of each SDB is calculated as follows:

Surface area of SDB (m^2) A_{SDB}

$$= \frac{\text{Organic loading rate per year (kg)}}{\text{TSS loading per year (kg/m}^2\text{)}}$$

A cross section design of the proposed SDB is presented in Figure 4.5. Based on the criteria, the area of the SDB is calculated as 43 m^2 with a total of 28 beds (Table 4.1).

HORIZONTAL FLOW CONSTRUCTED WETLAND

The effluent from the SDBs is further treated in the HFCWs. It functions as the secondary treatment and utilises natural treatment process. It is cost effective and provides a high buffering capacity and process stability.

HFCW consist of sand, gravel filter media (Figure 4.6) and is planted with local reed plants known as *Phragmites karka*. The long root system of these plants spreads in the bed and helps in the organic pollutant removal process.

Area of the wetland is calculated as follows:

$$A_h = \frac{Q_d (\ln C_i - \ln C_e)}{K_{BOD}}$$

TABLE 4.1: Sizing of Sludge Drying Bed

Parameters	Abbreviation	Value	Unit	Remarks
TS Concentration	TS	27	g/l (kg/m^3)	Based on analysis results of Kathmandu (Sherpa, 2005)
Total TS loading per year	TS	250	Kg/m^2	Organic loading rate 20-250 kg/m^2 per year
Total organic loading per year	OLR	301,320	kg	
Nos. Sludge drying bed	Nsludge	28	units	
Area of Sludge Drying bed	Asludge	43	m^2	

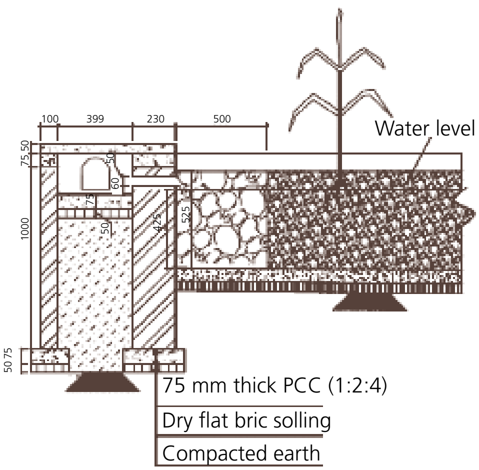
A_h = Surface area of bed (m^2)
Q_d = average daily flow rate of sewage (m^3/d)
C_i = influent BOD_5 concentration (mg/l)
C_e = effluent BOD_5 concentration (mg/l)
K_{BOD} = rate constant (m/d)

The parameters is based on the design guidelines of UN-Habitat (UN-Habitat, 2008). The design parameters considered are provided in Table 4.2.

DISCHARGE AND SLUDGE REUSE

The effluent from the HFCW can be discharged through the discharge tunnel of the existing conventional wastewater treatment system.

FIGURE 4.6: Cross section design of HFCW



The dried sludge from the SDBs should be stored for at least six months to ensure complete stabilization and total pathogen die-off. Thus treated sludge could be directly used as soil conditioner.

4.3.4 OPERATION AND MAINTENANCE

Proper operation and maintenance is a must for smooth functioning and effective performance of any system. Since it will be difficult to predict system functioning in the beginning, it is proposed to carry out an initial performance monitoring of the system based on characteristics/quality of raw and dried FS along with percolate. In addition, FS loading, water content of dried sludge relative to the time and clogging phenomenon should be properly monitored.

To achieve proper operation and maintenance, appropriate and sufficient human resources need to be assigned. Table 4.3 shows the list of required human resources.

The following activities are proposed to be carried out at regular basis for effective operation and maintenance of the FSM:

SLUDGE FEEDING

The FS should be fed to the SDBs directly from the tankers through the bar screen. The feeding in each bed should be done once a day for a maximum of 10 trips which is equivalent to $30m^3$ of FS per

