INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT

Training of Trainers (ToT) Module

SCBP
Sanitation Capacity Building Platform

Part-A: Learning Notes

ECOSAN SERVICES FOUNDATION

NIUA
National Institute of Urban Affairs

Contents

LIST OF ABBREVIATIONS

ABR	Anaerobic Baffled Reactors	MoHUA	Ministry of Housing and Urban Affairs
ASP	Activated Sludge Process	MoUD	Ministry of Urban Development
AMRUT	Atal Mission for Rejuvenation and Urban Transformation	NGO	Non-governmental Organization
BCC	Behaviour Change Communication	NIUA	National Institute of Urban Affairs
BMGF	Bill & Melinda Gates Foundation	NUSP	National Urban Sanitation Policy
BOD	Biochemical Oxygen Demand	O&M	Operation and Maintenance
CAPEX	Capital Expenditure	ODF	Open Defecation Free
COD	Chemical Oxygen Demand	OPEX	Operational Expenditure
CPHEEO	Central Public Health and Environmental Engineering Organization	OSS	On-site Sanitation
CSR	Corporate Social Responsibility	PPP	Public Private Partnership
Cu.m.	Cubic Metre	SBM	Swachh Bharat Mission
C-WAS	Centre for Water and Sanitation	SBR	Sequential Batch Reactor
ECOSAN	Ecological Sanitation	SCBP	Sanitation Capacity Building Platform
ESF	Ecosan Services Foundation	SDG	Sustainable Development Goals
FSSM	Faecal Sludge and Septage Management	SLB	Service Level Benchmark
FSTP	Faecal Sludge Treatment Plant	Sq. m.	Square Metre
HH	Household	STP	Sewage Treatment Plant
IHHL	Individual Household Latrine	TSS	Total Suspended Solids
JNNURM	Jawaharlal Nehru National Urban Renewal Mission	UASB	Upflow Anaerobic Sludge Blanket
LPCD	Litres Per Capita per Day	ULB	Urban Local Bodies
MBR	Membrane Bio Reactor	WASH	Water, Sanitation and Hygiene
MLD	Million Litre per Day	WSP	Waste Stabilization Pond

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About the Handbook

The Handbook is an initiative of SCBP to build capacities in IWSM for officials of urban local bodies (ULB), para state technical agencies, administrators and professionals from the private sector and Non-Governmental Organizations. It is meant to be freely used by any can organisation (public or private), national and state level training institutes, AMRUT and SBM Training institutes: for conducting a two to five days Training on Integrated Wastewater and Septage Management(IWSM).

The Handbook presents the key learning elements for the training module in a narrative format covering the aspect of: urbanization trend, urban sanitation facts and requirements, Open Defecation Free (ODF) priorities, sanitation systems, wastewater and septage management technologies and designing, financing in wastewater management and integrated approach towards wastewater management and septage management. It has the technical and non-technical aspects in sanitation sector and its management.

The Handbook has been developed based on the experience of delivering IWSM trainings to ULB officials, AMRUT training institutes and consultants by NIUA and ESF in 2017-18. Achieving ODF towns and cities, and sustaining them, will remain a challenge for many states. This Module attempts to bridge the ODF and ODF+ (IWSM) challenges that India faces.

The Handbook identifies key information and facts that need to be conveyed in all IWSM trainings, learnings and should be read together with Part B of the Presentations based training material. The Handbook is Part A of the IWSM Advanced Training Module. The other two Parts (B & C) are available on request.

A	Learning notes	Identifies the learning objectives and key learning outcomes that can guide trainers and trainees. Key learning outcomes are defined as specific points for each session, which need to be limited.
B	Module presentation slides	Contains the MS PowerPoint presentations and practical exercises that trainees can refer to during the training sessions and exercise work.
C	Training of trainer	This helps the trainers to understand how the sessions needs to carried out along with the tools and exercises that help to make the learning process effective.

About the Training Module

Title	Integrated Wastewater and Septage Management An Advanced Training Module
Purpose	There are centralized and decentralized / on site systems of treatment of wastewater and septage. While conventional sewerage may be a comprehensive system for sewage collection and transport, it also is a highly resource intensive technology for CapEx and OpEx. Consequently, high capital cost and significant O&M cost of this system inhibits its widespread adoption in all sizes of urban areas. Decentralized FSTP are emerging as solutions to the challenge of addressing safe treatment and disposal of septage. However, it does not imply that all small towns and cities need FSTP infrastructure. The Handbook attempts to instill a rational perspective for tackling urban sanitation challenge, without being prescriptive or offering single technology solutions. This is compendium of planning process and technologies involved in treatment of wastewater and septage.
Module is for	Municipal Commissioners and Executive Officers of Class II and Class III towns and cities, officials of the state parastatal departments and the ULBs including engineers, sanitary inspectors, public health officials and staff from the Finance and Accounts departments dealing with Sanitation.
Learning Objectives	The module aims to convey the following learning: • Understanding the current problems in the water and sanitation sector at the city level. • Understanding the different approaches and its applicability under different constraints to tackle these problems. • Decentralized wastewater and septage treatment solutions are technically sound options for Indian towns and cities and are not sub optimal solutions as compared to centralized sewerage systems. • Over view of decentralized wastewater treatment technologies and their applicability under different contexts. • Assessment and planning both technical and financial for FSSM at the city level.
Duration	The workshop is proposed to be conducted in three days. It could be extended by another day depending on the size of a batch of trainees and their interest and time given for all the sessions.

Integrated Wastewater and Septage Management (IWSM)

An Advanced Training Module

AGENDA

Time duration	Session Title
Day 1: Sustainable Sanitation and Water Management, Designing of Sanitation Systems	
9.30 am-10.00 am	Registration
10.00 am-10.45 am	Introduction, setting ground rules! Understanding expectations, aims and objectives.
10.45 am-11.00 am	*Coffee Break*
11.00 am –11.45 am	Water and Sanitation
11.45 am – 1.00 pm	Sustainable Sanitation and Water Management (SSWM)
1.00 pm - 2.00 pm	Lunch
2.00 pm- 3.15 pm	SSWM Group work: Define boundaries, identify sanitation components of your system/city
3.15 pm- 3.30 pm	Coffee Break
3.30 pm- 4.30 pm	Designing of Sanitation System

Time duration	Session Title
Day 2: Sanitation Systems and Technologies, Wastewater Treatment Technologies, Non-Technical Aspects	
10.00 am - 11.00 am	Sanitation Systems and Technologies
11.00 am - 11.15 am	Coffee Break
11.15 am - 12.30 pm	Wastewater Treatment Technologies
12.30 pm – 13.00 pm	Group Work: Conceptualising Wastewater Treatment Systems
1.00 pm - 2.00 pm	Lunch
2.00 pm – 3.15 pm	Non-Technical Aspects
3.15 pm - 3.30 pm	Coffee Break
3.30 pm – 16.30 pm	Group Work: Stakeholders Analysis

Time duration	Session Title
Day 3: Need of Faecal Sludge and Septage Management, Planning Process of FSSM, Financing of FSSM Planning Process,	
10.00 am -10.45 am	Need of Faecal Sludge and Septage Management
10.45 am -11.00 pm	Coffee Break
11.00 am- 12.15 pm	Faecal Sludge and Septage Management (FSSM) Planning Process
12.15 pm- 1.00 pm	Financing of Faecal Sludge and Septage Management (FSSM)
1.00 pm- 2.00 pm	Lunch
2.00 pm- 3.00 pm	Group Work: FSSM Planning Process
3.00 pm- 3.15 pm	Coffee Break
3.15 pm- 3.45 pm	Wrap-up and Feedback Session

Learning Notes

1 Water and Sanitation

1.1 Objectives

- To understand the concepts of environmental health.
- To gain knowledge on linkage between water supply and environmental sanitation.
- To acquire information and knowledge about new options in sanitation in order to support urban dwellers in reducing environmental health risks, improving their nutritional status and protecting their water sources.

1.2 Duration

45 min

1.3 Key facts

I. What are the goals of Environmental Sanitation?

Good health presupposes that the water we drink, the air we breathe and the food we eat are free from contaminants and pathogens, and that facilities, services and hygienic behaviour provide for a clean environment in which to live, with measures to break the cycle of disease and contamination. The goals of environmental health are the following:

- Maintain a natural and built environment free from undue hazards, and
- Provide essential environmental services to households and communities.

II. What are the needs for achieving a good environmental health?

Anyone changing the natural or built environment has an impact on environmental health. To achieve good environmental health, one should

- maintain a natural environment free from undue hazards,
- ensure a built environment free from undue hazards
- Provide essential environmental services to households and communities in order to achieve good individual and community health.

III. How will you distinguish between natural and built environment in Urban areas?

The natural is the natural resources water, air and soil and all services and facilities required to build keep the environment clean and protect health are built environment such as water supply, sanitation, solid waste management etc.

IV. What is F diagram?

The movement of pathogens from the feces of a sick person to where W they are ingested by somebody else can take many pathways, some direct and some indirect. This diagram illustrates the main pathways. They are easily memorized as they all begin with the letter 'f': fluids (drinking water) food, flies, fields (crops and soil), floors, fingers and H floods (and surface water generally).

V. What are the objectives and new principles of water supply and sanitation systems?

The principles governing the new approach are the following:

- Human dignity, quality of life and environmental security at household level should be at the center of the new approach. It should also be responsive and accountable to local and national needs and demands.
- In line with sound governance principles, decision-making should involve the participation of all stakeholders, especially the consumers and service providers.
- Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flows and waste management processes.
- The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, city), and waste diluted as little as possible.

(WSSCC/Eawag 2000, p.12)

1.4 Learning Notes

1.4.1 Environmental health

Environmental health is broader than hygiene and sanitation; it encompasses hygiene, sanitation and many other aspects of the environment that are not included in this Module such as global warming, climate change, radiation, gene technology, flooding and natural disasters. It also involves studying the environmental factors that affect health.

> *The World Health Organization defines Environmental health as follows;*
>
> *Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health*

Key phrases in this definition are ***environmental factors*** and ***potentially affect health***.

1.4.2 Components of Environmental health

Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behavior not related to environment, as well as behavior related to the social and cultural environment, and genetics. It is an international discipline, although practices vary from country to country, as do the people and organizations undertaking the work.

FIGURE 1: COMPONENTS OF ENVIRONMENTAL SANITATION

Environmental Health has been responsible for improving our life expectancy and quality of life. Practitioners have been instrumental in reducing air pollution, improving standards in housing and food safety, and mitigating infectious disease and effects of disasters. The components that make up Environmental Health can be grouped as follows;

TABLE 1: COMPONENTS OF ENVIRONMENTAL HEALTH

Description	Concerns
Personal hygiene	Hygiene of body and clothing
Water supply	Adequacy, safety (chemical, bacteriological, physical) of water for domestic, drinking and recreational use
Human waste disposal	Proper excreta disposal and liquid waste management
Soild waste management	Proper application of storage, collection, disposal of waste. Waste production and recycling
Vector Control	Control of mammals (such as rats) and **arthropods** (insects such as flies and other creatures such as mites) that transmit disease
Food hygiene	Food safety and wholesomeness in its production, storage, preparation, distribution and sale, until consumption
Healthful housing	Physiological needs, protection against disease and accidents, psychological and social comforts in residential and recreational areas
Institutional hygiene	Communal hygiene in schools, prisons, health facilities, refugee camps, detention homes and settlement areas
Water pollution	Sources, characteristics, impact and mitigation

Anyone changing the natural or built environment has an impact on environmental health. To achieve good environmental health, one should

- maintain a natural environment free from undue hazards,
- ensure a built environment free from undue hazards
- Provide essential environmental services to households and communities in order to achieve good individual and community health.

FIGURE 2: NATURAL AND BUILT ENVIRONMENT (SOURCE: EAWAG,2014)

The natural and built environment with its natural resources water, air and soil (blue); all services and facilities required to keep the environment clean and protect health (green). In this module, focus will be on water supply and environmental sanitation services, facilities and human behaviour behaviour (inside yellow line).

Interventions to reduce people's exposure to disease by providing a clean environment in which to live, and the measures to break the cycle of disease. It involves both behaviour and facilities, which jointly work together to form a hygienic environment. (Simpson-Hebert and Woods, 1998)

This comprises:

- access to a safe supply of water for domestic use
- access to water for washing and hygiene practice
- safe management of human excreta and wastewater
- solid waste management and (storm water) drainage

Water supply

Water supply system, infrastructure for the collection, transmission, treatment, storage, and distribution of water for homes, commercial establishments, industry, and irrigation, as well as for such public needs as firefighting and street flushing. Of all municipal services, provision of potable water is perhaps the most vital. People depend on water for drinking, cooking, washing, carrying away wastes, and other domestic needs. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfil both quality and quantity requirements. Definitions of 'access' (distance to the nearest water-point and per capita availability) and 'safe' (water quality) may vary from one country to another (DFID Manual, 1998). However, the overall valid standard is to provide at least 20 litres per person and day from a source within one kilometre of the user's dwelling (WHO/Unicef 2000, p. 77).)

As per census 2011, Nearly 70 percent households have access to tap water, out of which 62 percent have access to treated tap water. Thus, nearly 40 percent of urban households have no access to public supply and have to depend on other sources of water.2 Moreover, not all households that have access to public supply have access to it within the premise. Only 49 percent of households have access to piped water supply within their premises.

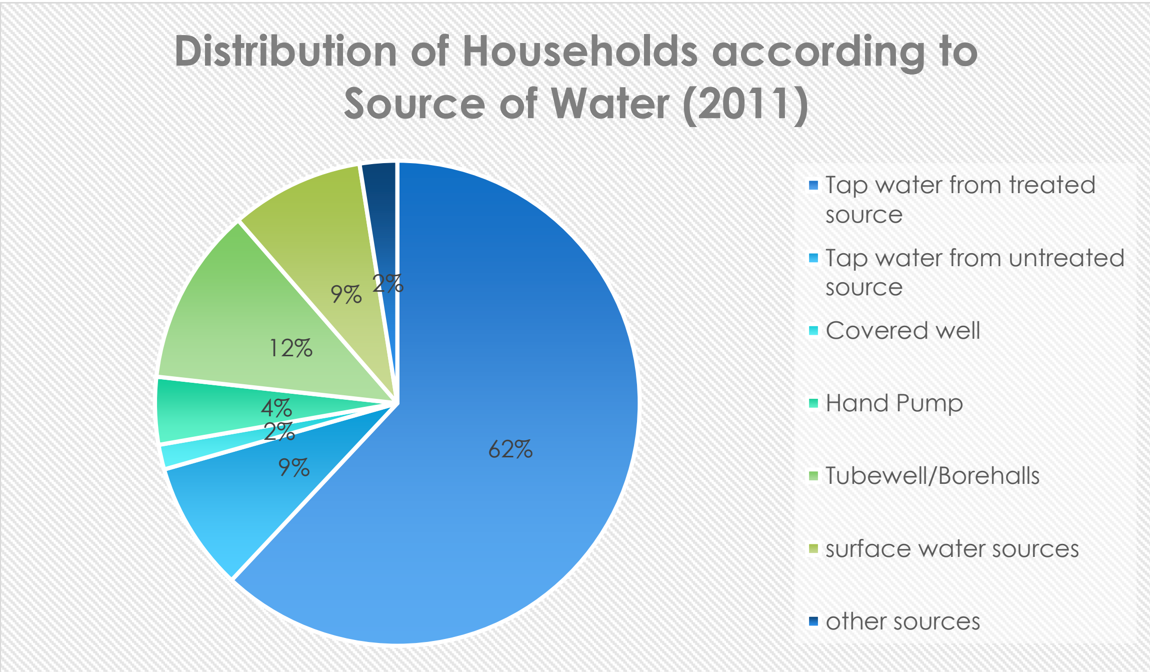

FIGURE 3: DISTRIBUTION OF HOUSEHOLDS ACCORDING TO SOURCE OF WATER

Sanitation

Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and feces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities. The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal.

Around 81 per cent of urban households have access to toilet facilities within the household premises, 6 per cent access public toilets, and 12 per cent are forced to resort to open defecation. Thus, nearly 10 million households still defecate in the open. Open defecation, and the lack of access to any kind of toilet facilities, individual or shared, is one of the biggest concerns and challenges for urban sanitation in India.

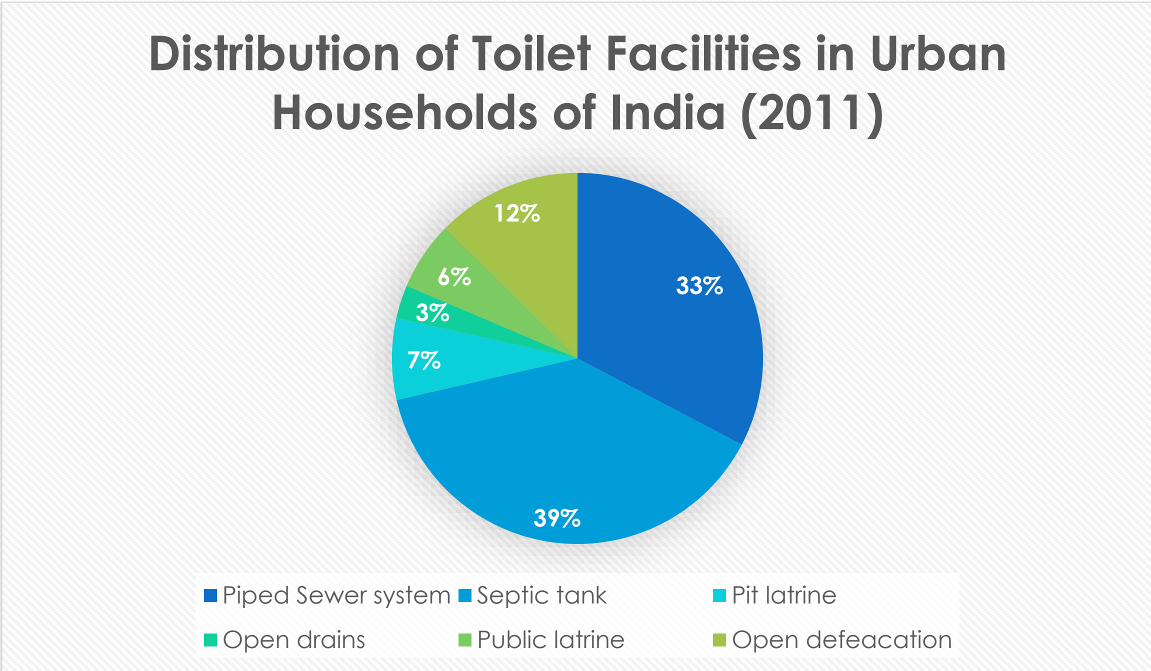

FIGURE 4 DISTRIBUTION OF TOILET FACILITIES IN URBAN HOUSEHOLDS OF INDIA (2011)

Environmental Sanitation

Environmental sanitation is defined as activities aimed at improving or maintaining the standard of basic environmental conditions affecting the well-being of people. These conditions include (1) clean and safe water supply, (2) clean and safe ambient air, (3) efficient and safe animal, human, and industrial waste disposal, (4) protection of food from biological and chemical contaminants, and (5) adequate housing in clean and safe surroundings. Also called as environmental hygiene.

1.4.3 Environmental Health and Disease Transmission

Waterborne or excreta related diseases are still significant causes of mortality and morbidity in many developing countries. The transmission routes of these and the health risk factors involved are important, in order to design and implement or modify excreta use schemes so that the transmission of these diseases are reduced (see also health risk management). The pathogens of concern for environmental transmission through feces mainly cause gastrointestinal symptoms such as diarrhoea, vomiting and stomach cramps. Several may also cause symptoms involving other organs and severe sequels or be an interrelated factor for malnutrition. This mechanism works through a variety of routes, as shown by the so-called "F Diagram" (WHO,2005).

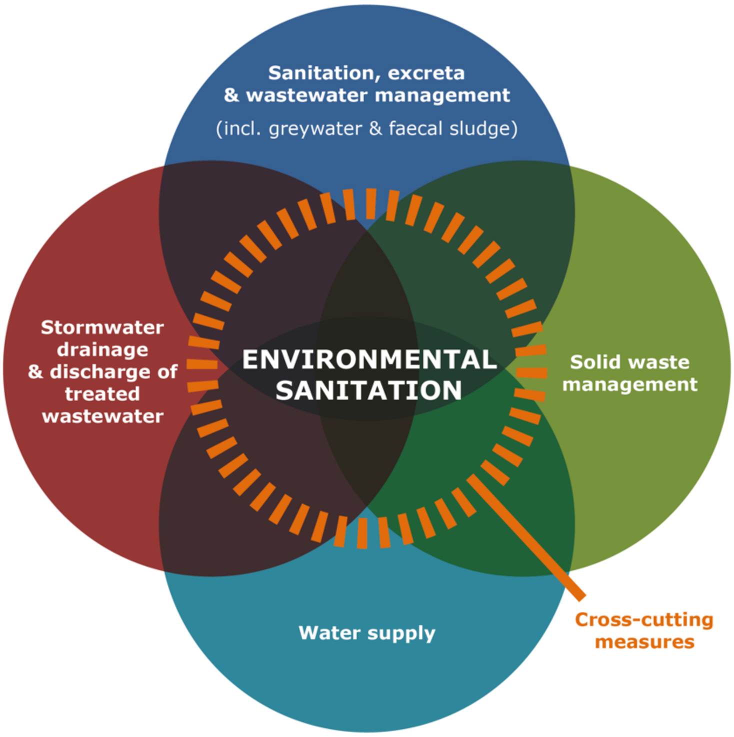

FIGURE 5: KEY COMPONENTS OF ENVIRONMENTAL SANITATION

The figure below shows the factors that are essential for diarrhoea transmission,

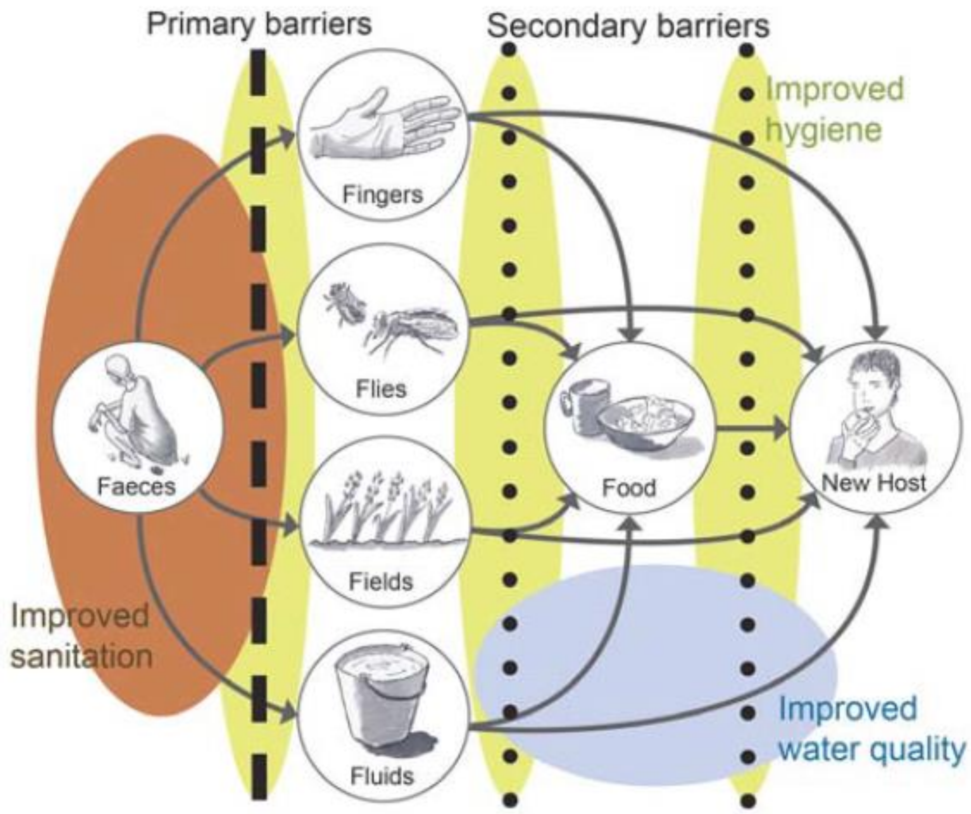

FIGURE 6: THE F DIAGRAM

If you understand the pathway of the disease, then you can design an intervention for the disease that targets the source, environment or the host. An intervention is a way of stopping the disease from being transmitted. The broken lines, in the figure above, indicate the possible interventions for the prevention and control of diarrhea. Some of these interventions are described in the table below.

TABLE 2 :POSSIBLE HEALTH INTERVENTIONS TO PREVENT DISEASE

Intervention strategies	Activities
Intervention at the source	➢ Avoid open defecation ➢ Install a latrine ➢ Always use a latrine to bury feces and urine
Intervention in the environment	➢ Use safe drinking water ➢ Handwashing ➢ Vector control and management ➢ Proper refuse and liquid waste management ➢ Provision of food safety ➢ Healthful housing

Intervention at the host	➢ Hygiene promotion through hygiene education and community mobilization ➢ Vaccination (if available) ➢ Healthy living

1.4.4 Resource and Waste Systems

The large number of people worldwide still lacking access to adequate water, sanitation, drainage, and solid waste disposal services provides sufficient evidence that conventional approaches to environmental sanitation are unable to make a significant dent in the still existing service backlog. At the same time, the world's natural supply of fresh- water is subject to increasing environ- mental and economic pressure. Unless determined action is taken, the situation is likely to worsen dramatically. Population growth and increasing per capita water demand, fuelled by rapid industrialisation in the developing world, will further contaminate and deplete the finite water sources already over- exploited in many countries.

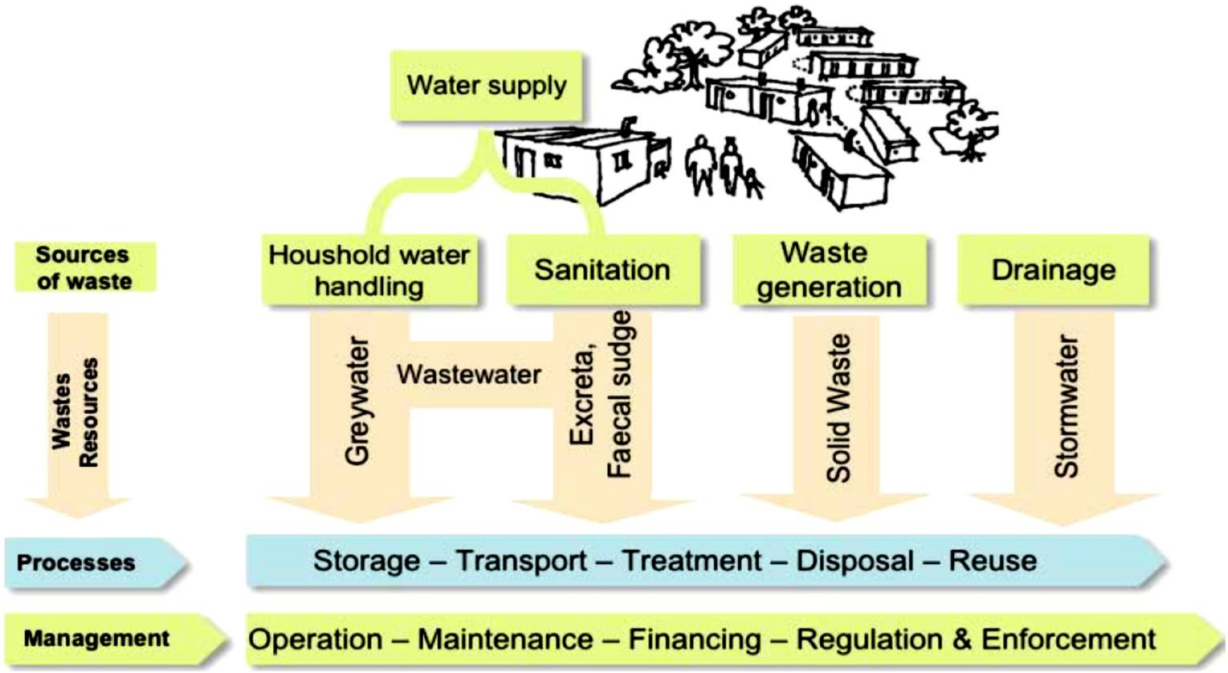

FIGURE 7: WASTE AND RESOURCE FLOW (SOURCE: EAWAG,2014)

The figure shows the sources of waste in the household and neighbourhood (green) and the waste and resource flows (brown). All waste and resource flows require an integrated management (green) within a settlement: regulatory system and its enforcement, as well as operation and maintenance for safe transport, treatment, safe disposal, and/or reuse (blue).

Only well-planned and well-managed cities will be able to meet the double challenge of demographic change and the massive transformations taking place in the global economy. It is a priority for city governments and administrations to anticipate these trends and to grasp the opportunities presented by the new roles for cities and their governments. The situation is urging for new planning approaches to overcome the serious lack of sanitation services, causing illnesses and stunting economic progress for hundreds of millions of people in developing countries. (Adapted from Lüthi et al., 2008a, p. 69)

Sanitation Planning

A system approach to environmental sanitation, which extends from the point of generation to the point of disposal/discharge or reuse – from the cradle to the grave is urgently needed, both at the planning and implementation level. Those who advocate a market-based approach argue that since people are consumers of sanitation services, the market should be able to provide them with the services they want at a price they are willing to pay. Others advocate a collective action model in which improved facilities are provided through the efforts of voluntary organisations. Both these approaches reduce the direct burden on the state and, hence, allow limited resources to extend further. However, both also have their limitations. The sanitation systems are often only considered partially. For example, on-site based sanitation solutions (latrine or septic tank-based) frequently do not include excreta and fecal sludge emptying, transport or treatment services and facilities. Additionally, local business opportunities, as well as demand and potential use of waste resources, such as water, nitrogen or biosolids, are given little attention. Failures or unsustainable solutions put a substantial financial burden on municipalities.

Excreta and Septage Management

In cities of developing countries, large amounts of excreta and fecal sludge collect in on-site sanitation facilities, such as private or public latrines, and septic tanks. As opposed to industrialised countries, where excreta is disposed of via cistern-water flush toilets, city-wide sewerage systems and central wastewater treatment plants, all of which are widespread technologies in industrialised countries but unaffordable or inappropriate in developing countries. If fecal sludge is collected at all from on-site sanitation technologies, they are most often disposed of in an uncontrolled manner without prior treatment, thus, posing severe health risks and polluting the environment.

1.4.5 Urban challenges

Over the last several decades, effective strategies have been developed to provide affordable sanitation services to the urban populations of developing countries. Rapid implementation of these approaches is, however, urgently need- ed in developing countries to close the growing gap between those with access to sanitation services and those without. Factors leading to deficiencies in water and sanitation can be found on every level – from local to international. The causes for the inadequacies are thus proximate (household/local), contributory (city & town) or underlying (global/international).

Challenges faced in the household level

1/4–2/3 of the urban population lives in slums (informal or illegal settlements). Many public or private official water and sanitation providers do not operate in illegal settlements. Moving from illegal to legal status is complicated and expensive. House plots don't have formal addresses and clear boundaries. Hence it is difficult for the ULBs to give individual connections to the households in illegal settlements. The transition of illegal to legal requires the agreement of several different agencies. The ULBs also lack qualified workforce such as lawyers and surveyors for such purpose.

Planning, funding, implementing, operating, and maintaining water and sanitation systems require qualified skills and expertise in different disciplinary fields. Since illegal settlements lack regular plot layouts, access roads, substantial waste collection, the tasks are far more complicated than in regulated settlements.

Challenges faced in the city level

The WHO/UNICEF Assessment identified cost recovery and inadequate operation and maintenance as two of the main constraints on the development of water supply and sanitation – both largely a consequence of the weakness or incapacity of water and sanitation agencies. The spatial distribution of the population has always been a key factor on the policy agenda of governments. The governments of developing countries have often expressed concern about their inability to provide basic services for their rapidly growing urban populations, including safe drinking water, sanitation, affordable housing, and public transport.

1.5 Further Readings

A. WHO (2005): Sanitation and hygiene promotion. Programming guidance. Geneva, WHO,URL .

B. IIED (2006): "Environment & Urbanization Brief - 13. Ecological Urbanization." Environment & Urbanization 18(1).URL

C. WHO (2007): Combating waterborne disease at the household level. WHO/The International Network to Promote Household Water Treatment and Safe Storage, Geneva. URL

D. WHO/UNICEF (2006): Meeting the MDG drinking water and sanitation target: The urban and rural challenge of the decade. Geneva. URL

2 Sustainable Sanitation and Water Management

2.1 Objectives

- To understand terminology of wastewater management and the byproducts of sanitation value chain
- To understand the different streams of wastewater and their quantities
- To explain the parameters of waste water characteristics
- To understand the local water, sanitation and nutrient cycle.

2.2 Duration

60 min

2.3 Key facts

I. How is "sanitation" defined and what are its objectives?

Sanitation is an intervention involving behavior and facilities aiming at interrupting the disease cycle. The word sanitation alone is taken to mean the safe management of human excreta. It, therefore, includes both the hardware (e. g. latrines and sewers) and the software (regulation, hygiene promotion) needed to reduce fecal-oral disease transmission. It also encompasses the reuse and ultimate disposal of human excreta.

A sanitation system must:

- Protect and promote health – it should keep disease-carrying waste and insects away from people, both at the site of the toilet, in nearby homes and the neighboring environment.
- Protect the environment – avoid air, soil, water pollution, return nutrients/ resources to the soil, and conserve water and energy.
- Be simple – the system must be operational with locally available resources (human and material). Where technical skills are limited, simple technologies should be favored.
- Be affordable – total costs (including capital, operational, maintenance costs) must be within the users' ability to pay.
- Be culturally acceptable – it should be adapted to local customs, beliefs and desires.
- Work for everyone – it should address the health needs of children, adults, men, and women.

II. What is the difference between sanitation and environmental sanitation?

Sanitation is the efficient use of tools and actions that keep our environment healthy. These include latrines or toilets to manage waste, food preparation, washing stations, effective drainage and other such mechanisms. Environmental sanitation is activities aimed at improving or maintaining the standard of necessary environmental conditions affecting the well-being of people.

These conditions include (1) clean and safe water supply, (2) clean and safe ambient air, (3) efficient and safe animal, human, and industrial waste disposal, (4) protection of food from biological and chemical contaminants, and (5) adequate housing in clean and safe surroundings. Also, called environmental hygiene.

III. What waste products are generated from a household?

The different sanitation systems generate the following products:

- Blackwater is the mixture of urine, feces and flushing water along with anal cleansing water (if anal cleansing is practiced) or dry-cleaning material (e.g. toilet paper).
- Greywater is used water generated through bathing, hand-washing, cooking or laundry. It is sometimes mixed or treated along with blackwater.
- Urine is the liquid not mixed with any feces or water.
- Excreta is the mixture of urine and feces not mixed with any flushing water (although small amounts of anal cleansing water may be included).
- Fecal sludge is the general term for the undigested or partially digested slurry or solid resulting from the storage or treatment of blackwater or excreta.
- Domestic wastewater comprises all sources of liquid household waste: blackwater and greywater. However, it generally does not include stormwater.
- Stormwater in a community settlement is runoff from house roofs, paved areas and roads during rainfall events. It also includes water from the catchment of a stream or river upstream of a community settlement.

IV. What are the main planning approaches and their characteristics?

Most planning approaches adopted in the past can be assigned to one of the three models described by McGranahan et al. (2001): The planning model, the market model based on the economic principles of demand and supply, and the collective action model. These are built on three different mechanisms of social interaction:

- Supply-driven approach: the bureaucratic organization is attempting to apply rationality of a higher order to people's behavior.
- Market approach: market processes relying on the 'invisible hand' of a market to transform individual preferences into aggregate outcomes.
- Collective action approach: voluntary association, where group decisions are collectively negotiated.

2.4 Learning Notes

2.4.1 Waste Products

The urban water cycle is one of the key processes connecting human activity to natural systems. The health and well-being of both human population and environment is therefore dependent on the integration of urban water systems with the natural systems. The generation of liquid waste from human activities is unavoidable. However, not all humans produce the same amount of liquid waste. The type and amount of liquid waste generated in households are influenced by behavior, lifestyle and standard of living of the population as well as by the governing technical and juridical framework. (Henze and Ledin, 2001)

The different sanitation systems generate the following products:

- Blackwater is the mixture of urine, feces and flushing water along with anal cleansing water (if anal cleansing is practiced) or dry-cleaning material (e.g. toilet paper).
- Greywater is used water generated through bathing, hand-washing, cooking or laundry. It is sometimes mixed or treated along with blackwater.
- Urine is the liquid not mixed with any feces or water.
- Brown water is blackwater without urine.
- Excreta is the mixture of urine and feces not mixed with any flushing water (although small amounts of anal cleansing water may be included).
- Fecal sludge is the general term for the undigested or partially digested slurry or solid resulting from the storage or treatment of blackwater or excreta.

Domestic wastewater comprises all sources of liquid household waste: Blackwater and greywater. However, it does not include stormwater.

Storm water in a community settlement is runoff from house roofs, paved areas and roads during rainfall events. It also includes water from the catchment of a stream or river upstream of a community settlement

2.4.2 Parameters to characterize Wastewater

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants.

The characteristics can be mainly divided into three categories; physical parameters, chemical parameters and biological parameters. In case of wastewater usually, measuring taste, odor etc. is not essential, but when it comes to water supply or primarily for drinking water color, odor, taste etc. are very important. And moreover, the solids present in water and wastewater are entirely different. In wastewater, mostly the solids are organic whereas in the raw water whatever is coming to the water treatment plant the solids may be mostly inorganically originating from clay silt and soil particles. And sometimes biological material also may be coming from plant fabrics and microorganisms

Solids

Solids can be classified into various categories depending upon the size of the particles.

- TS- Total Solids
- TSS-Total Suspended Solids

If the particle size is very small if it is completely dissolved in the solution we can call it as dissolved solids. If the particle size is in between 0.01 micrometer to 1 micrometer, they are colloidal solids. These colloidal solids are very stable that means they will not be settling down in the liquid or water so they will always be in that Brownian motion, so it is very difficult to remove them especially from water and wastewater.

Suspended solids are those solids that do not pass through a 0.2-um filter. About 70% of those solids are organic, and 30% are inorganic. The inorganic fraction is mostly sand and grit that settles to form an inorganic sludge layer. Total suspended solids comprise both settleable solids and colloidal solids. Settleable solids will settle in an Imhoff cone within one hour, while colloidal solids (which are not dissolved) will not settle in this period. Suspended solids are easily removed by settling and/or filtration. However, if untreated wastewater with a high suspended solids content is discharged into the environment, turbidity and the organic content of the solids can deplete oxygen from the receiving water body and prevent light from penetrating.

2.4.3 Organic constituents

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources.

Organic compounds usually are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. Organic matter is determined by following characteristics;

- BOD Biochemical oxygen demand
- COD Chemical oxygen demand

Biodegradable organics are composed mainly of proteins, carbohydrates and fats. If discharged untreated into the environment, their biological stabilization can lead to the depletion of natural oxygen and development of septic conditions.

BOD test results can be used to assess the approximate quantity of oxygen required for biological stabilization of the organic matter present, which in turn, can be used to determine the size of wastewater treatment facilities, to measure the efficiency of some treatment processes and to evaluate compliance with wastewater discharge permits.

2.4.4 Nutrients

Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there is typically an excess available in treated wastewater.

In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow fast depleting oxygen in the water. Deprived of oxygen, fish and other aquatic life die, emitting foul odors.

Nitrogen and phosphorus, also known as nutrients or bio stimulants, are essential for the growth of microorganisms, plants and animals. When discharged into the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life, which rob the water of dissolved oxygen. When discharged in excessive amounts on land, they can also lead to groundwater pollution.

2.4.5 Pathogens

Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals who are infected with or are carriers of a disease.

For example, greywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants

- TC (MPN) Total coliforms, most probable number
- FC (MPN) Fecal coliforms, most probable number

Pathogenic organisms present in wastewater can transmit communicable diseases. The presence of specific monitoring organisms is tested to gauge plant operation and the potential for reuse. Coliform bacteria include genera that originate in feces (e.g. Escherichia) as well as the genre not of fecal origin (e.g. Enterobacter, Klebsiella, Citrobacter). The assay is intended to be an indicator of fecal contamination; more specifically of E. coli which is an indicator microorganism for other pathogens that may be present in feces. Presence of fecal coliforms in water may not be directly harmful and does not necessarily indicate the presence of feces.

2.4.6 pH

The acidity or alkalinity of wastewater affects both treatment and the environment. Low pH indicates increasing acidity, while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter wastewater from industrial or commercial sources. Wastewater with an extreme concentration of hydrogen ions is difficult to treat biologically. If the concentration is not altered before discharge, the wastewater effluent may alter the concentration in natural waters, which could have negative effects on the ecosystem.

Alkalinity in wastewater results from the presence of calcium, magnesium, sodium, potassium, carbonates and bicarbonates, and ammonia hydroxides. Alkalinity in wastewater buffers (controls) changes in pH caused by the addition of acids.

Wastewater usually is alkaline due to the presence of groundwater (which has high concentrations of naturally occurring minerals) and domestic chemicals. The alkalinity of wastewater is essential where chemical and biological treatment is practiced, in biological nutrient removal and where ammonia is removed by air stripping.