TABLE 4.2: Sizing of Horizontal Flow Constructed Wetland

Design Parameters	Parameters	Value	Unit	Remarks
BOD concentration of influent	BOD_{in}	200	g/l	Conservative values for leachate quality are 200mg/L for BOD and 600mg/L for COD.
BOD concentration of influent	BOD_{out}	50	mg/l	50mg/L is based on national discharge requirement
Minimum temperature	T_{min}	16	°C	
Volume reduction		80%		Volume of leachate is reduced due reduction in solids content, evaporation and evapotranspiration in SDBs.
Daily flow	Q_{daily}	24.46	m^3	
Rate constant at 20°C	K20	0.17		Taken from the graph KBOD against Temp for substrate depth 40 cm and porosity 40%
Rate constant	K_{BOD}	0.13		Conservative design basis for horizontal flow wetlands allows for 60kg BOD/ha/day.
Nos. of bed	NHFCW	4		
Area for a bed	AHFCW	63		

day. The maximum FS application depth should not exceed 200 mm. After a 6 days resting period, the percolate from the SDB is discharged to the HFCWs while the solids is left for drying and stabilization till the next feeding after a month. The dried sludge is stored for a period of at least six months to achieve complete sludge stabilization.

The feeding and stabilization of FS should be carried out for a year before taking out the dried/stabilized sludge.
During excavation, it is to be noted that about 10 mm of the dried/stabilized FS should be left out as to reduce the possibilities of sticking out of sand along with the FS. The adherence of sand in the FS will reduce the nutrient value of the soil compost.

VEGETATION MANAGEMENT

Any unwanted vegetation apart from the designated vegetation shall be removed from the wetland at a regular basis. The designated vegetation in the wetland shall be harvested as per the growth of

TABLE 4.3: Human Resource requirement

Designation	Responsibility
Engineer	Prepare periodic plan and assign responsibilities to the staff to ensure the proper operation and maintenance of the system. Take necessary actions for effective functioning of the system.
Supervisor/ Operator	Supervise the operation and maintenance of the system. Follow the instructions of the Engineer. Engage skilled and unskilled workers as and when required.
Skilled/ unskilled workers	Carry out required repair/rehabilitation works to keep all the structures of the system intact. Work under the guidance of the Supervisor for desludging of FS haulage tanks, discharging settled FS to the wetlands, removal of dried FS sludge and transport to storage yard, etc.

the vegetation. In general, the vegetation shall be harvested once or twice in a year. Harvesting shall be focused on the cutting of the vegetation and leaving about 1m for its growth.

STORAGE

The excavated dried/stabilized sludge shall be stored for at least six months. Proper care shall be taken to protect the sludge from rain water. The stored sludge can then be packed and transported to the agricultural fields.

PERFORMANCE MONITORING

In order to ascertain the efficiency as well as proper operation of the FSM, physical, chemical and biological analysis of the influent and effluent samples shall be conducted regularly. The parameters to be analyzed depend on the budget and available facilities, however, the mandatory parameters to be analyzed are – TS, BOD_5, COD, TN, TP and pathogens. It is especially recommended to conduct the performance monitoring during the initial phases of operation to achieve effective operation and maintenance of the system.

Dried and stabilized sludge.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been drawn out from this study:

- Around 30 % of the households still use septic tanks as the main form of wastewater disposal and thus FS management is essential to manage the sludge generated from these sanitation systems. There are around 68,000 septic tanks in the Valley which generates around 76,600 m^3 of FS annually.
- There is lack of awareness in the among people regarding proper septic tank design, its operation and maintenance. The national building code and bylaws are not followed by households in the Valley due to weak monitoring and enforcement mechanism. Therefore new houses do not construct septic tanks. Majority of the households in the Valley prefer to have sewer connection compared to septic tanks.
- Currently all FS collected mechanically is disposed haphazardly into water bodies in the Valley due to absence of a treatment facility.
- The share of mechanical and manual emptying is around 34% each. In urban areas mechanical emptying is dominant while in peri-urban and rural areas manual emptying is practiced.
- There are around 10 private operators providing FS collection or septic tank emptying facilities in the Valley. There are also many individuals and groups who provide manual pit emptying services.
- Private operators are willing to dispose FS properly and ready to pay a tipping fee provided that the government offers a treatment facility and an enabling environment to operate FS collection services. There is an enormous potential for the private operators to expand their business of FS collection and thereby generate revenue by providing the sanitation services.
- The available space within the Gujeshowri WWTP facility under HPCIDBC should be used to construct a FS treatment facility based on the proposed design. This will not only

solve the FS management problem of the Valley but also prove as a demonstration unit for the entire country.