2.4.7 Electric conductivity

The measured EC value is used as a surrogate measure of total dissolved solids (TDS) concentration. The salinity (i.e. 'saltiness') of treated wastewater used for irrigation is also determined by measuring its electric conductivity.

2.4.8 Temperature

The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water. The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water.

2.5 Ecological sanitation

Ecological sanitation is an age-old "technology" that protects human and ecosystem health while preventing water pollution, conserving energy, and capturing nutrients. Based in basic biological principles that recognise that Earth is a closed-loop system, ecological sanitation utilises natural processes (in the case of composting toilets – the carbon cycle) to transform "waste" into a life-giving resource. Notably, it requires technical, institutional, social and economic management to 'close the loop.'

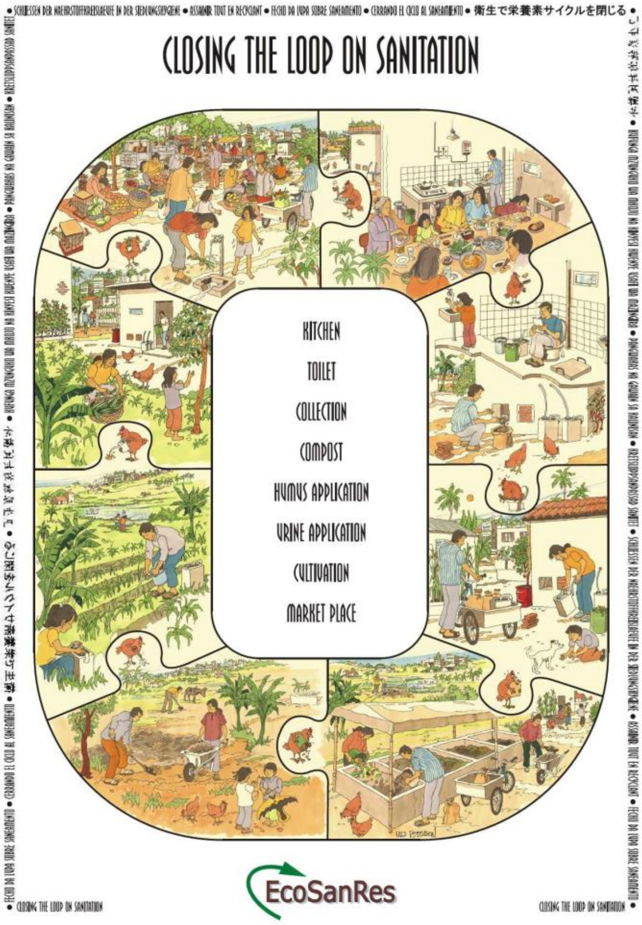

FIGURE 8: ECOLOGICAL SANITATION (SOURCE ECOSANRES,2005)

Ecological sanitation is not fixed to any one system but emphasises the need for a holistic systems approach based on ecological thinking to design sustainable treatment systems.

2.6 Characteristics of the main waste products in wastewater

2.6.1 Grey Water

The composition of grey wastewater depends on sources and installations from where the water is drawn, e.g. kitchen, bathroom or laundry. The chemical compounds present originate from household chemicals, cooking, washing and the piping. In general grey, wastewater contains lower levels of organic matter and nutrients compared to conventional wastewater, since urine, feces and toilet paper are not included.

Water consumption in low-income areas with water scarcity and rudimentary forms of water supply can be as low as 20–30 litres per person and day. Greywater volumes are even lower in regions where rivers or lakes are used for personal hygiene and for washing clothes and kitchen utensils.

Households in affluent areas with piped water may, however, generate several hundred liters per day. In urban and peri-urban areas of low and middle-income countries, greywater is most often discharged untreated into stormwater drains or sewers – provided they exist –from where it flows typically into aquatic systems. This practice may lead to oxygen depletion, increased turbidity, eutrophication, as well as microbial and chemical contamination of aquatic systems.

2.6.2 Urine

The concentration of nutrients in the excreted urine depends on the nutrient and liquid intake, the level of personal activity and climatic conditions.

Urine, rich in nitrogen and phosphorus, can be used as fertilizer for most non-nitrogen-fixing crops after appropriate treatment to reduce potential microbial contamination.

Since spinach, cauliflower and maize are crops with a high nitrogen content, they respond well to nitrogen fertilization. The nutrients in urine are present in ionic form, and their plant availability and fertilizing effect compare well with those of chemical (ammonium and urea-based) fertilizers (Kirch-mann and Petterson 1995, pp. 149−154; Johansson et al. 2001). Environmental transmission of urine- excreted pathogens is of minor concern in temperate climates. However, fecal cross-contamination may create a health risk. In tropical climates, fecal contamination of collected urine poses the primary health risk. Some (rare) urine- excreted pathogens should also be taken into account.

2.6.3 Feces

From a risk perspective, exposure to untreated feces is always considered unsafe because the high levels of pathogens whose prevalence is dependent on the given population. Enteric infections can be transmitted by pathogenic species of bacteria, viruses, parasitic protozoa, and helminths. (WHO 2006). Fecal compost can be applied as a complete phosphorus-potassium fertilizer or as a soil improver.

About 40−70% of the organic matter and slightly lower nitrogen content are lost through biological activity and volatilization. Most of the remaining nitrogen will become available to plants during degradation. The content of organic matter in feces also increases the water-holding and ion-buffering capacity of soils, an essential aspect to improving soil structure and stimulating microbial activity. (WHO 2006).

TABLE 3: CHARACTERISATION OF WASTE PRODUCTS (SANDEC,2004)

	Total	Grey water	Urine	Faces
Volume (L/cap.yr)	25,000-100,000	**25,000-100,000**	500	50
Nitrogen (kg/cap.yr)	2.0-4.0	5%	**85%**	10%
Phosphorus (kg/cap.yr)	0.3-0.8	10%	**60%**	30%
Potassium(kg/cap.yr)	1.4-2.0	34%	**54%**	12%
COD (kg/cap.yr)	30	**41%**	12%	**47%**
Faecal coliform (per 100 mL)	-	**10^4-10^6**	0	**10^7-10^9**

2.7 Sanitation and Nexus

Sustainable and Productive Sanitation is a Perfect Example of the Water, Energy and Food Security Nexus. Sanitation and wastewater treatment are closely interlinked with the given nexus approach of the conference. If the sanitation system is sustainable and productive, the benefits not only for public health but for water, energy and food security are enormous. Sustainable and productive sanitation systems save water and energy, contribute to renewable energy security (biogas), and contribute to food security through decentralized and cost-efficient provision of fertilizer, soil conditioner or nutrient rich irrigation water.

2.7.1 Sanitation and Water

Adequate sanitation without water is not thinkable. A toilet might need little or no water to flush but sanitation includes many other water-dependent processes such as the hygiene practice of hand washing with safe drinking water. Insufficient sanitation practices — such as the lack of containment of fecal matter and the inadequate treatment of wastewater — pose direct risks to drinking water sources and to public health. In many water, scarce regions, great amounts of the resource are needed for irrigation in agriculture. Treated domestic wastewater is an excellent source for irrigation because of its constant flow all year around and its contents of various plant nutrients. Wastewater is already re-used worldwide, with a large plant in Milan, Italy, posing a good example. But in most cases re-use is practiced out of necessity and without safe regulations, due to the lack of other water sources. Therefore, legislators need to both recognize the benefits of using treated wastewater, as well as assure its safety through better regulation and the provision of incentives to ensure adequate treatment and re-use according to the WHO guidelines (2006).

2.7.2 Sanitation and Food Security

The use of treated sanitation products — urine and feces — as fertilizers can help mitigate poverty and malnutrition and improve the trade balance of countries importing chemical fertilizers, especially in respect of phosphate fertilizer, a non-renewable resource. Food security can be increased with a fertilizer that is readily available for all at very little cost, regardless of infrastructure and economic resources

Source separation and safe handling of nutrients from the toilet systems is one way to facilitate the recirculation and use of excreta in crop production. Urine contains most of the macronutrients as well as smaller fractions of the micronutrients excreted by human beings. Nitrogen, phosphorus, potassium and Sulphur as well as micronutrients are all found in urine in plant available forms. Urine is a well-balanced nitrogen-rich fertilizer which can replace and give the same yields as chemical fertilizer in crop production. In addition, treated and sanitized fecal matter contains many nutrients and organic matter that improve soil fertility and combat desertification. Safe handling of urine and feces including treatment and sanitization before use per the WHO guidelines (2006) is a key component of sustainable sanitation as well as sustainable crop production.

2.7.3 Sanitation and Energy

High energy demand is required for conventional sanitation systems, especially for aerobic wastewater treatment targeting nitrogen (N2) removal. A tremendous amount of energy is required to re-capture N2 from the air to produce chemical fertilisers. On the other hand, sanitation products — wastewater, urine and fecal matter — contain a lot of energy. Firstly, the heat of the wastewater can be regained. Secondly, energy in the form of biogas can be gained through anaerobic digestion — a process already applied in large scale plants in industrialized countries, using the sewage sludge at the "end of the pipe". The energy yields would be even higher if anaerobic systems were applied at the source, for example through pour flush biogas toilets, and UASB treatment of wastewater.

2.8 Integrated Wastewater Management(IWM)

The aspects of wastewater management are explored with integrated perspective. It is a holistic view of the entire wastewater system is required for proper wastewater management, starting from the wastewater generation until the ultimate disposal schemes. The functional elements of integrated wastewater management system are generation and composition, collection, treatment (including sludge treatment) and disposal and reuse. A successful wastewater management decision requires a comprehensive, impartial evaluation of centralized and decentralized treatment systems. However, centralized systems should be evaluated based on the investment of the associated collection sewers and their operation and maintenance (O&M). Selecting appropriate technology for wastewater treatment should be based on area-specific integrated factors such as land availability, wastewater quality, desired finished water quality, socio-economic factors and local and provincial regulations.

2.8.1 Economics of IWM

In a centralized approach, the ULB has to bear the capital and O&M cost of the infrastructure. However, taking into consideration the efficiency of collection of taxes in Indian cities, maintaining the infrastructure and providing services to the masses becomes more of a burden.

On the contrary, in a decentralizes approach (depending on the selected sanitation system) the household (who is the consumer of the services) bears most of the cost. Since private service providers in terms of collection – transport and treatment are available, the costs get distributed among different stakeholders.

2.9 Further Readings

A. JENSSEN, P.D.; HEEB, J.; HUBA-MANG, E.; GNANAKAN, K.; WARNER, W.; REFSGAARD, K.; STENSTROEM, T.A.; GUTERSTRAM, B.; ALSEN, K.W. (2004): Ecological Sanitation and Reuse of Wastewater. Ecosan. A Thinkpiece on ecological sanitation.URL

B. ESREY, S.A.; ANDERSSON, I.; HILLERS, A.; SAWYER, R. (2001): Closing the loop – Ecological Sanitation for food security. Stockholm: Swedish International Development Cooperation Agency. URL

C. JENSSEN, P.D.; GREATOREX, J.M.; WARNER, W. S. (Editor) (2004): Sustainable Wastewater Management in Urban Areas.

3 Sanitation Systems and Technologies

3.1 Objectives

- To explain different terminologies used in sanitation
- To explain the objectives of sanitation
- To categorize different sanitation systems and technologies
- To Identify and select criteria for the selection of sanitation technology in a given context.

3.2 Duration

60 min

3.3 Key facts

I. What are the Functional Groups of a sanitation system?

A functional group is a grouping of technologies that have similar functions. There are five different functional groups from which technologies can be chosen to build a system. The five functional groups are:

- User Interface
- Collection and Storage/Treatment
- Conveyance
- Use and/or Disposal

II. What is a Sanitation system?

A Sanitation System is a context-specific series of technologies and services for the management of these wastes (or resources), i.e. for their collection, containment, transport, transformation, utilization or disposal. A sanitation system is comprised of Products (wastes) which travel through Functional Groups which contain Technologies which can be selected according to the context. By selecting a Technology for each Product from each applicable Functional Group, one can design a logical Sanitation System. A sanitation system also includes the management, operation and maintenance (O&M) required to ensure that the system functions safely and sustainably.

III. How can sanitation systems be classified?

Sanitation systems can be mainly classified as waterless and water-based systems. Classification is usually defined by user interface and collection technology. Waterless systems are single pits, Waterless Alternating Double Pits and waterless urine diversion systems whereas, the water-based systems are Pour Flush with Urine Diversion, Decentralized Blackwater Treatment, (Semi-) Centralized Blackwater Treatment, Sewerage with (Semi-) Centralized Treatment and Sewerage with (semi-) centralized treatment.

3.4 Learning Notes

3.4.1 Sanitation

Sanitation as a whole is a "big idea" covering everything from safe collection, and disposal of human excreta (feces and urine); to the management of solid wastes (trash or rubbish.) Each community, region or country must understand the most sensible and cost-effective way of thinking about sanitation, both in the short and long term, then establish appropriate national plans and priorities, and last but not least – implement!

> *Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities (WHO,2015)*

It is important to understand that sanitation can act at different levels, protecting the household, the community and society. In the case of latrines, it is easy to see that this sanitation system acts at a household level. However, poor design or inappropriate location may lead to migration of waste matter and contamination of local water supplies putting the community at risk. Further down effects of waterborne sewage contamination affect the entire society by ill health and environmental damage.

For countries with very low access to basic sanitation, the effective management of excreta at the household level may have the greatest health implications and benefits but may also be the biggest challenge. In other cases, for example, in a particularly congested urban community, some form of off-site (sewerage) sanitation may be the only viable choice. Yet, in other countries or communities a more complete solution might include a focus on protecting the environment.

Objectives of the sanitation

- Safe sanitation systems should keep disease-carrying waste and insects away from people, both at the site of the toilet, in nearby homes and in the neighboring environment.
- It should avoid air, soil, water pollution, return nutrients/resources to the soil, and conserve water and energy.
- The system must be operational with locally available resources (human and material). Where technical skills are limited, simple technologies should be favored.
- Total costs (including capital, operational, maintenance costs) must be within the users' ability to pay.
- It should be adapted to local customs, beliefs and desires.
- It should address the health needs of children, adults, men, and women.

Sanitation systems can be classified mainly as water based and water less system.

TABLE 4: CLASSIFICATION OF SANITATION SYSTEMS

Waterborne or Wet – Requires water for its functioning	Non- Waterborne or dry- No need water for its functioning
• Full flush or cistern flush (water comes from the cistern) • Pour flush (use of bucket to throw water for flushing purpose) • Low flush toilet (flushing mechanism release small quantity of water) • Aqua privy	• Urine diverting dry toilet (UDDT) • Dry toilet (sit or squat pan) • VIP toilet • Vault toilet

3.4.2 Functional Groups of the sanitation

A sanitation system should consider all the products generated and all the Functional Groups these products are subjected to before being suitably disposed of. Domestic products mainly run through five different Functional Groups, which form together a system. Note: depending on the system, not every Functional Group is required.

A functional group is a grouping of technologies that have similar functions. There are five different functional groups from which technologies can be chosen to build a system.

User Interface (U)

Describes the ways the type of toilet, pedestal, pan, or urinal with which the user comes in contact; it is the way by which the user accesses the sanitation system. In many cases, the choice of User Interface will depend on the availability of water. Note that Greywater and Storm water do not originate at the User Interface but may be treated along with the products that originate from it.

Collection and Storage/Treatment (S)

Describes the ways of collecting, storing, and sometimes treating the products that are generated at the user interface. Treatment that is provided by these technologies is often a function of storage and usually passive (e.g. no energy inputs). Thus, products that are 'treated' by these technologies often require subsequent treatment before Use and/or Disposal.

Conveyance (C)

Describes the transport of products from one functional group to another. Although products may need to be transferred in various ways between functional groups, the longest, and the most critical gap is between user interface or collection and storage/treatment and (semi-) centralized treatment. Therefore, for the sake of simplicity, conveyance only describes the technologies used to transport products between these functional groups.

(Semi-) Centralized Treatment (T)

Semi-) Centralized Treatment refers to treatment technologies that are appropriate for large user groups (i.e., neighborhood to city level applications). The operation, maintenance, and energy requirements of technologies within this functional group are generally higher than for smaller- scale technologies at the S level. The technologies are divided into 2 groups: the first groups are primarily for the treatment of Blackwater, brown water, greywater or effluent (e.g. biogas settlers, ABRs, WSPs, constructed wetlands, whereas the second group (e.g. planted or unplanted drying beds, composting, anaerobic digestion) are mainly for the treatment of sludge. Technologies for pre-treatment and post-treatment are also described.

Use and/or Disposal (D)

Refers to the methods by which products are ultimately returned to the environment, either as useful resources or reduced-risk materials. Furthermore, products can also be cycled back into a system (e.g., by using treated greywater for flushing).

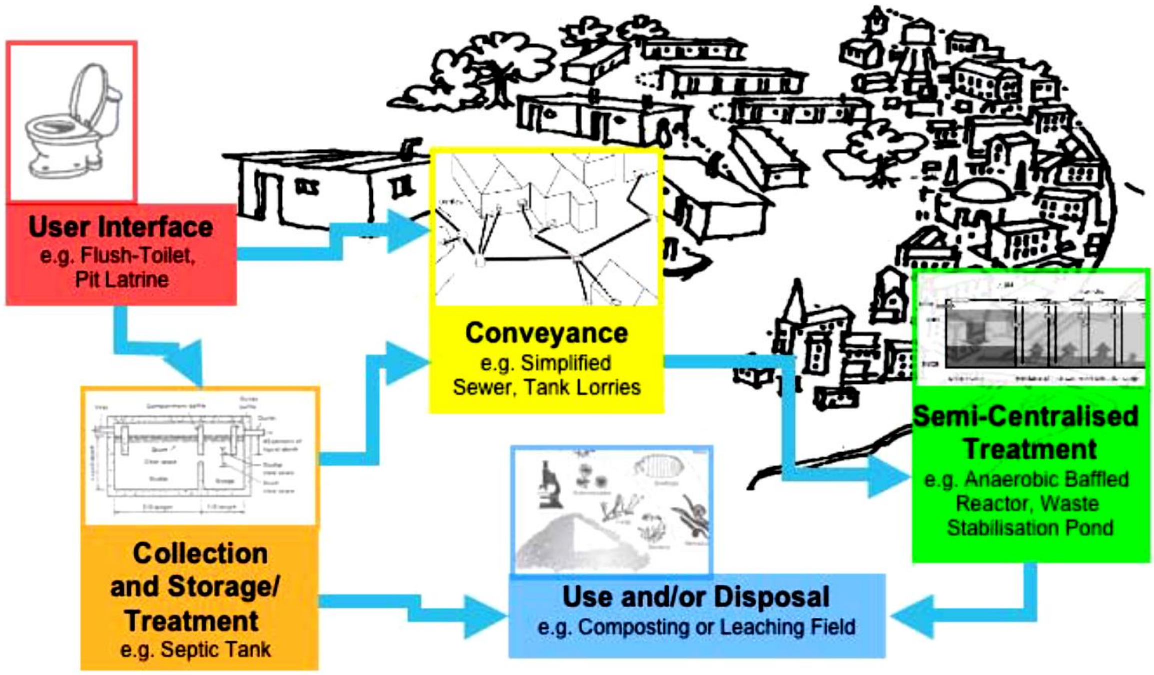

FIGURE 9: FUNCTIONAL GROUPS OF SANITATION (SOURCE: SANDEC,2008)

3.4.3 User Interface

The user interface must guarantee that human excreta is hygienically separated from human contact to prevent exposure to fecal contamination. The user interface is the way in which the sanitation system is accessed. Choice of the user interface has a significant impact on the entire system design, as it defines the products or product mixtures fed into the system. Therefore, the user interface strongly influences the technological choices of subsequent processes.

Selection of user interface depends on the following six technical and physical criteria

- Availability of space
- Ground condition
- Groundwater level and contamination
- Water availability
- Climate

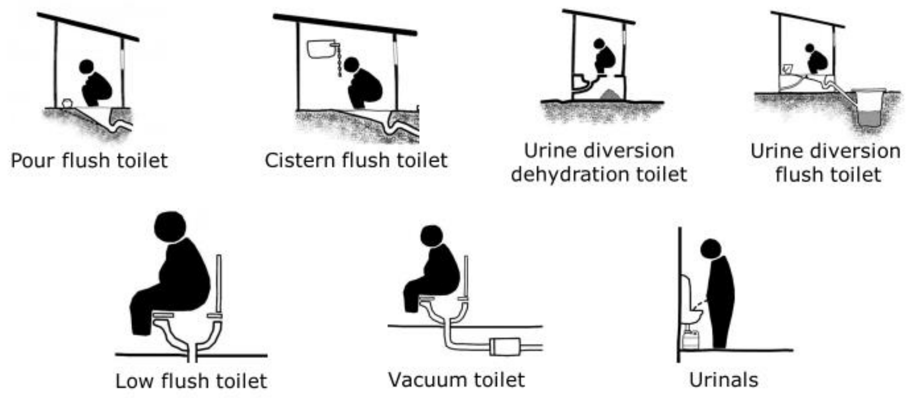

FIGURE 10: USER INTERFACE OPTIONS (SOURCE: SSWM TOOLBOX)

Major Technological Options under "User Interface"

A. **Dry toilets**

A dry toilet is a toilet that operates without freshwater. The dry toilet may be a raised pedestal on which the user can sit or a squat pan over which the user squats. In both cases, excreta (both urine and feces) fall through a drop hole. Here, a dry toilet refers specifically to the device over which the user sits or squats. In other literature, a dry toilet may refer to a variety of technologies or combinations of technologies.

The dry toilet is usually placed over a pit; if two holes are used, the pedestal or slab should be designed in such a way that it can be lifted and moved from one pit to another.

Pros	***Cons***
• *No need for flushing water* • *Can be made on site with locally available materials* • *Meagre cost*	• *Since dry toilets do not have a water seal; odours are normally noticeable even if the vault or pit used to collect excreta is equipped with a vent pipe* • *The excreta pile is visible except where a very deep pit is used* • *Safety concerns for children, disabled, elderly*

The slab or pedestal base should be well sized to the pit so that it is both safe for the user and prevents storm water from infiltrating the pit (which may cause it to overflow). The hole can be closed with a lid to prevent unwanted intrusion from insects or rodents. Pedestals and squatting slabs can be made locally with concrete (if sand and cement are available).

B. Urine diverting dry toilet (UDDT)

A urine-diverting dry toilet (UDDT) is a toilet that operates without water and has a divider so that the user, with little effort, can divert the urine away from the feces.

It is important that the two sections of the toilet are well separated to ensure that a) feces do not fall into and clog the urine collection area in the front, and that b) urine does not splash down into the dry area of the toilet. There are also 3-hole separating toilets that allow anal cleansing water to go into a third, dedicated basin separate from the urine drain and feces collection. Both a pedestal and a squat slab can be used to separate urine from feces depending on user preference.

Urine tends to rust most metals; therefore, metals should be avoided in the construction and piping of the UDDT. To limit scaling, all connections (pipes) to storage tanks should be kept as short as possible; whenever they exist, pipes should be installed with at least a 1% slope, and sharp angles (90°) should be avoided. A pipe diameter of 50 mm is sufficient for steep slopes and where maintenance is easy. Larger diameter pipes (> 75 mm) should be used elsewhere, especially for minimum slopes, and where access is difficult. To prevent odors from coming back up the pipe, an odour seal should be installed at the urine drain.

The UDDT is built such that urine is collected and drained from the front area of the toilet, while feces fall through a large chute (hole) in the back. Depending on the Collection and Storage/Treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecating. The UDDT is simple to design and build, using such materials as concrete and wire mesh or plastic. The UDDT design can be altered to suit the needs of specific populations (i.e., smaller for children, people who prefer to squat, etc.).

Pros	***Cons***
• *No need for water* • *Since faeces are dry and urine is separated, smells are minimal, though a lid should be used*	• *Its use may be difficult for some people (heavy, old and young)* • *Faeces can be accidentally deposited in the urine section and*

• *Can be built on site with locally available materials* • *Very inexpensive*	*lead to clogging and cleaning problems* • *Urine pipes/fittings can become blocked with time*

C. Urine-Diverting Flush Toilet (UDFT)

The urine-diverting flush toilet (UDFT) is similar in appearance to a cistern flush toilet except for the diversion in the bowl. The toilet bowl has two sections so that the urine can be separated from the feces. Both sitting and squatting models exist. Urine is collected in a drain in the front of the toilet and feces are collected in the back. The urine is collected without water, but a small amount of water is used to rinse the urine-collection bowl when the toilet is flushed. The urine flows into a storage tank for further use (use of urine at small or large-scale) or processing (storage, desiccation, struvite production), while the feces are flushed with water to be treated (onsite pre-treatment and treatment in septic tanks, biogas settlers, anaerobic baffled reactors; semi-decentralized treatment units, e.g. DEWATS systems; centralized sewage treatment plants).

Pros	***Cons***
• *Requires less water than a traditional flush toilet* • *No real problems with odours if used correctly* • *Looks like, and can be used almost like, a cistern flush toilet*	• *Limited availability; cannot be built or repaired locally* • *High capital and low to moderate operating costs (depending on parts and maintenance)* • *Labour-intensive maintenance* • *Requires training and acceptance to be used correctly* • *Is prone to clogging and misuse* • *Requires a constant source of water* • *Men usually require a separate urinal for optimum collection of urine*

3.4.4 Collection and Storage treatment

This section explains how the output products of a user interface can be collected, stored, and treated on-site. The functional group Collection and Storage/Treatment describes the ways of receiving, storing, and sometimes treating the products generated at the user interface. The treatment provided by these technologies is often the function of storage, and is usually passive, without requiring energy input. Products that emanate from these technologies often require subsequent treatment before use or disposal. There's quite a wide range of technologies which belong to this functional group. The technical and physical criteria for choosing appropriate collection, storage and treatment technology are as follows;

- Ground condition (Soil and strata (percolation and cost of construction)
- Groundwater level and contamination (Cross contamination (pathogens))
- Climate-Temperature (degree of treatment) and rainfall (percolation rate)

A. Twin pit for pour flush toilet

This technology consists of two alternating pits connected to a pour flush toilet. The blackwater (and in some cases greywater) is collected in the pits and allowed to slowly infiltrate into the surrounding soil. Over time, the solids are sufficiently dewatered and can be manually removed with a shovel. The twin pits for pour flush technology can be designed in various ways; the toilet can be located directly over the pits or at a distance from them. The superstructure can be permanently constructed over both pits, or it can move from side to side depending on which one is in use. No matter how the system is designed, only one pit is used at a time. While one pit is filling, the other full pit is resting.

As liquid leaches from the pit and migrates through the unsaturated soil matrix, pathogenic germs are sorbed onto the soil surface. In this way, pathogens can be removed prior to contact with groundwater. The degree of removal varies with soil type, distance travelled, moisture and other environmental factors.

The difference between this technology and the double VIP or Fossa Alterna is that it allows for water and it is not necessary to add soil or organic material to the pits. As this is a water-based (wet) technology, the full pits require a longer retention time (two years is recommended) to degrade the material before it can be excavated safely

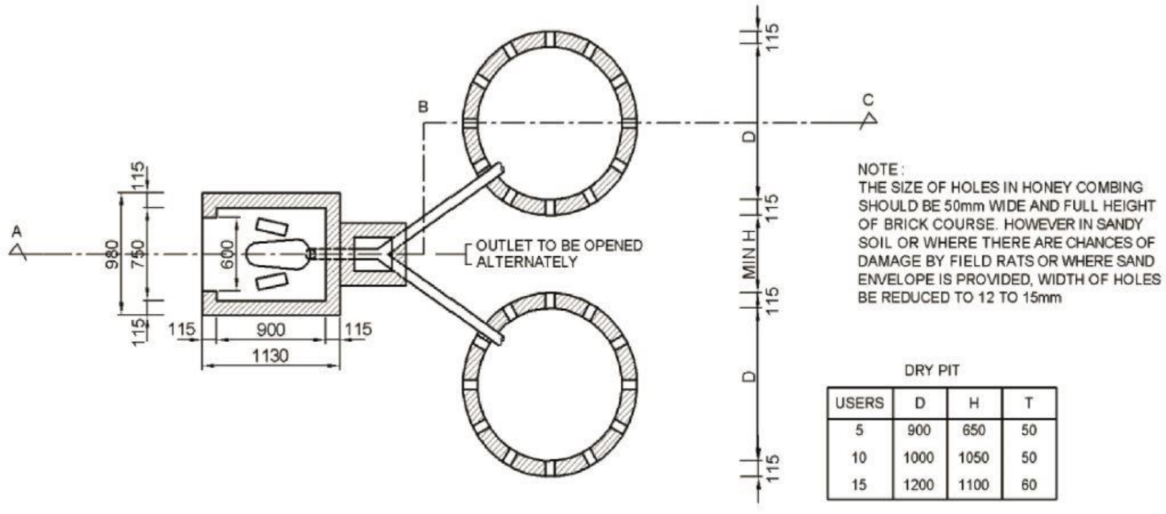

FIGURE 11 :TWIN PIT POUR FLUSH TOILET SYSTEM (SOURCE: CPHEEO, 2013)

Twin pits for pour flush are a permanent technology appropriate for areas where it is not possible to continuously build new pit latrines. If water is available, this technology is appropriate for almost every type of housing density.

Pros	*Cons*
• *Because double pits are used alternately; their life is virtually unlimited* • *Excavation of humus is easier than faecal sludge* • *Potential for the use of stored faecal material as soil conditioner* • *Flies and odours are significantly reduced (compared to pits without a water seal)* • *Can be built and repaired with locally available materials* • *Low (but variable) capital costs depending on materials; no or low operating costs if self-emptied* • *Small land area required*	• *Manual removal of pit humus is required* • *Clogging is frequent when bulky cleansing materials are used* • *Higher risk of groundwater contamination due to more leachate than with waterless system*

B. Septic Tank

A septic tank is a watertight chamber made of concrete, fibreglass, PVC or plastic, through which Blackwater and greywater flow for primary treatment. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

Liquid flows through the tank, and heavy particles sink to the bottom, while scum (mostly oil and grease) floats to the top. Over time, the solids that settle to the bottom are degraded anaerobically. However, the rate of accumulation is faster than the rate of decomposition, and the accumulated sludge and scum must be periodically removed. The effluent from the septic tank must be dispersed by using a Soak Pit or Leach Field or transported to another treatment technology via a Solids-Free Sewer.The removal of 50% of solids, 30 to 40% of BOD and a 1-log removal of E. coli can be expected in a well-designed and maintained the septic tank, although efficiencies vary greatly depending on operation and maintenance and climatic conditions.

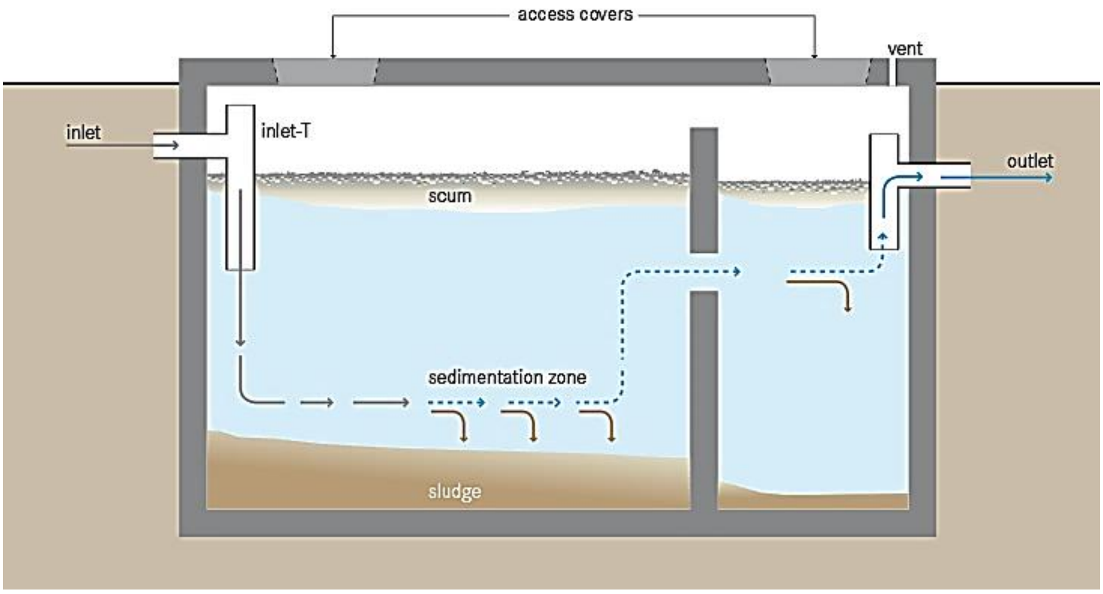

FIGURE 12: SCHEMATIC DIAGRAM OF SEPTIC TANK (SOURCE: TITLEY ET ALL, 2014)

The design of a septic tank depends on the number of users, the amount of water used per capita, the average annual temperature, the desludging frequency and the characteristics of the wastewater. The retention time should be 48 hours to achieve moderate treatment.The retention time should be 48 hours to attain moderate treatment.

No. of Users	Length (m)	Breadth (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

FIGURE 13 : RECOMMENDED SIZE OF SEPTIC TANKSUPTO 20 USEWRS (SOURCE: CPHEEO, 2013)

This technology is most commonly applied at the household level. Larger, multi-chamber septic tanks can be designed for groups of houses and public buildings (e.g., schools).

No. of Users	Length (m)	Breadth (m)	Liquid depth (cleaning interval of)	
			2 years	3 years
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
150	10.0	3.00	1.0	1.24
200	12.0	3.30	1.0	1.24
300	15.0	4.00	1.0	1.24

FIGURE 14: RECOMMENDED SIZE OF SEPTIC TANK FOR HOUSING COLONY UPTO 300 USERS (SOURCE: CPHEEO, 2013)

A septic tank is appropriate where there is a way of dispersing or transporting the effluent. If septic tanks are used in densely populated areas, onsite infiltration should not be used. Otherwise, the ground will become oversaturated and contaminated, and wastewater may rise up to the surface, posing a serious health risk. Instead, the septic tanks should be connected to some Conveyance technology, through which the effluent is transported to a subsequent Treatment or Disposal site. Even though septic tanks are watertight, it is not recommended to construct them in areas with high groundwater tables or where there is frequent flooding.

Because the septic tank must be regularly desludged, a vacuum truck should be able to access the location. Often, septic tanks are installed in the home, under the kitchen or bathroom, which makes emptying difficult.Septic tanks can be installed in every type of climate, although the efficiency will be lower in colder climates. They are not efficient at removing nutrients and pathogens.

Pros	Cons
• *Simple and robust technology* • *No electrical energy is required* • *Low operating costs* • *Long service life* • *Small land area needed (can be built underground)*	• *Low reduction in pathogens, solids and organics* • *Regular desludging must be ensured* • *Effluent and sludge require further treatment and appropriate discharge*

C. Anaerobic Baffle reactor

An anaerobic baffled reactor (ABR) is mainly a small septic tank (settling compartment) followed by a series of anaerobic tanks (at least three). Most of the solids are removed in the first and largest tank. Effluent from the first tank then flows through baffles and is forced to flow up through activated sludge in the subsequent tanks. Each chamber provides increased removal and digestion of organics: BOD may be reduced by up to 90%. Increasing the number of chambers also improves performance. (Tilley 2008)

The majority of settleable solids are removed in a sedimentation chamber in front of the actual ABR. Small-scale stand-alone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate Settler or another preceding technology (e.g., existing Septic Tanks). Designs without a settling compartment are of particular interest for (Semi-) Centralized Treatment plants that combine the ABR with other technologies, or where prefabricated, modular units are used.

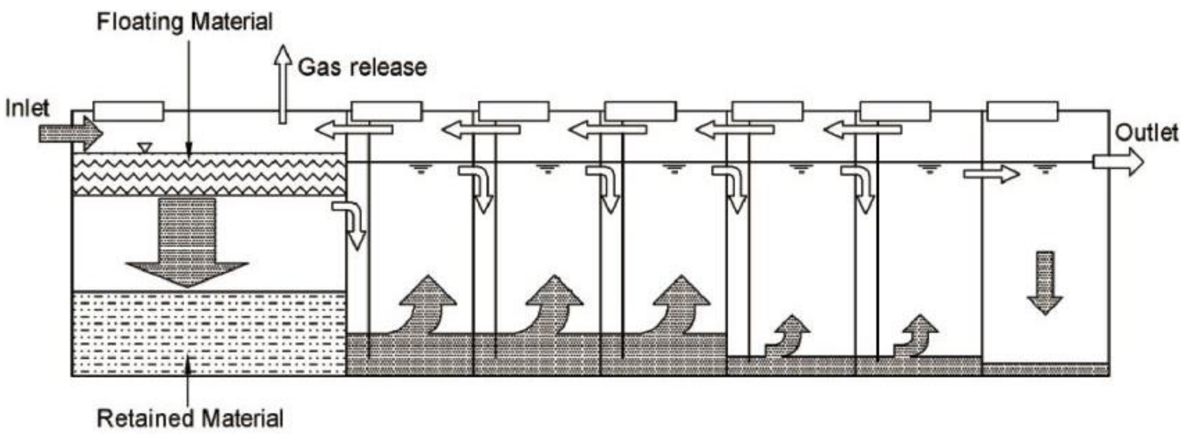

FIGURE 15: SCHEMATIC DIAGRAM OF ABR (SOURCE: CPHEEO, 2013)

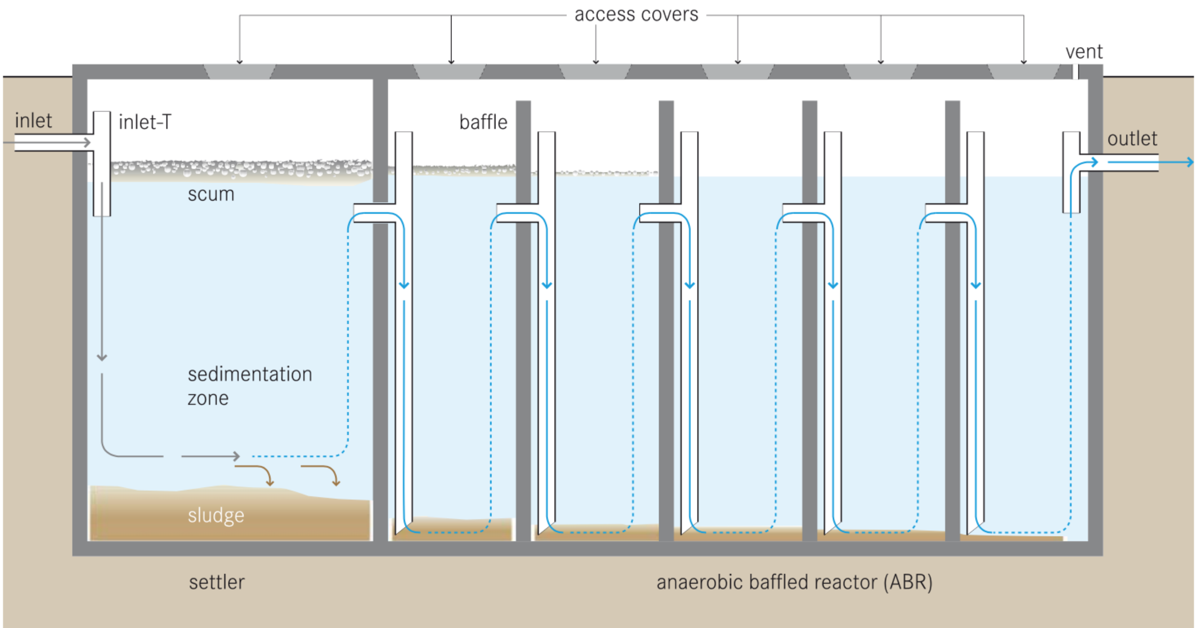

FIGURE 16: SCHEMATIC DIAGRAM OF ABR (SOURCE: EAWAG,2005)

This technology is easily adaptable and can be applied at the household level, in small neighbourhoods or even in bigger catchment areas. It is most appropriate where a relatively constant amount of blackwater and greywater is generated. A (semi-) centralised ABR is applicable when there is a pre-existing Conveyance technology, such as a Simplified Sewer.

This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. However, a vacuum truck should be able to access the location because the sludge must be regularly removed (particularly from the settling compartment).

ABRs can be installed in every type of climate, although the efficiency is lower in colder climates. They are not efficient at removing nutrients and pathogens. The effluent usually requires further treatment.

Pros	***Cons***
• *Low cost when divided among members of a housing cluster or small community* • *Minimum operation and maintenance*	• *Requires expert design and skilled construction; partial construction work by unskilled labourers* • *Requires secondary treatment and discharge*

• *Resistant to organic and hydraulic shock loads* • *Reliable and consistent treatment*	

D. Anaerobic up-flow filter

An anaerobic up-flow filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, particles are trapped, and organic matter is degraded by the active biomass that is attached to the surface of the filter material.With this technology, suspended solids and BOD removal can be as high as 90% but is typically between 50% and 80%. Nitrogen removal is limited and usually does not exceed 15% regarding total nitrogen (TN).