- The PPP approach as proposed in this study should be followed to manage FS in the Valley. A strong coordination should exist between HPCIDBC, the municipalities, the FS operators and other relevant stakeholders with clearly defined roles and responsibilities for smooth operation of services.

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APPENDIX A

ANALYSIS OF FS TREATMENT OPTIONS

1.0 FS TREATMENT OPTIONS

A. PRIMARY TREATMENT OPTIONS

Primary treatment is done to further stabilize the FS and separate the solids and liquid. The quality of solids and liquid after primary treatment depends on the process that is adopted. Post-treatment of solids and/or liquids may be necessary to achieve treatment objectives.

A1. CO-TREATMENT OF RAW FS WITH WASTEWATER

FS can be treated along with wastewater or with the sludge generated from wastewater treatment plants. Treatment at WWTP can take several different approaches. FS is added either to the liquid stream unit processes or to the solids stream unit processes in the WWTP. To be successful, the WWTP must have adequate capacity to treat the FS without adversely affecting unit processes. While a WWTP provides a high level of treatment, WWTPs are not available at all places and even those might require modifications to accept FS as the high BOD of FS may upset the WWTP processes.

TABLE A.1: Pros and Cons of co-treatment of raw FS with wastewater

Pros	Cons
FS, when diluted with waste water, can be treated with well-known and reliable waste water treatment technologies	FS is mixed with chemically more contaminated waste water or waste water sludge
Co-treatment of FS and waste water may be economic	Agricultural reuse might be impossible and the resource FS be wasted
	If the treatment plant is not designed to handle such a concentrated influent then the whole system could be a failure

A2. DIGESTION FOR BIOGAS PRODUCTION

Fresh FS rich in biodegradable organic matter is digested anaerobically, alone or together with animal dung or vegetal waste. The methane produced during the digestion is captured and can be used for cooking, lightening electricity generation. Liquid effluent and accumulated sludge leaving the digestion process are then treated separately. Only fresh FS is appropriate for biogas production. FS collected from septic tanks, pit latrines will produce low amount of biogas as they have already undergone partial degradation. The sludge needs to have minimum solids content of 3% (source) otherwise mixing with animal dung or with vegetal waste may increase solids content and content of digestible organic matter.

TABLE A.2: Pros and Cons of sludge digestion for biogas production

Pros	Cons
Production of combustible and generation of revenues	As part of sludge treatment biogas comes out as a byproduct due to digestion of partially stabilized sludge. In this case production of gas could be only minimal.
Stabilization of fresh sludge	Settling is incomplete, effluents requires further treatment compared to effluents from other primary FS treatment processes
Little land requirements	Initial investment is high, operation requirements are quite considerable
	Removal of settled and thickened solids can cause difficulties

A3. IMHOFF TANK (SETTLING AND DIGESTION)

The Imhoff tank allows settling of solids in presence of digestion processes. Inclined walls make sure that rising gas bubbles produced by anaerobic digestion do not disturb the settling process. Solids will accumulate at the bottom and stabilize by digestion and thickening. The digested sludge will be removed periodically by pumping or hydrostatic pressure and further be treated. The clarified supernatant generally requires further treatment. The Imhoff tank can be used for insufficiently stabilized FS to allow settling and digestion in one single stage. It can be used when conditions are not favorable for biogas digesters and when no space for stabilization ponds is available.

Table A.3: Pros and Cons of FS primary treatment in Imhoff Tank

Pros	Cons
Settling and digestion in a single step	Expensive structure
Little land requirement	Complicated operation and maintenance
Possibility of methane generation	Risk of obstruction of sludge draw-off pipe by thickened sludge when draw-off is not done in adequate frequency

A4. SETTLING/THICKENING TANKS

In settling or thickening tanks, the solids accumulate at the bottom and the clarified supernatant can further be treated. The accumulated sludge is removed periodically through draw-off pipes. Another possibility of sludge removal is manually or by front-loaders after removal of the liquid column and a period of drying. Removed sludge generally requires further treatment. Settling tanks can be used for partly stabilized FS such as sludge from septic tanks and most other sanitation facilities. Settlings tanks are not appropriate for very fresh sludge from public toilets, but may still be suitable if the fresh sludge is diluted with more stabilized sludge.