Pre- and primary treatment is essential to remove solids and garbage that may clog the filter. The majority of settleable solids are removed in a sedimentation chamber in front of the anaerobic filter. Small-scale stand-alone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate Settler or another preceding technology (e.g., existing Septic Tanks). Designs without a settling compartment are of particular interest for (Semi-) Centralized Treatment plants that combine the anaerobic filter with other technologies, such as the Anaerobic Baffled Reactor (ABR).

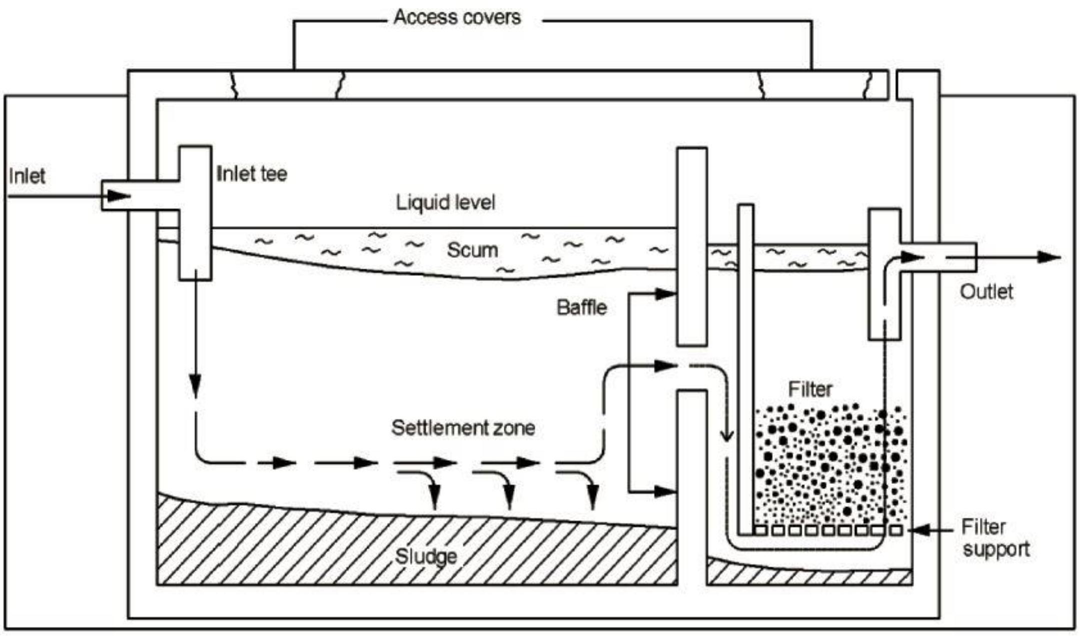

FIGURE 17: BASIC SCHEMATIC OF UP-FLOW ANAEROBIC FILTER (SOURCE: CPHEEO, 2013)

These filters are usually operated in upflow mode because there is less risk that the fixed biomass will be washed out. The water level should cover the filter media by at least 0.3 m to guarantee an even flow regime. The hydraulic retention time (HRT) is the most critical design parameter influencing filter performance. An HRT of 12 to 36 hours is recommended.

The microbial growth is retained on the stone media, making possible higher loading rates and efficient digestion. The capacity of the unit is 0.04 to 0.05 m3 per capita or 1/3 to 1/2 the liquid capacity of the septic tank it serves. BOD removals of 70% can be expected. The effluent is clear and free from odour. This unit has several advantages viz, (a) high degree of stabilization; (b) little sludge production; (c) low capital and operating cost; and (d) low loss of head in the filter (10 to 15 cm) in normal operation. (Source: CPHEEO, 2013)

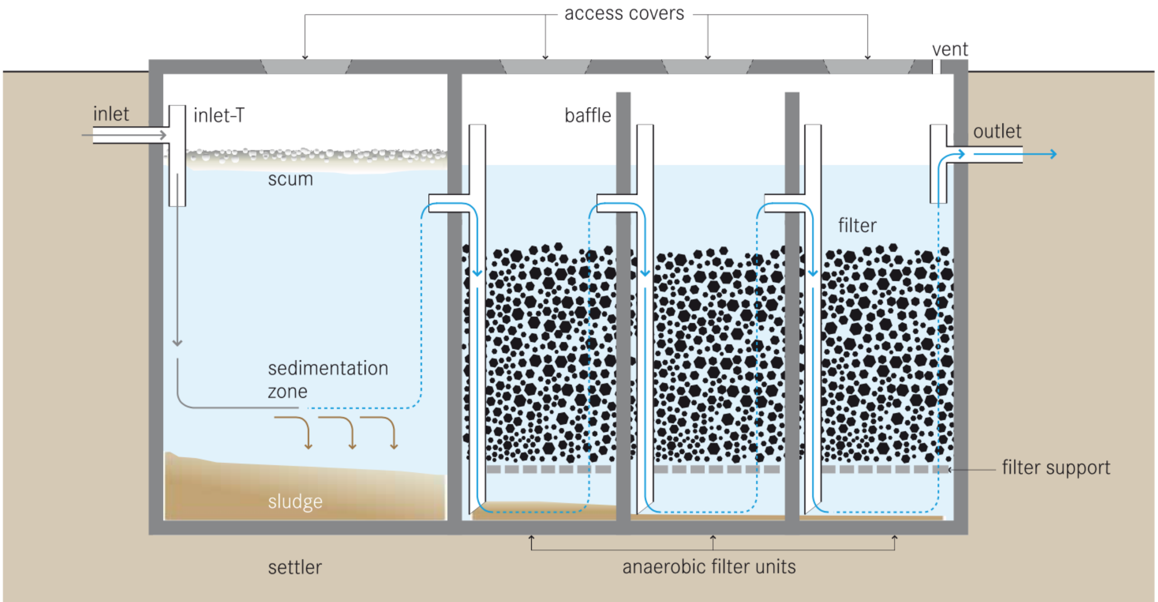

FIGURE 18:SCHEMATIC DIAGRAM OF ANAEROBIC UP FLOW FILTER (SOURCE: EAWAG,2005)

The ideal filter should have a large surface area for bacteria to grow, with pores large enough to prevent clogging. The surface area ensures increased contact between the organic matter and the attached biomass that efficiently degrades it. Ideally, the material should provide between 90 to 300 m2 of surface area per m3 of occupied reactor volume. Typical filter material sizes range from 12 to 55 mm in diameter. Materials commonly used include gravel, crushed rocks or bricks, cinder, pumice, or specially formed plastic pieces, depending on local availability.

The connection between the chambers can be designed either with vertical pipes or baffles. Accessibility to all chambers (through access ports) is necessary for maintenance. The tank should be vented to allow for controlled release of odorous and potentially harmful gases.

This technology is easily adaptable and can be applied at the household level, in small neighbourhoods or even in bigger catchment areas. It is most appropriate where a relatively constant amount of blackwater is generated. The anaerobic filter can be used for secondary treatment, to reduce the organic loading rate for a subsequent aerobic treatment step, or for polishing.

This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. Accessibility by vacuum truck is important for desludging.

Pros	***Cons***
• *No electrical energy is required* • *Low operating costs* • *Long service life* • *High reduction of BOD and solids* • *Low sludge production; the sludge is stabilized* • *Moderate area requirement (can be built underground)*	• *Requires expert design and construction* • *Low reduction of pathogens and nutrients* • *Effluent and sludge require further treatment and appropriate discharge* • *Risk of clogging, depending on pre- and primary treatment* • *Removing and cleaning the clogged filter media is cumbersome*

3.4.5 Conveyance

If waste products cannot be safely disposed of or even suitably reused on site, they have to be transported elsewhere.Conveyance describes the way in which products are moved from one process to another. Although products may need to be moved in various ways to reach the required process, the long- est and most important gap lie between on-site storage and (semi-) centralised treatment.

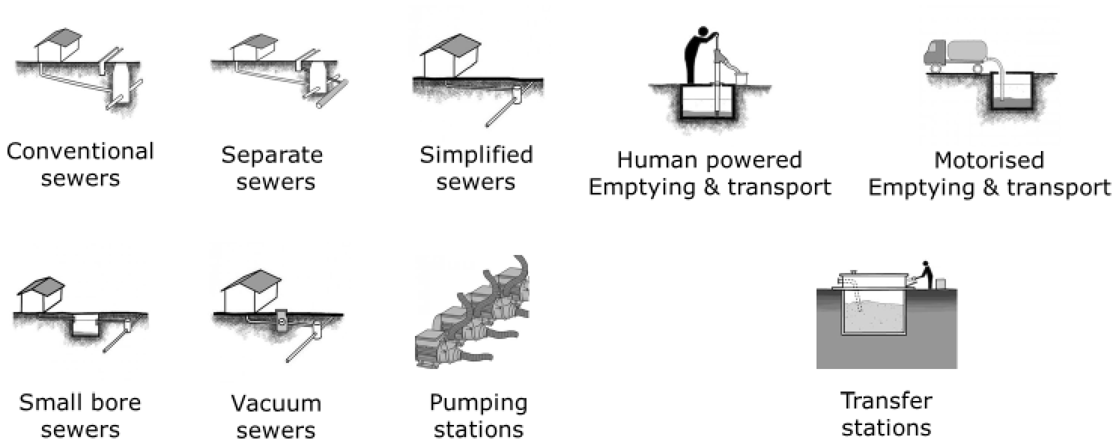

FIGURE 19: CONVEYANCE SYSTEMS IN SANITATION (SOURCE: SSWM TOOL BOX)

The technical and physical criteria for choosing appropriate conveyance technology/system are as follows;

- Water availability,
- Ground condition,
- Ground water level and contamination.

A. Human-powered emptying

Human-powered emptying and transport refer to the different ways in which people can manually empty and/or transport sludge and solid products generated in on-site sanitation facilities.

Human-powered emptying of pits, vaults and tanks can be done in one of two ways:

- using buckets and shovels, or
- using a portable, manually operated pump specially designed for sludge (e.g., the Gulper, the Rammer, the MDHP or the MAPET).

Some sanitation technologies can only be emptied manually, for example, the fossa alterna or dehydration vaults. These technologies must be emptied with a shovel because the material is solid and cannot be removed with a vacuum or a pump (e.g. the fossa alterna, aroborloo, composting toilets or UDDTs). When sludge is viscous or watery, it should be emptied with a hand pump, a MAPET or a vacuum truck, and not with buckets because of the high risk of collapsing pits, toxic fumes, and exposure to non-sanitised sludge. Manual sludge pumps are relatively new inventions and have shown promise as being low-cost, effective solutions for sludge emptying where, because of access, safety or economics, other emptying techniques are not possible.

Hand pumps can be used for liquid and, to a certain degree, viscous sludge. Domestic refuse in the pit makes emptying much more difficult. The pumping of sludge, which contains coarse solid wastes or grease, can lead to clogging of the device, and chemical additives can corrode pipes, pumps and tanks. The hand pump is a significant improvement over the bucket method and could prove to be a sustainable business opportunity in some regions. Manually operated sludge pumps are appropriate for areas that are not served or not accessible by vacuum trucks, or where vacuum truck emptying is too costly.

Manual sludge pumps like the Pooh Pump or the Gulper are relatively new inventions and have shown promise as being low-cost, effective solutions for sludge emptying where, because of access, safety or economics, other sludge emptying techniques are not possible. Sludge hand pumps work on the same concept as water hand pumps: the bottom of the pipe is lowered into the pit/tank while the operator remains at the surface. As the operator pushes and pulls the handle, the sludge is pumped up and is then discharged through the discharge spout. The sludge can be collected in barrels, bags or carts, and removed from the site with little danger to the operator. Hand pumps can be locally made with steel rods and valves in a PVC casing.

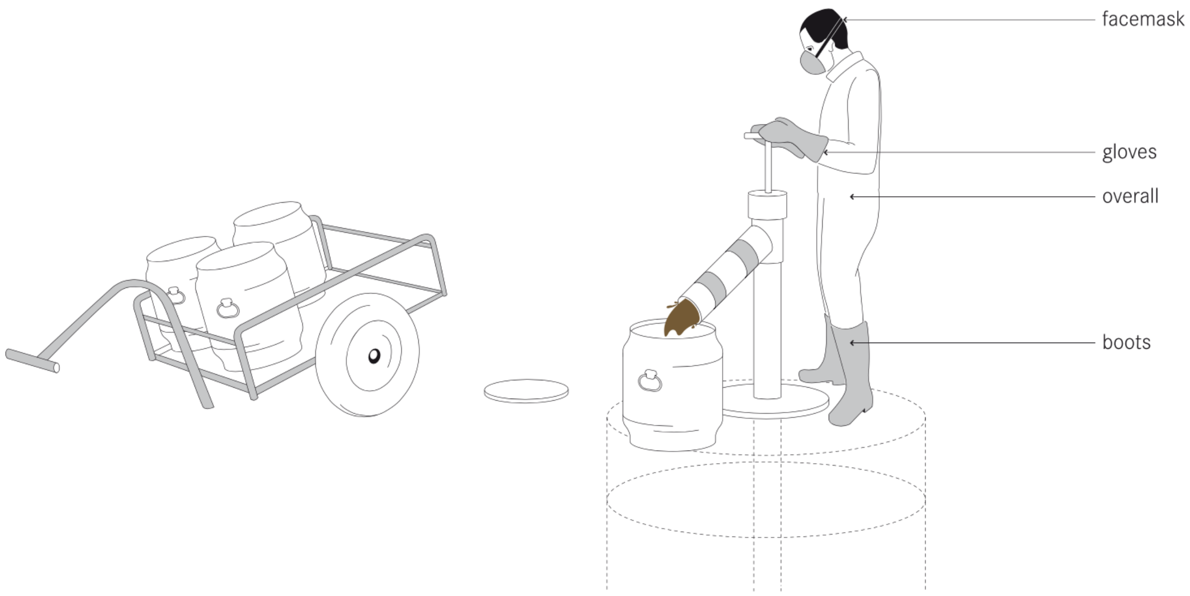

FIGURE 20 : HUMAN POWERED EMPTYING AND TRANSPORT (SOURCE: TITLEY ETALL,2014)

Pros	Cons
• *Potential for local jobs and income generation* • *Simple hand pumps can be built and repaired with locally available materials* • *Low capital costs; variable operating costs depending on transport distance* • *Provides services to areas/communities without sewers*	• *Spills can happen which could pose potential health risks and --generate offensive smells* • *Time-consuming: emptying pits out can take several hours/days depending on their size* • *Garbage in pits may block pipe* • *Some devices may require specialized repair (welding)*

B. Motorised Emptying and Transport

Motorized emptying and transport refer to a vehicle equipped with a motorised pump and a storage tank for emptying and transporting fecal sludge and urine. Humans are required to operate the pump and manoeuvre the hose, but sludge is not manually lifted or transported. A truck is fitted with a pump which is connected to a hose that is lowered down into a tank (e.g., Septic Tank) or pit, and the sludge is pumped up into the holding tank on the vehicle. This type of design is often referred to as a vacuum truck. Alternative motorised vehicles or machines have been developed for densely populated areas with limited access. Designs such as the Vacutug, Dung Beetle, Molsta or Kedoteng carry a small sludge tank and a pump and can negotiate narrow pathways.

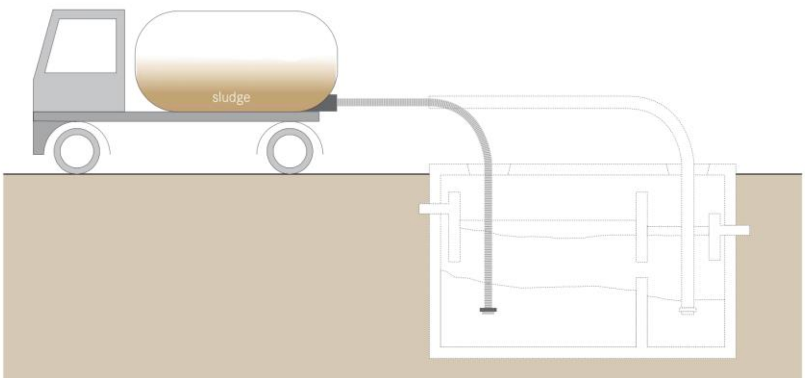

FIGURE 21 :SCHEMATIC DIAGRAM OF MOTORISED EMPTYING AND TRANSPORT (EAWAHG,2005)

Depending on the Collection and Storage technology, the sludge can be so dense that it cannot be easily pumped. In these situations, it is necessary to thin the solids with water so that they flow more easily, but this may be inefficient and costly. Garbage and sand make emptying much more difficult and clog the pipe or pump. Multiple truckloads may be required for large septic tanks.

Although large vacuum trucks cannot access areas with narrow or non-driveable roads, they remain the norm for municipalities and sanitation authorities. These trucks can rarely make trips to remote areas (e.g., in the periphery of a city) since the income generated may not offset the cost of fuel and time. Therefore, the treatment site must be within reach from the serviced areas.

Transfer Stations and adequate treatment are also crucial for service providers using the small-scale motorised equipment. Field experiences have shown that the existing designs for dense urban areas are limited regarding their emptying effectiveness and travel speed, and their ability to negotiate slopes, poor roads and very narrow lanes. Moreover, demand and market constraints have prevented them from becoming commercially viable. Under favourable circumstances, small vehicles like the Vacutug can recover the operating and maintenance costs. However, the capital costs are still too high to run a profitable business sustainably.

Both the sanitation authority and private entrepreneurs may operate vacuum trucks, although the price and level of service may vary significantly. Private operators may charge less than public ones but may only afford to do so if they do not discharge the sludge at a certified facility. Private and municipal service providers should work together to cover the whole faecal sludge management chain.

Pros	***Cons***
• *Fast, hygienic and effective sludge removal* • *Efficient transport possible with large vacuum trucks* • *Potential for local job creation and income generation* • *Provides an essential service to non-sewered areas*	• *Cannot pump thick, dried sludge (must be thinned with water or -manually removed)* • *Garbage in pits may block hose* • *Cannot empty deep pits due to limited suction lift*

	• *Very high capital costs; variable operating costs depending on use and maintenance* • *Hiring a vacuum truck may be unaffordable for poor households* • *Not all parts and materials may be locally available* • *May have difficulties with access*

C. Transfer stations

Transfer stations or underground holding tanks act as intermediate dumping points for fecal sludge when it cannot be easily transported to a (Semi-) Centralized Treatment facility. A vacuum truck is required to empty transfer stations when they are full.

Operators of human-powered or small-scale motorised sludge emptying equipment (see Human-Powered and Motorized Emptying and Transport) discharge the sludge at a local transfer station rather than illegally dumping it or travelling to discharge it at a remote treatment or disposal site. When the transfer station is full, a vacuum truck empties the contents and takes the sludge to a suitable treatment facility. Municipalities or sewerage authorities may charge for permits to dump at the transfer station to offset the costs of operating and maintaining the facility.

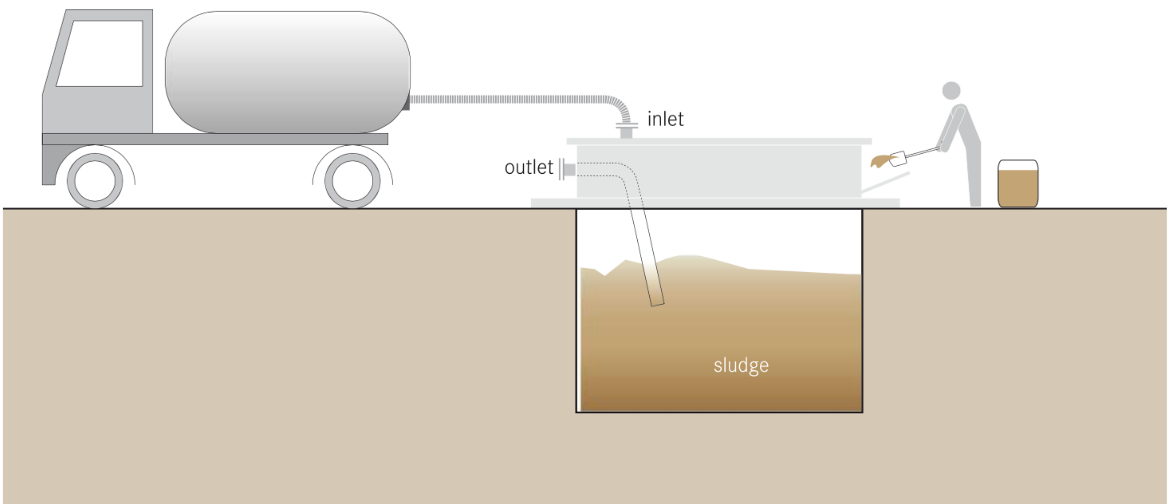

FIGURE 22:SCHEMATIC PRESENTATION OF TRANSFER STATION (SOURCE: EAWAG,2005)

In urban settings, transfer stations have to be carefully located. Otherwise, odours could become a nuisance, especially, if they are not well maintained.A transfer station consists of a parking place for vacuum trucks or sludge carts, a connection point for discharge hoses, and a storage tank. The dumping point should be built low enough to minimise spills when labourers manually empty their sludge carts.

Additionally, the transfer station should include a vent, a trash screen to remove large debris (garbage) and a washing facility for vehicles. The holding tank must be well constructed to prevent leaching and surface water infiltration. A variation is the sewer discharge station (SDS), which is like a transfer station but is directly connected to a conventional gravity sewer main. Sludge emptied into the SDS is released into the sewer main either directly or at timed intervals (e.g., by pumping) to optimise the performance of the sewer and of the wastewater treatment plant, and reduce peak loads.

Transfer stations can be equipped with digital data recording devices to track the quantity, input type and origin, as well as collect data about the individuals who dump there. In this way, the operator can collect detailed information and more accurately plan and adapt to differing loads.

The system for issuing permits or charging access fees must be carefully designed so that those who most need the service are not excluded because of high costs, while still generating enough income to sustainably operate and maintain the transfer stations.

Pros	***Cons***
• *Makes sludge transport to the treatment plant more efficient, especially where small-scale service providers with slow vehicles are involved* • *May reduce the illegal dumping of faecal sludge* • *Costs can be offset with access permits*	• *Requires expert design and construction* • *Can lead to odours if not properly maintained*

• *Potential for local job creation and income generation*	

3.4.6 Semi-centralised treatment

Compared to household-centred storage technologies, these treatment technologies are designed to accommodate increased volumes of flow and provide, in most cases, improved removal of nutrients, organics and pathogens.(Semi-) centralised treatment refers to the treatment systems which, unlike those used on-site, are larger, require a greater inflow (that can usually not be met by just one family) and often more skilled operation.

The technical and physical criteria for choosing appropriate technology for treatment are as follows;

- Availability of space and other resources (Choice of technology)
- Climate (Temperature affects rate of reactions)
- Ground condition (Flood-prone area)
- Groundwater level and contamination (Cross contamination from tanks underground)

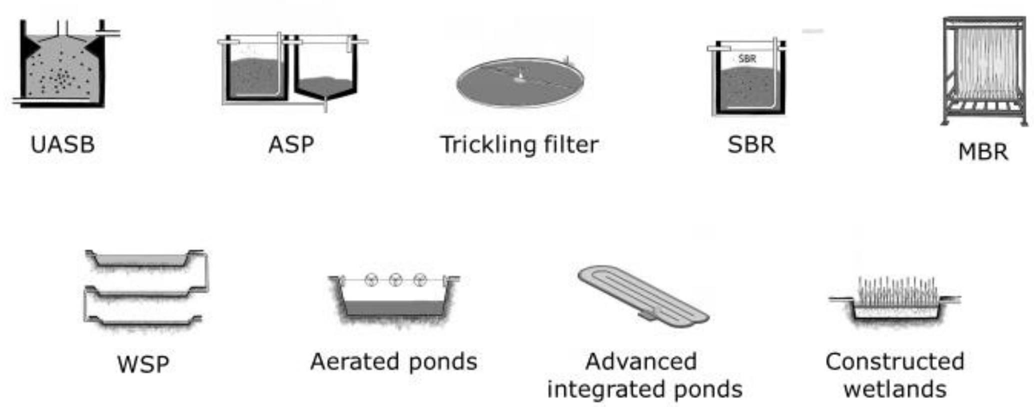

FIGURE 23 : TECHNOLOGIES FOR SEMI CENTRALISED TREATMENT (SOURCE: SSWM TOOL BOX)

A. Upflow Anaerobic Sludge Blanket Reactor (UASB)

The upflow anaerobic sludge blanket reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it.

The sludge blanket is comprised of microbial granules (1 to 3 mm in diameter), i.e., small agglomerations of microorganisms that, because of their weight, resist being washed out in the upflow. The microorganisms in the sludge layer degrade organic compounds. As a result, gases (methane and carbon dioxide) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls.

After several weeks of use, larger granules of sludge form which, in turn, act as filters for smaller particles as the effluent rises through the cushion of sludge. Because of the upflow regime, granule-forming organisms are preferentially accumulated as the others are washed out. UASB is not appropriate for small or rural communities without constant water supply or electricity. The technology is relatively simple to design and build, but developing the granulated sludge may take several months. The UASB reactor has the potential to produce higher quality effluent than Septic Tanks and can do so in a smaller reactor volume. Although it is a well-established process for large-scale industrial wastewater treatment and high organic loading rates up to 10 kg BOD/m3/d, its application to domestic sewage is still relatively new.

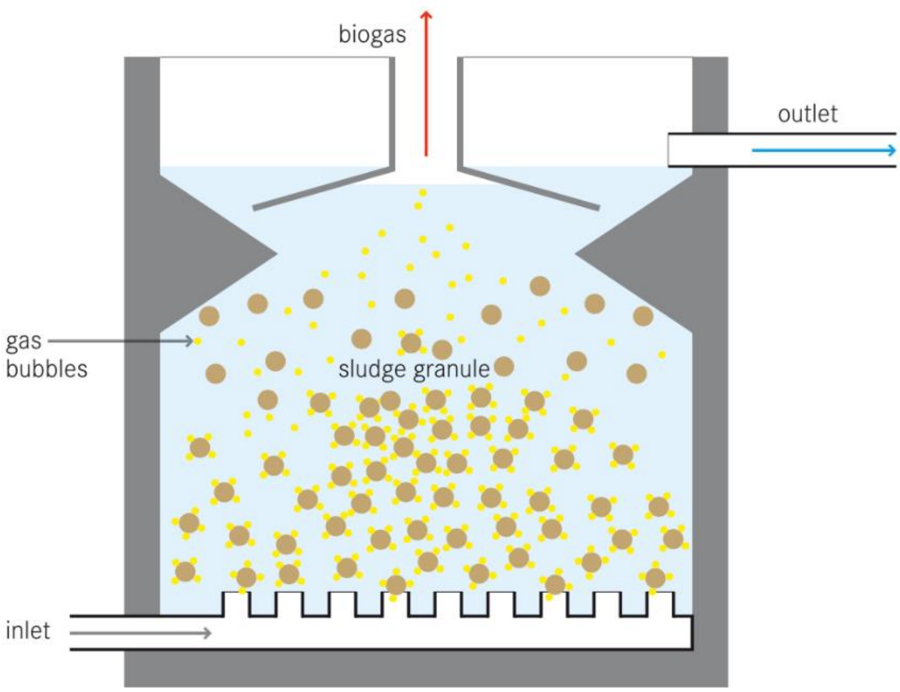

FIGURE 24: SCHEMATIC DIAGRAM OF UASB

Pros	*Cons*
• *High reduction of BOD* • *Can withstand high organic and hydraulic loading rates* • *Low sludge production (and, thus, infrequent desludging required)* • *Biogas can be used for energy (but usually first requires scrubbing)*	• *Treatment may be unstable with variable hydraulic and organic loads* • *Requires operation and maintenance by skilled personnel; difficult to maintain proper hydraulic conditions (Upflow, and settling rates must be balanced)* • *Long start-up time to work at full capacity* • *A constant source of electricity is required* • *Not all parts and materials may be locally available* • *Requires expert design and construction* • *Effluent and sludge require further treatment and/or appropriate discharge*

B. Activated Sludge Treatment

An activated sludge process refers to a multi-chamber reactor unit that makes use of highly concentrated microorganisms to degrade organics and remove nutrients from wastewater to produce high-quality effluent. To maintain aerobic conditions and to keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required.

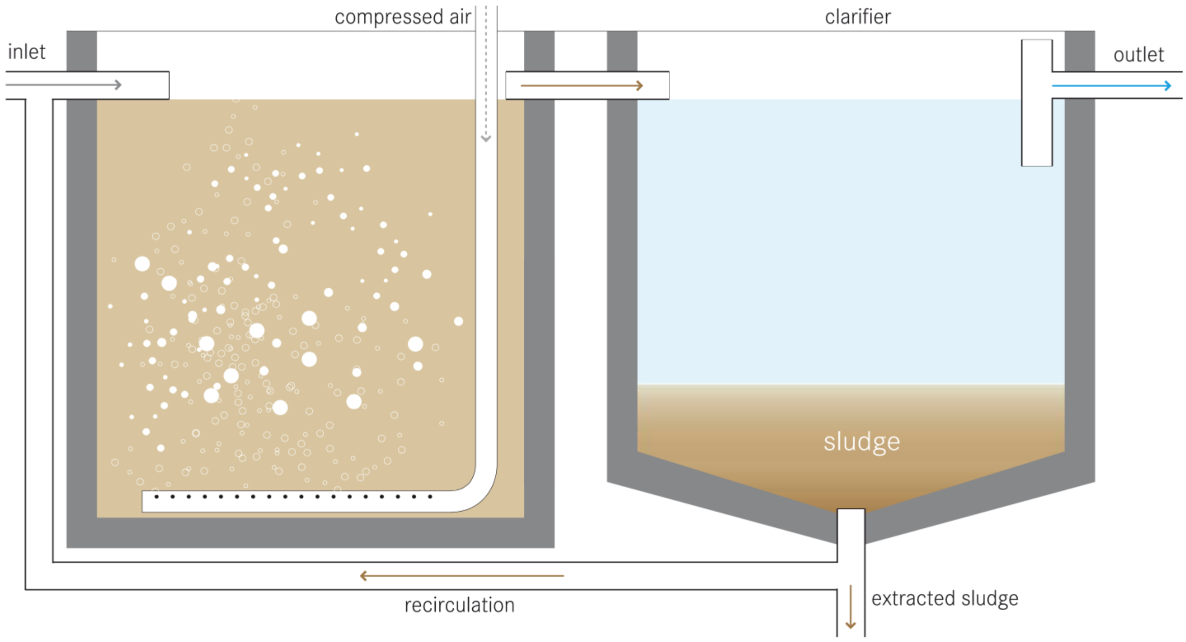

FIGURE 25 : SCHEMATIC DIAGRAM OF ACTIVATED SLUDGE TREATMENT (SOURCE: EAWAG,2005)

Different configurations of the activated sludge process can be employed to ensure that the wastewater is mixed and aerated in an aeration tank. Aeration and mixing can be provided by pumping air or oxygen into the tank or by using surface aerators. The microorganisms oxidise the organic carbon in the wastewater to produce new cells, carbon dioxide and water. Although aerobic bacteria are the most common organisms, facultative bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment, and wastewater characteristics.An activated sludge process is only appropriate for a Centralized Treatment facility with a well-trained staff, constant electricity and a highly developed management system that ensures that the facility is correctly operated and maintained.

Because of economies of scale and less fluctuating influent characteristics, this technology is more effective for the treatment of large volumes of flows.An activated sludge process is appropriate in almost every climate. However, treatment capacity is reduced in colder environments.

The flocs (agglomerations of sludge particles), which form in the aerated tank, can be removed in the secondary clarifier by gravity settling. Some of this sludge is recycled from the clarifier back to the reactor. The effluent can be discharged into a river or treated in a tertiary treatment facility if necessary for further use.

Pros	Cons
• *Resistant to organic and hydraulic shock loads* • *Can be operated at a range of organic and hydraulic loading rates* • *High reduction of BOD and pathogens (up to 99%) at after secondary treatment* • *High nutrient removal possible* • *Can be modified to meet specific discharge limits*	• *High energy consumption, a constant source of electricity is required - High capital and operating costs* • *High capital and operating costs* • *Requires operation and maintenance by skilled personnel* • *Prone to complicated chemical and microbiological problems* • *Not all parts and materials may be locally available* • *Requires expert design and construction* • *Sludge and possibly effluent require further treatment and/or appropriate discharge*

C. Trickling filter

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are [no-ecompendium]aerobically [no-ecompendium]degraded by the biofilm covering the filter material.

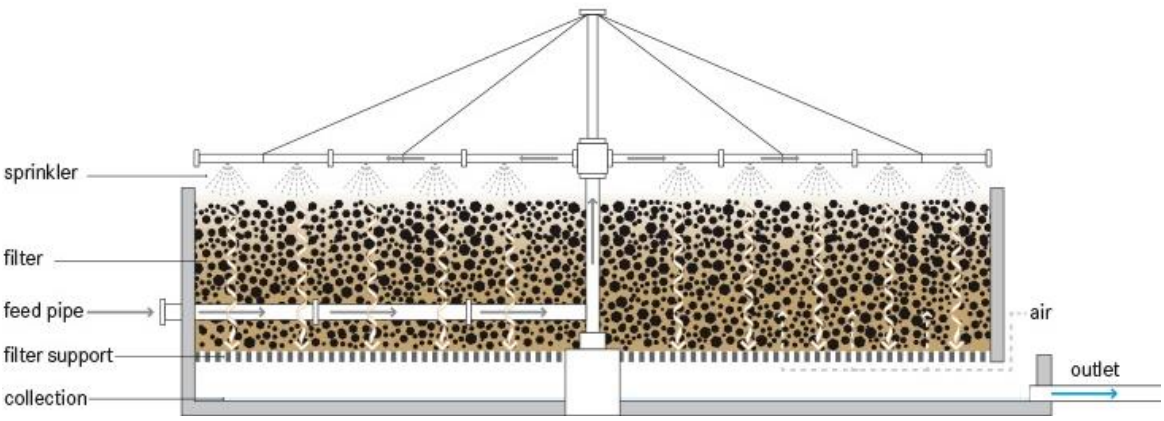

FIGURE 26:SCHEMATIC DIAGRAM OF TRICKLING FILTER (SOURCE: TILLEY ET AL. 2014)

The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass.

The incoming pre-treated wastewater is 'trickled' over the filter, e.g., with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass, and the inner layers may be anoxic or anaerobic.

This technology can only be used following primary clarification since high solids loading will cause the filter to clog. A low-energy (gravity) trickling system can be designed, but in general, a continuous supply of power and wastewater is required.

Compared to other technologies (e.g., Waste Stabilization Ponds), trickling filters are compact, although they are still best suited for peri-urban or large, rural settlements.

Pros	***Cons***
• *Can be operated at a range of organic and hydraulic loading rates* • *Efficient nitrification (ammonium oxidation)* • *Small land area required compared to constructed wetlands*	• *High capital costs* • *Requires expert design and construction, particularly, the dosing system* • *Requires operation and maintenance by skilled personnel* • *Requires a constant source of electricity and constant wastewater flow* • *Flies and odours are often problematic* • *Risk of clogging, depending on pre- and primary treatment* • *Not all parts and materials may be locally available*

D. Waste Stabilization Ponds (WSP)

Waste Stabilization Ponds (WSPs) are large, man-made water bodies. The ponds can be used individually or linked in a series of improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics.

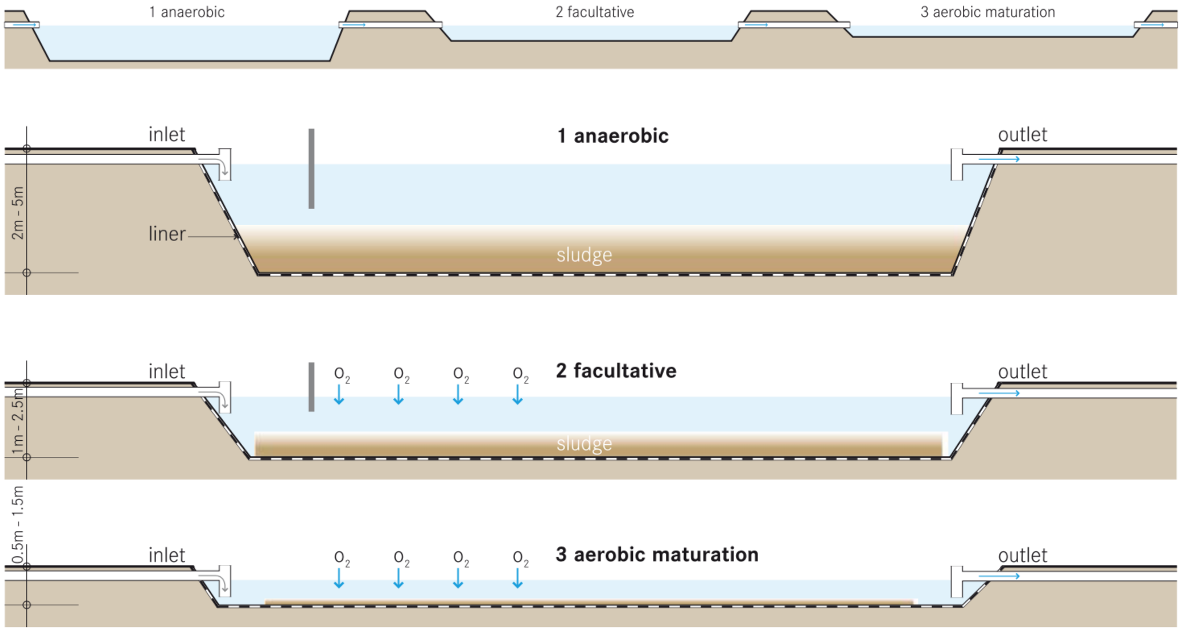

FIGURE 27: SCHEMATIC DIAGRAM OF WSP (SOURCE EAWAG,2005)

For the most effective treatment, WSPs should be linked in a series of three or more with the effluent being transferred from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep man-made lake is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the accumulated sludge (see also anaerobic digestion general). Anaerobic bacteria convert organic carbon into methane and through this process, remove up to 60% of the BOD.

In a series of WSPs, the effluent from the anaerobic pond is transferred to the facultative pond, where further BOD is removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.

Anaerobic and facultative ponds are designed for BOD removal, while aerobic ponds are designed for pathogen removal (see also pathogens and contaminants). An aerobic pond is commonly referred to as maturation, polishing, or finishing pond because it is usually the last step in a series of ponds and provides the final level of treatment. It is the shallowest of the ponds, ensuring that sunlight penetrates the full depth for photosynthesis to occur. Photosynthetic algae release oxygen into the water and at the same time consume carbon dioxide produced by the respiration of bacteria. Because photosynthesis is driven by sunlight, the dissolved oxygen levels are highest during the day and drop off at night. Dissolved oxygen is also provided by natural wind mixing.

WSPs are among the most common and efficient methods of wastewater treatment around the world. They are especially appropriate for rural communities that have large, open and unused lands, away from homes and public spaces and where it is feasible to develop a local collection system. They are not appropriate for very dense or urban areas.

Pros	***Cons***
• *Resistant to organic and hydraulic shock loads* • *High reduction of solids, BOD and pathogens* • *High nutrient removal if combined with aquaculture* • *Low operating cost* • *No electrical energy required* • *No real problems with flies or odours if designed and maintained correctly*	• *Requires large land area* • *High capital cost depending on the price of land* • *Requires expert design and construction* • *Sludge requires proper removal and treatment*

E. Aerated Pond Treatment

An aerated pond is a large, mixed aerobic reactor. Mechanical aerators provide oxygen and keep the aerobic organisms suspended and mixed with water to achieve a high rate of organic degradation.

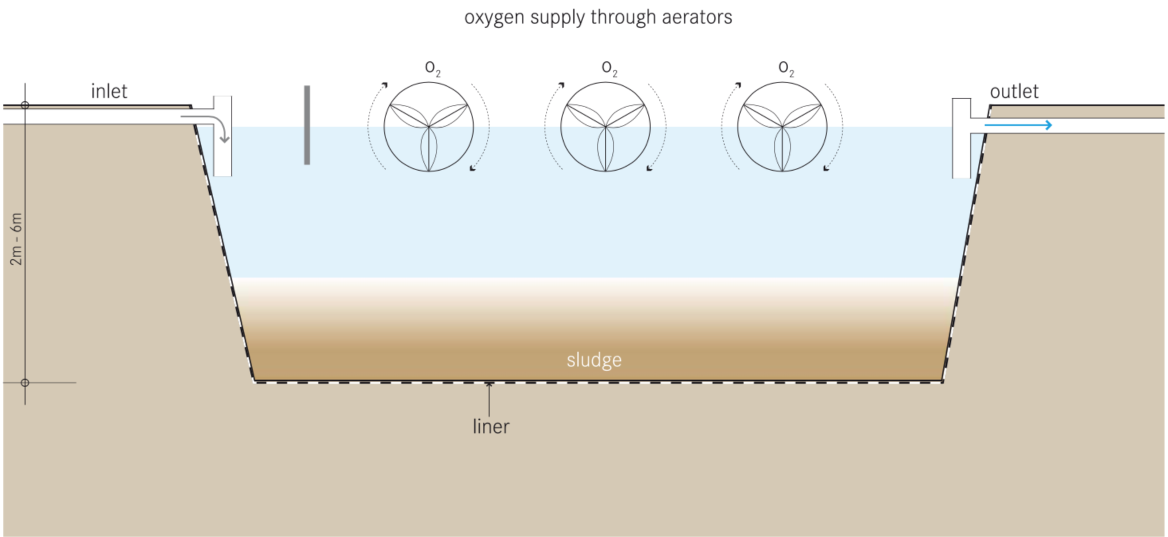

FIGURE 28:SCHEMATIC DIAGRAM OF AERATED POND (SOURCE: EAWAG,2005)

Increased mixing and aeration from the mechanical units mean that the ponds can be deeper and tolerate much higher organic loads than a maturation pond (see waste stabilization ponds). The increased aeration allows for increased degradation and increased pathogen removal. As well, because oxygen is introduced by the mechanical units and not by light-driven photosynthesis, the ponds can function in more northern climates. A mechanically aerated pond can efficiently handle concentrated influent and significantly reduce pathogen levels. It is especially important that electricity service is uninterrupted and that replacement parts are available to prevent extended downtimes that may cause the pond to turn anaerobic.