Table A.5: Pros and Cons of FS primary treatment in settling/thickening tanks

Pros	Cons
Simple and reliable process	Not suitable for fresh FS
Little land requirement	Lower sedimentation properties
Lower cost	

A5. SEDIMENTATION/ STABILIZATION PONDS

The sedimentation ponds use the same principle of sedimentation of solids as the settling tanks. Ponds are larger and have longer sediment removal intervals. Due to high volume and high retention time it provides good stabilization capacity for fresh sludge. The sediment is removed after removal of the liquid column followed by period of drying. Both liquid and sediments require further treatment. Sedimentation or stabilization ponds can be used as a primary FS treatment option when land availability is not a problem.

Table A.6: Pros and Cons of FS primary treatment in sedimentation/ stabilization ponds

Pros	Cons
Simple operation	High land requirements
Cheap construction	Odour released could be a nuisance
Better sedimentation properties as settling tanks	Could provide a habitat for mosquitoes and flies
Higher stabilization capacity	

A6. SLUDGE DRYING BEDS

Drying beds consist of a gravel-sand filter, equipped with a drainage system. Raw or pre-settled FS is loaded on the bed for dewatering. Liquid is removed from the filter bed through filtration and partly by evaporation while the solids is allowed to dry on the bed and then scraped off. The solids needs to be further treated for pathogen removal if dried sludge is to be reused. The quality of the effluent from the bed may still require a polishing treatment depending upon the effluent quality requirements.

Drying beds can be used as first treatment stage and as second stage for dewatering of settled sludge. Drying beds cannot receive undiluted fresh FS (poor dewatering characteristics, odor emissions).

Table A.7: Pros and Cons of FS primary treatment in drying beds

Pros	**Cons**
Low moisture content of dried solids and relatively good percolate quality (compared to settling facilities)	Solids are not yet hygienically safe (unlike constructed wetlands)
Simple operation and maintenance	Higher costs
Technology is well known and reliable	Require larger area

A7. CONSTRUCTED WETLAND SLUDGE DRYING BEDS

A constructed wetland sludge drying bed is a bed equipped with a drained gravel and sand filter and planted with marsh plants. The sludge is loaded on the bed and dewatered by percolation in the filter and by evapo-transpiration through the plants. The root system of the plants maintains the permeability of the sludge layer and sludge

can be added continuously. Sludge has to be removed only once every few years. The long solids retention period favors further mineralization and pathogen die-off and allows direct reuse of solids in agriculture. Percolate quality considerably improves but may still require a polishing treatment. Constructed wetlands can be used when the sludge is to be reused in agriculture.

Table A.8: Pros and Cons of FS primary treatment in constructed wetlands

Pros	Cons
Include dewatering, stabilization and hygienization in a single treatment stage, unlike all other treatment techniques	Experiences from pilot plants only are available so far
Dewatered sludge can be used in agriculture without further treatment	Requires care for plant growth
Percolate quality compares favorable to other primary treatments	Requires larger area thus higher costs

A8. STABILIZATION PONDS

Stabilization ponds for FS effluent treatment can be anaerobic or/and facultative ponds depending on the organic pollutant concentration. The first anaerobic pond after the primary treatment will still receive some suspended solids that will accumulate on its bottom. After occasional removal, the sediments can be treated together with the solids that have been separated in primary treatment. Ponds can be used when sufficient land is available. High ammonia concentrations in the effluent, for example in FS from public toilets, may inhibit growth for algae and bacteria and thus the functioning of ponds.

Table A.9: Pros and Cons of FS primary treatment in stabilization ponds

Pros	Cons
Simple, well-known and reliable technology	High land requirements
Cost economic	Possibility of odour and insects nuisances
	Possible inhibition of functioning through NH_3/NH_4 in case of very fresh FS

B. POST TREATMENT OF SOLIDS

Post treatment of solids assures the necessary quality corresponding to the treatment goals. If the solids are to be reused for food crop production, the treatment of solids has to provide hygienic safety of the solids. If solids will be used for non-food crops, be disposed off, or used for other purposes, the treatment basically has to provide adequate consistency of the solids.

B1. CO-COMPOSTING WITH SOLID WASTE

Pre-treated FS (with reduced moisture content) is composted together with organic solid waste. If the composting is well done, temperatures in the heaps reach 55-60°C and all pathogens are destroyed. The produced compost constitutes a very good soil conditioner. Composting is a very interesting option when agricultural reuse of FS and solid waste is desired. Solid waste needs to be available in sufficient quantity and quality (sorting).