Aerated ponds can be used in both rural and peri-urban environments. They are most appropriate for regions with large areas of inexpensive land located away from homes and businesses. Aerated lagoons can function in a larger range of climates than Waste Stabilization Ponds, and the area requirement is smaller compared to a maturation pond.

Pros	*Cons*
• *Resistant to organic and hydraulic shock loads* • *High reduction of BOD and pathogens* • *No real problems with insects or odors if designed and maintained correctly*	• *Requires a large land area* • *High energy consumption, a constant source of electricity is required* • *High capital and operating costs depending on the price of land and of electricity* • *Requires operation and maintenance by skilled personnel* • *Not all parts and materials may be locally available* • *Requires expert design and construction [no-ecompendium] supervision [/no-ecompendium]* • *Sludge and possibly effluent require further treatment and/or appropriate discharge*

F. Horizontal Subsurface Flow Constructed Wetland

Horizontal subsurface flow constructed wetlands a large gravel and sand-filled basin that is planted with wetland vegetation. As wastewater flows horizontally through the basin, the filter material filters out particles and microorganisms degrade the organics.

The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach, and a base for the vegetation. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter

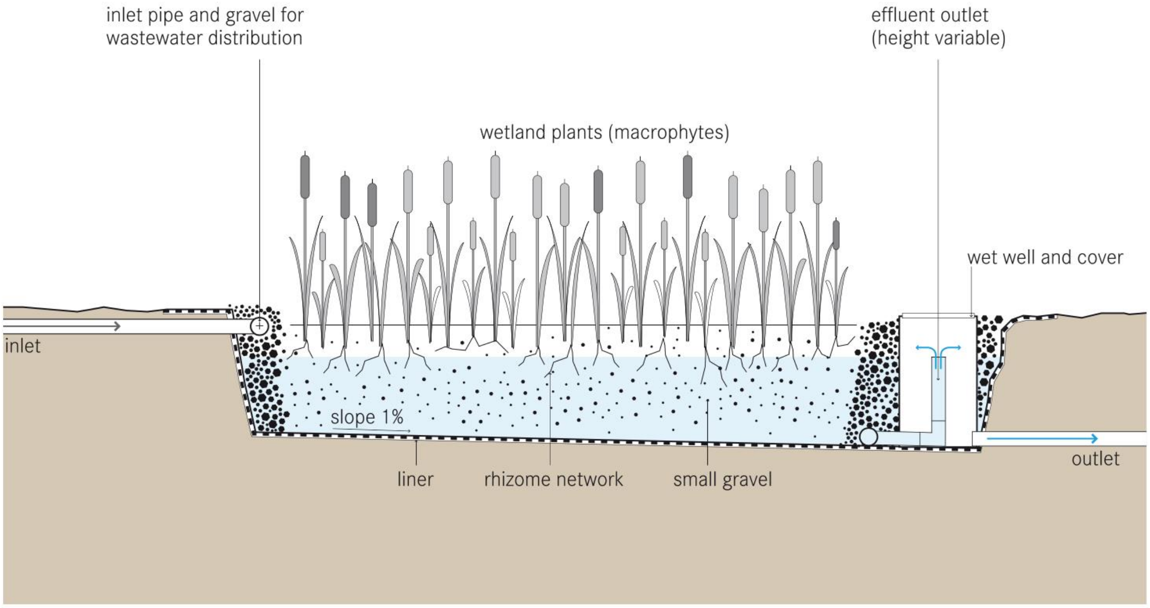

FIGURE 29:SCHEMATIC DIAGRAM OF HORIZONTAL CONSTRUCTED WETLANDS (SOURCE: EAWAG, 2005)

The design of horizontal subsurface flow constructed wetland depends on the treatment target and the amount and quality of the influent. It includes decisions about the number of parallel flow paths and compartmentation. The removal efficiency of the wetland is a function of the surface area (length multiplied by width), while the cross-sectional area (width multiplied by depth) determines the maximum possible flow. A surface area of about 5 to 10 m2 per person equivalent is required.

Pre- and primary treatment is essential to prevent clogging and ensure efficient treatment. The influent can be aerated by an inlet cascade to support oxygen-dependent processes, such as BOD reduction and nitrification. The bed should be lined with an impermeable liner (clay or geotextile) to prevent leaching. It should be wide and shallow so that the flow path of the water in contact with vegetation roots is maximized. A wide inlet zone should be used to evenly distribute the flow. A well-designed inlet that allows for even distribution is important to prevent short-circuiting. The outlet should be variable so that the water surface can be adjusted to optimize treatment performance.

Small, round, evenly sized gravel (3 to 32 mm in diameter) is most commonly used to fill the bed to a depth of 0.5 to 1 m. To limit clogging, the gravel should be clean and free of fines. Sand is also acceptable but is more prone to clogging than gravel. In recent years, alternative filter materials, such as PET, have been successfully used. The water level in the wetland is maintained at 5 to 15 cm below the surface to ensure subsurface flow. Any native plant with deep, wide roots that can grow in the wet, nutrient-rich environment is appropriate. Phragmites australis (reed) is a common choice because it forms horizontal rhizomes that penetrate the entire filter depth.

The horizontal subsurface flow constructed wetland is a good option where land is cheap and available. Depending on the volume of the water and the corresponding area requirement of the wetland, it can be appropriate for small sections of urban areas, as well as for peri-urban and rural communities. It can also be designed for single households.

Pros	***Cons***
• *High reduction of BOD suspended solids and pathogens* • *Does do not have the mosquito problems of the Free-Water Surface Constructed Wetland* • *No electrical energy is required* • *Low operating costs*	• *Requires a large land area* • *Little nutrient removal* • *Risk of clogging, depending on pre- and primary treatment* • *Long start-up time to work at full capacity* • *Requires expert design and construction supervision*

G. Vertical Flow Constructed Wetland

A vertical flow constructed wetland is a planted filter bed that is drained at the bottom. Wastewater is poured or dosed onto the surface from above using a mechanical dosing system. The water flows vertically down through the filter matrix to the bottom of the basin where it is collected in a drainage pipe. The important difference between a vertical and horizontal wetland is not simply the direction of the flow path, but rather the aerobic conditions.

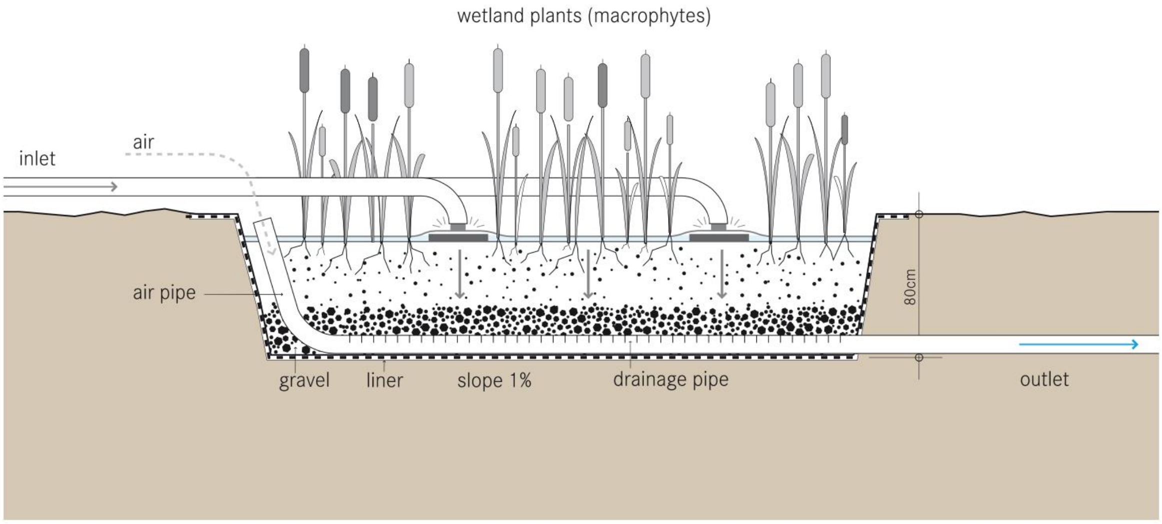

FIGURE 30:SCHEMATIC DIAGRAM OF VERTICAL CONSTRUCTED WETLAND (SOURCE: EAWAG, 2005)

By intermittently dosing the wetland (4 to 10 times a day), the filter goes through stages of being saturated and unsaturated, and, accordingly, different phases of aerobic and anaerobic conditions. During a flush phase, the wastewater percolates down through the unsaturated bed. As the bed drains, air is drawn into it and the oxygen has time to diffuse through the porous media. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach and a base for the vegetation. The top layer is planted and the vegetation is allowed to develop deep, wide roots, which permeate the filter media. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics.

However, the primary role of vegetation is to maintain permeability in the filter and provide habitat for microorganisms. Nutrients and organic material are absorbed and degraded by the dense microbial populations. By forcing the organisms into a starvation phase between dosing phases, excessive biomass. The vertical flow constructed wetland is a good treatment for communities that have primary treatment (e.g., Septic Tanks) but are looking to achieve a higher quality effluent.

Because of the mechanical dosing system, this technology is most appropriate where trained maintenance staff, constant power supply, and spare parts are available. Since vertical flow constructed wetlands are able to nitrify, they can be an appropriate technology in the treatment process for wastewater with high ammonium concentrations. Vertical flow constructed wetlands are best suited to warm climates but can be designed to tolerate some freezing and periods of low biological activity. growth can be decreased and porosity increased.

Pros	***Cons***
• *High reduction of BOD, suspended solids and pathogens* • *Ability to nitrify due to good oxygen transfer* • *Does not have the mosquito problems of the Free-Water Surface or Horizontal Wetland* • *Less clogging than in a Horizontal Subsurface Flow Constructed Wetland* • *Requires less space than a Free-Water Surface or Horizontal Flow Wetland* • *Low operating costs*	• *Requires expert design and construction, particularly, the dosing system* • *Requires more frequent maintenance than a Horizontal Subsurface Flow Constructed Wetland* • *A constant source of electrical energy may be required* • *Long start-up time to work at full capacity* • *Not all parts and materials may be locally available*

3.4.7 Use or Disposal

Use and/or disposal refers to the ways in which products are ultimately returned to the soil, either as harmless substances or useful resources. Furthermore, products can also be re-introduced into the system as new products. A typical example is the use of partially treated greywater used for toilet flushing.

It can be done in following ways

Agriculture: The dried fecal matter is used as soil conditioner in agriculture. The soil conditioner improves the texture of the soil and helps to increase the moisture retention capacity of the soil. The sterile urine after disinfection is used as fertilizer in the agriculture. Urine as a liquid fertilizer contains high amount of nitrates and phosphates which can reduce the consumption of inorganic fertilizers.

Aquaculture: The term aquaculture refers to the controlled cultivation of aquatic plants and animals by making use of various types of wastewater as a source for nutrients and/or warm temperatures for plants and fish to grow. Fish can be grown in ponds that receive effluent or sludge where they can feed on algae and other organisms that grow in the nutrient-rich water. The fish, thereby, remove the nutrients from the wastewater and are eventually harvested for consumption. You can also read the description of plant aquacultures.

Recharge or disposal: This can be done is several ways. The most common way is to have a leach field of soak pit. However, there are other ways like soil aquifer treatment, short crop rotation which are popular in other countries and utilize the treated wastewater in most sophisticated way.

Energy products from sludge: The sludge can be processed to make solid or liquid fuel depending on treatment process used. The biogas generated through anaerobic digestion can be directly used as liquid fuel or alternatively converted into electricity. Dried sludge can also be used as solid fuel in furnaces or brick kiln due to its high calorific value.

3.5 Sanitation Value chain

It is imperative to look at the sanitation market as a value chain where value can be added at each stage. It will, therefore, develop technologies, systems and services which accomplish this at each section of the chain, as shown in the picture below;

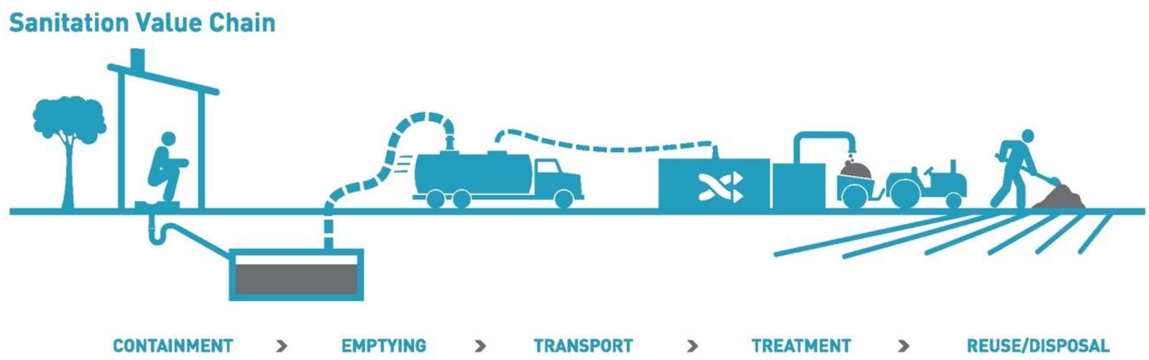

FIGURE 31:SANITATION VALUE CHAIN (SOURCE: BMGF,N,Y)

All technologies, ideas and knowledge have been delineated with regard the Sanitation Value Chain. The links in this chain are:

Containment – any type of latrine or tank which is used to capture and store fecal sludge;

Emptying – any type of device used to empty storage devices;

Transport – physically moving the sludge from the storage device to the treatment plant;

Treatment – treating sludge so that it is safe to dispose of or, ideally, reused;

Reuse – regaining value from the sludge by making it's nutritional or calorific content available for agriculture, energy, etc.

The Sanitation Value Chain provides a useful method to divide different technologies into their useful functions and identify the type of partners that may be required. For instance, technology in the 'capture and storage' stage will require partners with construction expertise; whereas a technology in the 'treatment' phase will require partners with bio-chemical processing expertise.

3.6 Further Readings

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4 Design of Sanitation Systems

4.1 Objectives

- To understand Identified factors that affect the design and selection of sanitation technologies.
- To get good exposure to benefits and drawbacks of decentralized systems.
- To understand Identified need of systematic planning, framework of strategic planning of urban sanitation solutions.
- To understand Identified the right approach towards drafting a city sanitation plan.

4.2 Duration

60 min

4.3 Key facts

I. What should be planning of sanitation systems include?

Planning and implementation of sanitation projects should be based on sanitation system functional requirements rather than technologies. This shall improve the sustainability of sanitation systems. Sanitation systems can be regarded as sustainable if they protect and promote human health, do not contribute to environmental degradation or depletion of the resource base, and are technically and institutionally appropriate, economically viable and socially acceptable – furthermore, they also have to remain functioning over time.

II. How do we differentiate between urban planning and management?

Urban planning is the discipline of land use planning exploring several aspects of the built and social environments of municipalities and communities. Civic functions addressed in planning are broad, encompassing land use, transportation, housing, open space and recreation, public and human services, and conservation of environmental and heritage resources. (Lüthi et al., 2008a, p. 75)

Urban management is the continuous activity of mobilising and applying diverse resources in a coordinated manner to plan, programme, build, operate, and maintain public services and the environment to achieve the sustainable development objectives of city governments. Good urban management is closely linked to good urban governance, which can be defined as an efficient and effective response to urban problems by accountable local governments working in partnership with civil societies.

Urban planning that strategically antic- ipates and plans ahead, and urban man-agement that coordinates and manages urban transformation are the keystones of good urban governance. (Lüthi et al., 2008a, p. 75)

III. How will you define "Good governance"?

"Good governance is, inter alia, participatory, transparent and accountable. It is also effective, equitable and promotes the rule of law." (UNDP, 1997, p. 3)

"Good governance implies inclusion and representation of all groups in the urban society, including accountability, integrity and transparency of local government actions in defining and pursuing shared goals." (The World Bank, 2000, p. 10)

"Good urban governance can be defined as an efficient and effective response to urban problems by accountable local governments working in partnership with civil societies." UNCHS (1999)

IV. What are the main planning approaches?

Most planning approaches adopted in the past can be assigned to one of the three models described by McGranahan et al. (2001): The planning model, the market model based on the economic principles of demand and supply, and the collective action model.

- Supply-driven approach: bureaucratic organization attempting to apply rationality of a higher order to people's behavior.
- Market approach: market process- es relying on the 'invisible hand' of the market to transform individual preferences into aggregate outcomes.
- Collective action approach: voluntary association, where group decisions are collectively negotiated.

V. What technical and physical criteria are required when designing a sanitation system?

Space is a key criterion in the selection of both storage and treatment technologies and availability of water may influence the choice of off-site or rather on-site technologies

4.4 Learning Notes

4.4.1 Systematic Planning of Sanitation

Planning in its most general sense is about decision making and can be defined as "a process of making choices among the options that appear open for the future and then securing their implementation" (Roberts, 1974).

Over the last several decades, effective strategies have been developed to provide affordable sanitation services to the urban populations of developing countries. Rapid implementation of these strategies is, however, urgently need- ed in developing countries to close the growing gap between those with access to sanitation services and those without. Poor planning, design and operation, as well as inadequate maintenance mean that the facilities in place are often also qualitatively poor. Most sanitation master plans have paid insufficient attention to financial and institutional constraints and have tended to ignore what sanitation users actually want and are willing and able to pay.

	Planning model	**Market model**	**Collective action model**
Overriding principle	Bureaucratic organisation	Market processes	Community action
Decision-makers	Administrators, engineers, public officials	Individuals, households, vendors, enterprises	Leaders and members of grass-root organisations
Criteria for decisions	Policy and conformity to a plan	Efficiency, maximisation of profit or utility	Interests of members and visions of leader
Guides for behaviour	Targets, regulations and technical standards	Price signals, incorporating taxes and subsidies	Agreements and accepted goals
Sanctions	Government authority backed by coercion	Financial loss	Social pressure
Mode of operation	Top-down	Individualistic	Bottom-up

FIGURE 32:COMPARISON OF THREE DIFFERENT PLANNING MODELS (MCGRANAHAN ET AL., 2001).

4.4.2 Strategic Sanitation Approach

Strategic planning is an integrated, comprehensive approach that emphasizes not only the technical and economic aspects but also the challenges of institutional capacity and public participation. Central to the approach is the comprehensive systems analysis of the strategic options selected. The strategic planning process differs from sectoral planning in its global approach and from the classical master planning approach, in its methodology and its orientation – it is more flexible and responsive, less static and not overly complicated.

The urgency of the urban sanitation crisis and emergence of some successes in the water and sanitation sector have prompted the United Nations Development Program(UNDP)-World Bank Water and Sanitation Program to develop an approach to address future urban sanitation problems.

The strategic sanitation approach promoted by the Water and Sanitation Program since the early 1990s is meant to be flexible and adaptive to allow incorporation of lessons from new experiences and innovations in the sanitation sector worldwide. It was the first planning methodology to break with the tradition- al top-down, supply-driven thinking. Its innovative elements comprise:

- A more extensive choice of technology options.
- Recognition and analysis of consumers' willingness to pay for perceived benefits.
- Methods of matching service levels to affordability to achieve optimum coverage with economic efficiency.
- Innovative financing mechanisms and institutional frameworks, including unbundling of investments into affordable parts.
- Capacity-building initiatives to allow all levels of government and other stakeholders implement responsive and sustainable programs.

4.4.3 Framework of Strategic Planning

Strategic planning of sanitation is done in three steps

Step 1: Where are we now? – Grounding plans for current situations.