Table A10: Pros and Cons of FS post treatment as co-composting with solid waste

Pros	Cons
Allows producing a good and pathogen free soil conditioner in relatively short time	Contaminants in solid waste may reduce compost quality
Simple operation	Proper aeration is required
Co-treatment can safe resources	Requires longer time for good quality compost product

B2. STORAGE AND NATURAL DRYING

Storage over at least 6 months allows natural pathogen die-off in dewatered sludge from settling facilities or drying beds. Further drying of sludge contributes to pathogen die-off and increases the safety of the method. Storage and natural drying will be used if the FS is to be reused in agriculture and if co-composting or constructed wetlands (other processes delivering hygienically safe biosolids) are not favored.

Table: Pros and Cons of FS post treatment as storage and natural drying

Pros	Cons
Cost economic	High land requirements
Simple operation and maintenance	Longer time required
	Requires appropriate monitoring of pH and moisture content for better pathogen die-off

B3. LAND APPLICATION

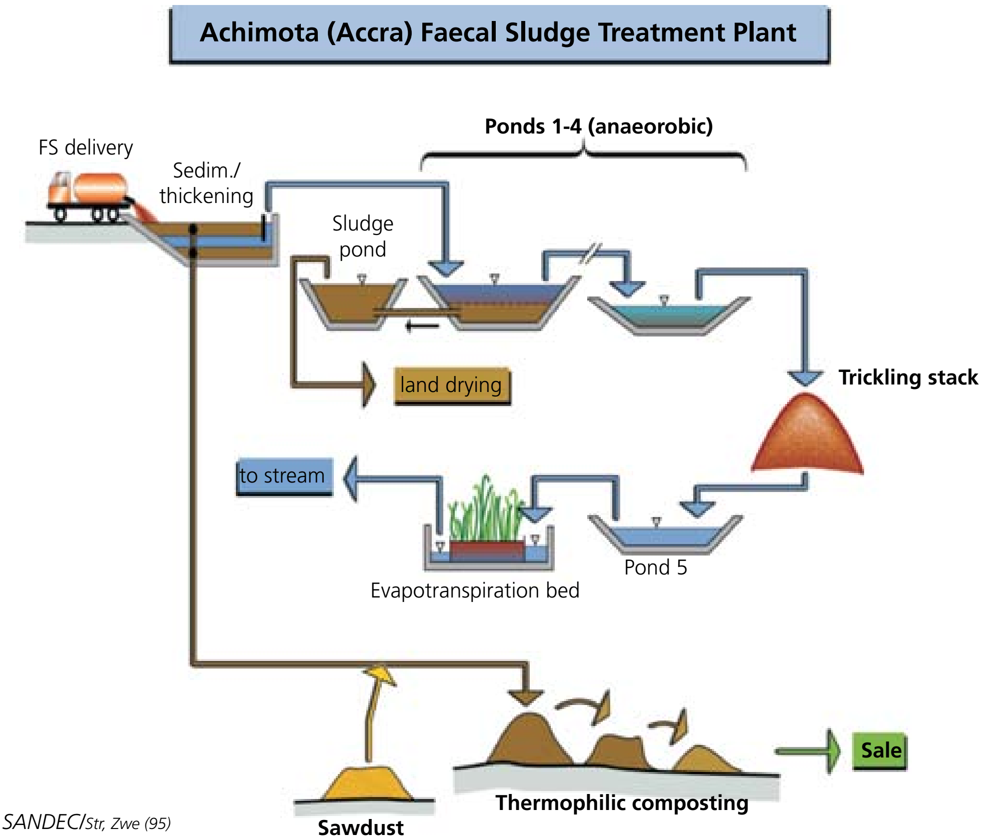
Land application of FS is an economical and environmentally sound method of handling FS. This is a low cost option, with less energy requirement and recycles the nutrients and organic matter into the land. FS can be applied to the land as fertilizer and soil conditioner. Application rates depend on the slope, soil type, depth of application, drainage class and hydraulic loading. FS must not be applied before or during rainfall. Thus, an interim storage facility is needed. A properly managed land application program achieves beneficial reuse of waste organic matter and nutrients without adversely affecting public health. Pre-treatment is required due to the high risks of pathogens.

Land application includes spreading FS from FS hauler trucks, specially designed land application vehicles, or tank wagons onto sites using spray irrigation, ridge and furrow irrigation, and overland flow.

Table: Pros and Cons of FS post treatment as land application

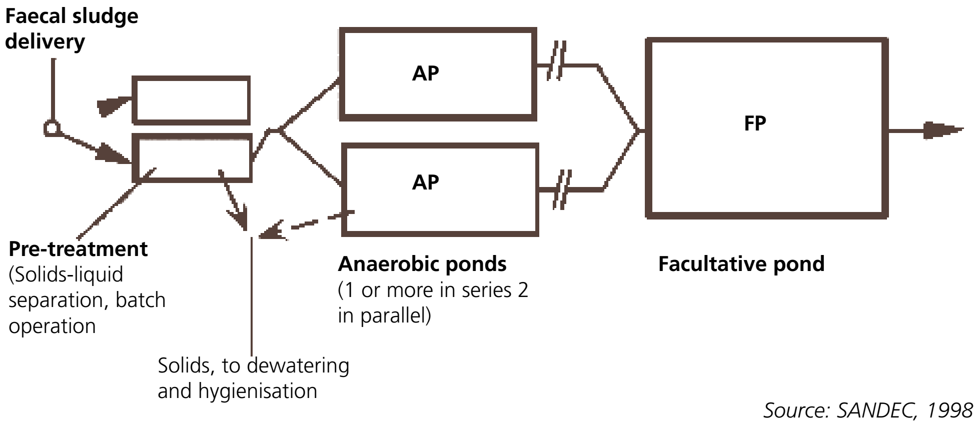
Pros	Cons
Economical and Environmental Friendly approach	Not suitable for the areas with less availability of land
Easiness in handling the sludge	Difficulty in getting local people consent
	Odor problem
	Danger from pathogens if proper care is not taken
	Pre-treatment is a must which can contribute to high cost
	Detail study required in terms of FS characteristics and soil study for any area to adopt land application

Figure A.1: FSM at Accra/Ghana



Source: SANDEC, 1998

FIGURE A.2: Process layout at Accra/Ghana



Source: SANDEC, 1998

2.0 EXAMPLES OF FS TREATMENT IN DEVELOPING COUNTRIES

There are not much experiences of FS treatment in developing countries, however, a few examples of FS treatment is explained in the following sections.

A. SEDIMENTATION/THICKENING TANKS AT ACCRA/GHANA

The FSM at Accra/Ghana was designed for 150 m^3 FS/day, 20 to 40 % of which originate from unsewered public toilets and 60 to 80% from septic tanks. Figure A.1 and A.2 shows the layout of the FSM at Accra/Ghana. The first treatment step consists of a solids-liquid separation in two parallel, batch-operated settling/thickening tanks. The settled sludge is stored in the tank and the supernatant flows from the tank into the following pond. Results of 4 years of monitoring reveal that the performance of the sedimentation tanks strongly depends on the plant's state of maintenance and operation. The loading and resting periods should not exceed 4 to 5 weeks each. In practice, the tanks are emptied every 4 to 5 months, only. This reduces the efficiency of the solids-liquid separation process considerably.

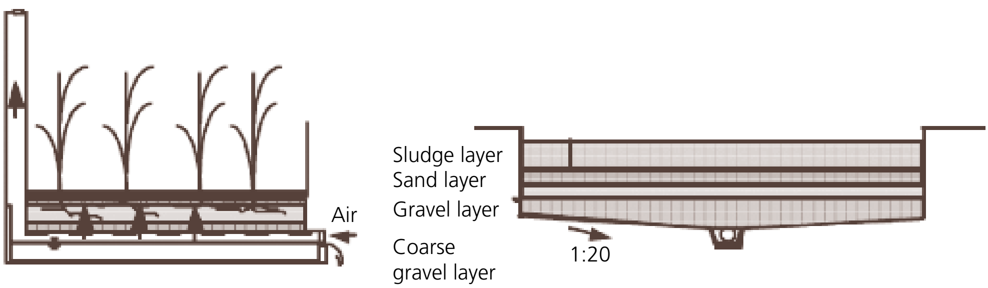
B. DRYING BEDS AT ACCRA/GHANA

Sludge drying beds, if suitably designed and operated, can produce a solids product, which may be used either as soil conditioner or fertilizer in agriculture, or deposited in designated areas without causing damage to the environment. Although drying bed treatment is usually not classified as a solids liquid separation process, it serves to effectively separate solids from liquids and to yield solids concentrate. Gravity percolation and evaporation are the two processes responsible for sludge dewatering and drying. In planted beds, evapo-transpiration provides an additional effect. Unplanted and planted sludge drying beds are schematically illustrated in Figure A.3 below. The ratio between drained and evaporated liquid is dependent on type of sludge, weather conditions and operating characteristics of the particular drying bed. In planted drying beds, this ratio is likely to be much lower. Drying bed percolate tends to exhibit considerably lower levels of contaminants than settling tank supernatant.

C. CONSTRUCTED WETLANDS AT BANGKOK/THAILAND

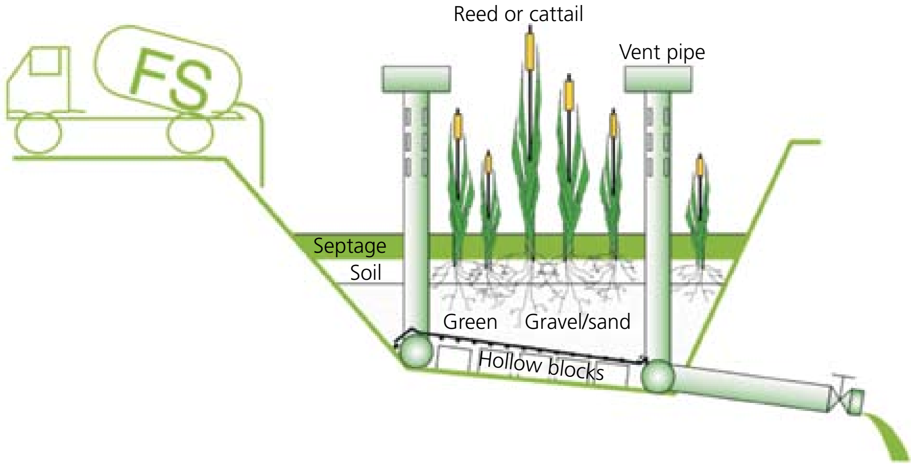
At the Asian Institute of Technology (AIT) in Bangkok, three pilot scale constructed wetlands were investigated to study the potential of constructed wetland for FS

Figure A.3: Sludge Drying Beds at Accra/ Ghana



Source: Heinss **et al** (1998)

FIGURE A.4: Constructed Wetland at AIT, Thailand,



Source: Koottatep (2003)

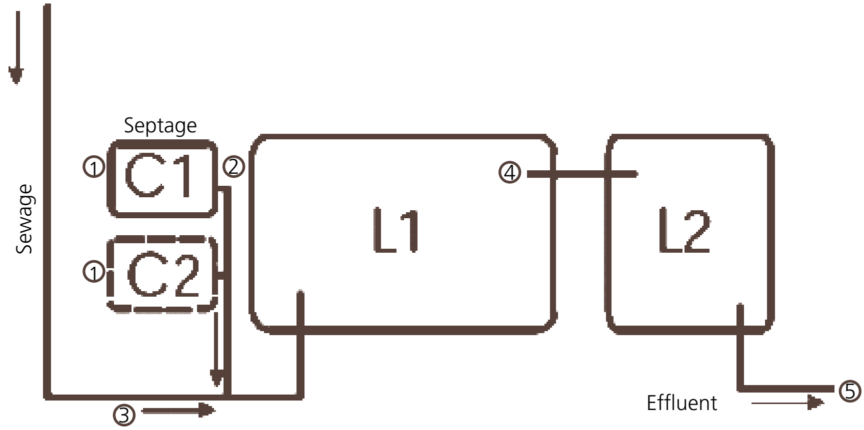
treatment. The wetland consists of gravel or sand filters planted with emergent plants such as reeds, bulrushes or cattails (Figure A.4).

Constructed wetlands have been successfully operated for treating Bangkok septage exhibiting 14,000-18,000 mg TS/L by the Asian Institute of Technology (AIT) from 1997-2004. An optimum loading rate of 250 TS (Total Solid)/m^2-year was established based on 6 years of field research with 3 pilot constructed wetland beds (Koottatep *et al.*, 2002). The beds were planted with *Typha angustifolia* (narrow-leaved cattail) with surface area 25 m^2 and fed with 8 m^3 of septage once a week. Impounding of the percolate was made to secure sufficient humidity for the cattails to prevent wilting during dry seasons. Also, impounding improved the TCOD (Total Chemical Oxygen Demand) removal as well as N (Nitrogen) through denitrification. Ponding periods of 6 days were found optimum. The final effluent showed 70-80% TS, 96-99% SS, and 95-98% TCOD removal. **The CW was able to accumulate 70 cm of sludge after 4 years of operation while maintaining their full permeability.** The TS content of the dewatered sludge varied from 20-25% in the uppermost layer (< 20 cm) to 30% in the deeper layers. Under steady loading conditions, the percolate quality was constant. TCOD in the percolate amounted to 250-500 mg/L, TS to 1,500-4,000 mg/L and SS to 100-300 mg/L.

D. WASTE STABILIZATION PONDS AT ALCORTA/ARGENTINA

In Latin America, the majority of households, which avail of sanitation systems, are usually served by sewered sanitation. Many small towns, however, are largely or even fully served by onsite sanitation systems. In Alcorta, a town of 4,000 inhabitants, 35% of the population is connected to a sewer system whereas 65% use septic tanks and cesspools which are emptied by vacuum trucks. A series of two stabilization ponds treat both wastewater and septage. The two ponds

FIGURE A.5: Schematic diagram of combined treatment unit of septage and water



Source: Ingallinella, 2002

are operated alternatively: one pond is loaded while the sludge accumulated in the other one is drying. The idea is that the settled sludge should be easy to handle and partly mineralized/hygienized at the end of the drying cycle. The effluent of the sedimentation ponds is co-treated with wastewater in a series of two waste stabilization ponds (Figure A.5).

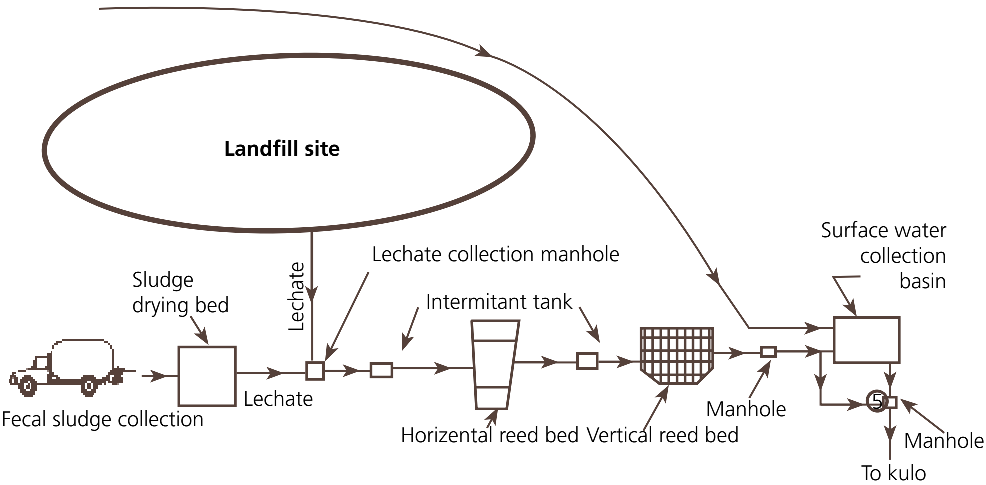
E. CONSTRUCTED WETLANDS AT POKHARA, NEPAL

The FSM at Pokhara, Nepal promotes the used of planted sludge drying bed or the Constructed wetland system similar to the AIT, Thailand and Accra, Ghana. The effluent from the drying bed is being treated with the landfill leachate through series of constructed wetlands as shown in Figure A.6.

The FS treatment plant has been designed for the septage volume of 35 m^3 per day with Total Solid (TS) Content of 15 kg per m^3 and BOD_5 value of 5,000 mg/L.

FS and leachate treatment system in Pokhara, Nepal.

FIGURE A.6: Process layout of FS and leachate treatment system



Source: Shrestha, 1999

Government of Nepal
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