The identification of the baseline or boundary condition assesses the conditions for the project. Subjects to be addressed can include geographic limits, socio-economic patterns, cultural habits, system financing, legal frameworks, natural environmental conditions or the present infrastructure. The proposed sanitation system needs to be defined with these critical questions: where does the system begin and end? Does it include all wastewater fractions of the household?The first step necessarily comprises;

- Collection of baseline data and to assess the service level benchmarking.
- Identifying the systems and the water and nutrient flow in the local systems. If the need is to have a bigger system can be classified into smaller system for better and deeper analysis of the current situation.
- While doing so identifying the actual problems faced by the population, the root cause of the problems.

STEP 2: Where do we want to go? – Identifying objectives

After identifying the problems and their causes, one needs to set the aims and objectives of the whole process.

- The targets should include the needs of all the categories of the demography of the city, especially the urban poor.
- The targets set should be environmentally acceptable. Example: If the treated wastewater is disposed into surface water bodies, the nitrates and phosphates should be monitored. Regarding quantity, the adequate amount of treated wastewater ought to be put back into the natural water system to sustain its ecological services.
- Sustainable systems should be identified. While doing so, importance should be given to the operation and maintenance cost, since this cost has to be borne by the ULB.

STEP 3: How do we get from here to there? – Moving towards objectives

Once the targets are set, methodology to implement the strategies should be identified. The ultimate focus of the process should be to improve the sanitation services without burdening the ULB too much.

The plans should be flexible and adaptable to accommodate any change in the ground situation. If the need is, the plans should also be revised according to the developments happening in the system.

There is no one best planning method. A review of existing models suggests that no single approach to sanitation provision can address all aspects of the problem, irrespective of whether it is based on planning, the market, local or collective initiatives. The question is not “which is the best model”, but rather how to combine planning, market-oriented aspects and local initiatives into strategies making best use of all three

4.4.4 Designing of sanitation system

A sanitation system has to manage all the waste products generated. Waste products should be processed from "from cradle to grave". Appropriate systems and technologies have to be identified based on technical, social, economic, and resource aspects. The most site-specific system option has to be selected on a case-to-case basis.

Designing focuses only on the actual selection of the most appropriate system and technologies based on local needs, demands and habits. Furthermore, the sanitation system should be designed using the existing infrastructure.

A system is a set of technologies, each processing the products until they are ultimately disposed of. In other words, processing all the waste products "from the cradle to the grave" should be considered. Here, eight different treatment systems are defined, each of which contains multiple technologies that can be linked to form an efficient system.

Though the system templates (i.e. groups of processes and products) are predefined, the exact system and favored technologies still have to be selected from among the options provided. The choice is context-specific and should be made by the local environment, culture and resources. Despite the different technology options available, a comprehensive study of the specific situation is necessary before making the final decision. (Tilley 2008).

The steps required when selecting a site-specific system:

- Identify the types of products generated or those the stakeholders would be willing to produce (e.g. separated urine).
- Select the most feasible systems, i. e. the systems that include the appropriate products and number of process steps the stakeholders would be willing to operate and maintain.
- Select the specific technologies for each product for each process in each of the systems identified.
- Select one of the systems based on the social, economic and resource aspects of the associated technologies.

An ideal system should manage all the waste products which are generated in the built environment. For identifying an appropriate system, local needs, demands and habits are to be assessed

Although greywater and stormwater management forms an essential part of sanitation, this document is primarily concerned with systems and technologies related directly to excreta. A more detailed and holistic approach is described in the Compendium compiled by Tilley (2008). Refer to Morel and Di- energy (2006) for a more comprehensive summary dedicated to greywater technologies.

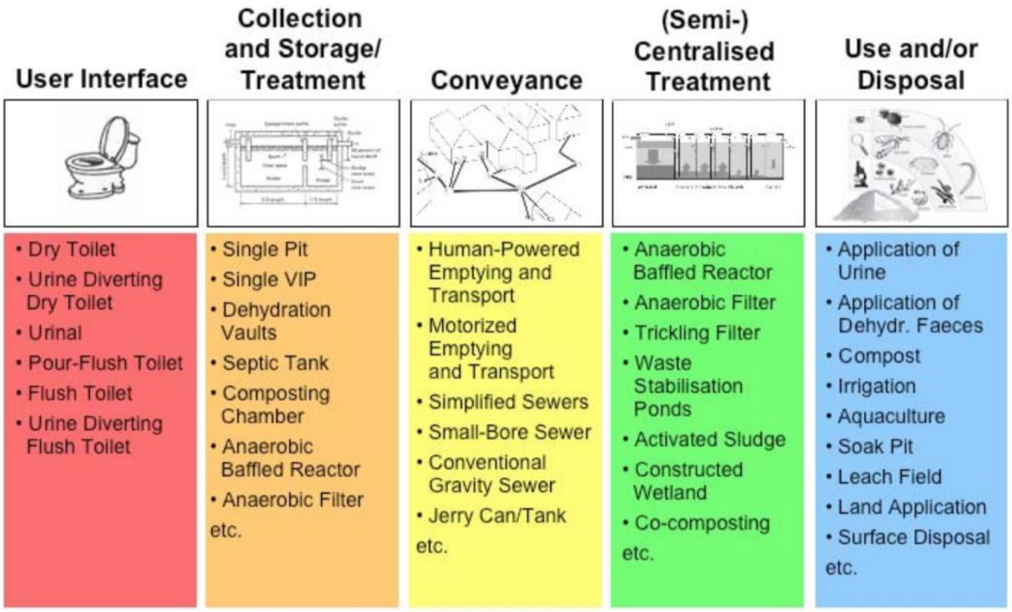

FIGURE 33:MAIN PROCESSING SYSTEMS OF SANITATION (SOURCE: TITLEY,2008)

4.4.5 Decentralized Systems

The conventional, centralized wastewater management concept, consisting of a water-borne wastewater collection system leading to a central treatment plant, has been successfully applied over many decades in densely populated areas of industrialized countries and has significantly contributed to improving the hygienic conditions in these areas. However, the appropriateness of this model in the context of cities in developing countries must be questioned, given their urgent need for affordable and sustainable infrastructure.

Limitations of centralized systems

Aside from its proven benefits, the centralized wastewater management system is nothing more than a transport system for human excreta and industrial waste to a central discharge point or a treatment system. By using valuable drinking water as the transport medium, this system is wasteful of water and nutrients that could otherwise be easily treated and reused. A centralized wastewater management system reduces wastewater reuse opportunities and increases the risk to humans and the environment in the event of system failure. (Eawag 2007)

In the past, conventional thinking favored centralized systems since they are easier to plan and manage than decentralized treatment units. This belief is partly true if municipal administration systems are centralized. However, experience reveals that centralized systems have been particularly poor at reaching peri-urban areas and informal settlements (Parkinson and Taylor 2003). Centralized treatment systems are usually much more complicated and require professional and skilled operators. Operation and maintenance of centralized systems must be financed by the local government often unable or unwilling to guarantee regular operation.

The decentralised wastewater management approach:

- *Increases responsiveness to local demands and needs and, hence, enhances willingness of communities to pay for improved services (Parkinson and Taylor 2003).*
- *Broadens the technology options permitting tailoring the solutions to the prevailing conditions.*
- *Minimises the freshwater requirements for waste transport.*
- *Reduces the risks associated with system failure.*
- *Allows segregation of different wastewater fractions (greywater, blackwater, stormwater) at source.*
- *Increases local wastewater reuse opportunities.*
- *Allows incremental development and investment in the community wastewater system.*

According to Black (1994), engineering solutions based on centralized systems built and maintained by subsidized public agencies are inappropriate to the extraordinary pace and character of the urbanization process in the developing world.

Potential of the decentralized sanitation approach

At the international level, increased emphasis has been placed on a more holistic approach to waste disposal, stressing the benefits of reducing the strength or quantity of waste at source and, whenever possible, treating, recycling or reusing it close to its generation point (Schertenleib and Morel 2003). It is obvious that a decentralized wastewater management approach is better suited to solve sanitation problems as close to their source as possible. Decentralized systems appear to offer some potential advantages.

Constraints of Decentralized systems

Even where policy-makers accept the decentralized approach, they may lack the capacity to plan, design, implement, and operate decentralized systems, thus leading to severe constrains in ensuring its widespread implementation.

Most developing countries have no suitable institutional arrangements for managing decentralized systems and lack an appropriate policy framework to promote a decentralized approach. There is a risk that decentralisation will lead to fragmentation and failure to address overall problems adequately. Without technical assistance and other capacity building measures, problems of institutional capacity existing under a centralised operation are simply passed on to the new structures.

Without a formal institutional framework within which decentralized systems can be located, efforts to introduce decentralized management are likely to remain fragmented and unreliable. Decentralisation therefore requires greater coordination between the government, private sector and civil society. Decentralized systems must be compatible with the knowledge and skills available at local level, as even the simplest technologies often fail in practice for lack of attention to operational and maintenance requirements.

4.5 Further Readings

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5 Non-Technical Aspects

5.1 Objectives

- To identify the stakeholders involved in sanitation planning and their segmentation for utilizing their strengths
- To understand the importance of having a conducive enabling environment in the sanitation planning process
- To understand importance of institutional arrangements, political, economic and financial aspects in sanitation planning.

5.2 Duration

60 min

5.3 Key facts

I. Which stakeholders should be considered when planning environmental sanitation?

To adopt integrated planning approaches like the HCES, it is essential to identify all key stakeholders as well as secondary stakeholders within a given project framework. These can be all or some of the following:

TABLE 5: LIST OF STAKEHOLDERS IN FSM PLANNING PROCESS

Key stakeholders	Secondary stakeholders
• Community • Municipality • utility • sector NGOs • CBOs	• Other NGOs • Private sector • sector specialists/experts • universities • donors • other funding institutions

II. What do you mean by an enabling environment?

An Enabling Environment is a set of interrelated sector functions that impact the capacity of governments and public and private partners to engage in the WASH service delivery development processes in a sustained and efficient manner.

5.4 Learning Notes

5.4.1 Stakeholders

"Stakeholders are people, groups, or institutions which are likely to be affected by a proposed intervention (either negatively or positively), or those which can affect the outcome of the intervention" (RIETBERGEN-McCRACKEN et al. 1998). Stakeholders are those persons or organisations who directly or indirectly are affected by – or can affect – the environmental sanitation situation within a particular community or area. A distinction is made between process leaders, primary stakeholders, and secondary stakeholders. Participatory planning requires the involvement of concerned stakeholders. This includes identifying public concerns and values and developing a broad consensus on planned initiatives. It is also about utilising the vast amount of information and knowledge that stakeholders hold to find workable, efficient and sustainable solutions (CAP-NET 2008).

The identification criteria of stakeholders for Sustainable Sanitation and Water Management will have to answer the following questions:

- Who are the people/groups/institutions that are interested in the intended initiative? What is their role (polluter, regulator, direct consumer, indirect consumer, etc.)?
- Who are the potential beneficiaries?
- Who might be adversely impacted? Who has constraints about the initiative?
- Who may impact the initiative? Who has the power to influence?

To adopt integrated planning approaches, it is essential to identify all key stakeholders as well as secondary stakeholders within a given project framework.

5.4.2 Enabling Environment

Progress in providing access to sanitation in low- and middle-income countries has been slow. In many countries, demographic growth outweighs any progress that has been made, despite the billions of dollars poured into the WASH sector. For example, much infrastructure is not adapted to its specific context and/or is not sustainable, thus, failing to serve the population properly in the long run. The conventional approach in sanitation provision in these areas has clearly failed to reach large (and often most) parts of the respective populations. Major barriers to progress in sanitation coverage lie within the institutions, policies and socio-economic realities of low- and middle-income countries. The dearth of pragmatic solutions to the need for quick increases in sanitation coverage is mainly due to the lack of an enabling environment to develop more realistic, cost-effective plans.

An "enabling environment" can be seen as the set of inter-related conditions that impact the potential to bring about sustained and effective change (adapted from World Bank, 2003). This includes political, legal, institutional, financial and economic, educational, technical and social conditions which encourage and support specific activities. An enabling environment is vital to the success of any development investment; without it, the resources committed to bringing about change will be ineffective. Therefore, an essential part of the decision to undertake the planning process is to review the existing environment and to decide what needs to be addressed to allow the programme to succeed, and to work towards securing these changes. These guidelines will help to identify which of the conditions need to be addressed and adjusted to bring about an environment that enables change.

The six key elements of an enabling environment are;

- The level of government support, regarding political backing and favourable national policies and strategies;
- The legal and regulatory framework, with appropriate standards and codes at national and municipal levels;
- Institutional arrangements that accept and support the community-centred approach used;
- Effective skills and capacity ensuring that all
- participants understand and accept the
- concepts and planning tools;
- Financial arrangements that facilitate the mobilisation of funds for implementation; and,
- Socio-cultural acceptance, i.e. matching service provision to the users' perceptions, preferences, and commitments to both short-term and long-term participation.

These main elements of the enabling environment should be identified during the planning process and the knowledge and understanding of the enabling environment should be continuously improved. Without a thorough understanding of the existing environment, problems and bottlenecks will arise in the planning process. Of course, there never will be 'the perfect enabling environment' – but there are degrees of more or less enabling or disabling factors which can hinder or facilitate progress.

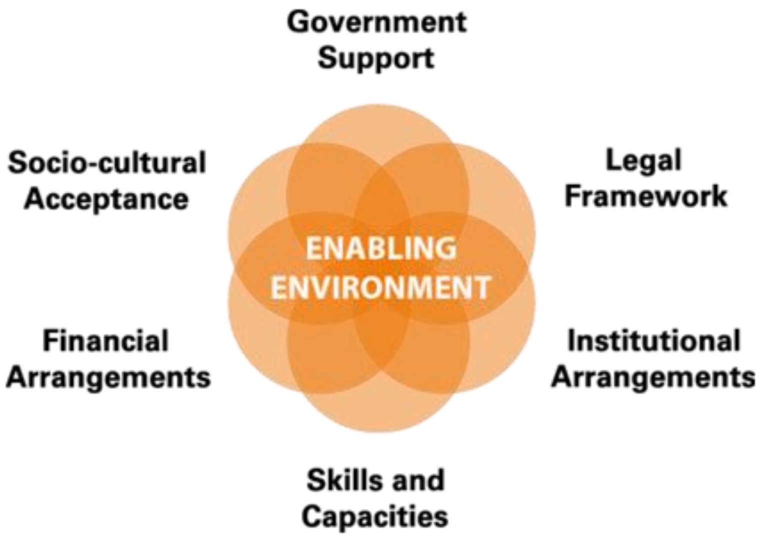


FIGURE 34: FACTORS OF ENABLING ENVIRONMENT (SOURCE: EAWAG,2008)

5.4.3 Institutional and Political aspects

Institutional factors are norms, regulations and informal rules that shape the relationship between the actors in a given context and sector.

Institutional factors outside the WASH sector include:

- Decentralization: transfer of governance to sub-national units of government that may include administrative, fiscal, and political devolution to such units, and which may affect aspects including fiscal policy, human resources management and public procurement.
- Public Finance Management: budgeting prioritization of competing needs.
- Anti-Corruption Means and Provisions: measures adopted by governments to prevent fraud, bribery, extortion and use of public resources and power for personal gain.
- Social Norms: power relationships, social decision-making processes
- Others: context specific factors like quality assurance, equity and sustainability.

Regulation and Standards

Laws, regulations, standards and codes defined in greater detail, within the overall policy framework, how the government expects the sector to perform its functions.

Regulations specify how services are to be provided and by whom, what delivery standards have to be met, ownership of infrastructure and services, and how tariffs and other cost recovery methods are to be designed and implemented. Standards and codes specify, for example, the level of wastewater treatment needed to protect the quality of receiving waters, the design of sanitation technologies, or the quality of material and equipment to be used in the performance of environmental services.

Many existing regulations and standards are based on those developed in industrialised countries (in the wastewater domain, e.g. range of current technologies, sewer diameters, effluent standards, wastewater reuse regulations, etc.), under conditions entirely different of those in developing countries, and so they are not appropriate. If there are laws which prevent the installation of a certain technology, or standards which have become norms over time, it may be very difficult or impossible to introduce a new system.

Organisational set up

The success of any sanitation programme greatly depends on the existence of a functional organisational setup of sanitation stakeholders with clearly defined responsibilities. In general, three types of organisations manage and organise sanitation systems: private organisations, which run the businesses at a profit; public utility companies, financed by public funds (taxes) and operating at a loss or on a cost-recovery basis; and community groups or individuals who operate and maintain a sanitation system without any external funds.

Private companies have recently emerged as an alternative to state-run utilities, which are sometimes inefficient and financially unsustainable. They have, however, been criticised for catering only to customers who can pay. They do not provide equitable services nor invest in infrastructure.

On the other hand, public utilities are often overburdened and underfunded. Although they have a mandate to provide services to all inhabitants of an area, the need for cost recovery and the sheer volume of work make these institutions appear inefficient and obsolete.

To fill these service gaps, community groups, NGOs, homeowners, and citizens groups have begun to organise themselves and provide their services, often with little or no input from government institutions.

Political aspects

Political support is often assumed, but rarely explicitly assured before project implementation. Clear commitment within municipal government to improve services for all, especially the poor, is a crucial precondition for the success of sanitation interventions. Lack of explicit political support is often the initial cause of project failure. Unless there is a political commitment towards increasing community participation and decentralisation of service provision, translated into national sector policies and strategies, projects will be isolated and vulnerable. A proven political commitment to decentralise decision making, service provision and promote community participation, which is supported by the highest levels of government and the top management of the sector agencies, is a crucial precondition for an enabling political environment.

5.4.4 Financial Aspects

Implementing or upgrading urban environmental sanitation services is costly. The willingness of the different partners to contribute both money and time should be assessed early on, to ensure an enabling financial environment. Financial contributions and investments will be required from the community, from governmental agencies, and from the private sector (such as companies taking on solid waste treatment and disposal or producing components for latrines). When estimating the project costs, all aspects must be taken into accounts, such as administrative, hardware costs (including extension and upgrading), training, social marketing programmes, knowledge development and information sharing and any O&M needs.

External support can encourage community-based financing but must do so without negatively distorting community expectations. Innovations in funding basic infrastructures, such as micro-credit systems or community development funds, are promising but still widely untested funding tools in most countries. It is of paramount importance to assess the community's willingness and ability to pay before proposing funding schemes in a given context for:

- up-front hardware construction (e.g. new toilet facilities)
- long-term maintenance costs (e.g. regular emptying services)

Not only do the technical solutions have to be context-specific but the funding and cost-sharing arrangements must be as well.

For the financial arrangements to contribute to the enabling environment, they must be locally anchored, easily accessible and sustainable, i.e. ensure full cost-recovery. Without additional revenues supporting infrastructure upgrading, it will be almost impossible to achieve full cost recovery and thus sustainability of these new services. Sources of capital financing that deserve exploration include:

- National or provincial grants and budget allocations, e.g. within the context of a 5-year development plan or similar national framework;
- Municipal funds, e.g. to provide operating subsidies to meet annual O&M costs;
- Targeted government funds, available to successful applicants in various countries (e.g. Environment Protection Fund, Poverty Eradication Fund, Small and Medium-sized Enterprise Promotion Funds);
- Credits from private or parastatal banks;
- Revolving funds administered through a local NGO/CBO or financial institution, such as self-help housing loans or micro-credit systems;
- Private sector involvement, i.e. transferring the burden of capital financing to the small, medium and large private sector industry which will recover its costs either from the service provider or from the users directly;
- Capital financing by users, either in cash or in kind (typically labour and materials), mainly at the household level.

Sustainability of environmental sanitation services largely depends on securing adequate O&M funding. The number of options to finance O&M is often limited, as O&M costs are usually not directly covered from central budget allocations. Recurrent costs should be covered by the users themselves. This can be either through direct in-kind inputs from the users (e.g. households clean their toilets and local drains, transport their solid waste to the next collection point, establish a management fund to contract service providers etc.) or through funding from service providers' revenues, derived from user payments (service fees, tariffs, municipal taxes). Without reasonable assurance that users are willing and able to pay most if not all recurrent costs, the project should be seriously reconsidered.

5.5 Key readings

I. Cranfield University, Aqua Consult and IRC (2006): Landscaping and Review of Approaches to support service provision for Water, Sanitation and Hygiene. Cranfield University. URL

II. Kalbermatten, J.M., Middleton, R. and Schertenleib, R. (1999): Household-centred Environmental Sanitation. Sandec/Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland. URL

III. Wright, A.M. (1997): Toward a Strategic Sanitation Approach: Improving the Sustainability of Urban Sanitation in Developing Countries. UNDP-World Bank Water and Sanitation Program. The World Bank, Washington, UNDP, 38 pp. URL

IV. Eawag/Sandec (2005): Household-centred Environmental Sanitation, Implementing the Bellagio Principles in Urban Environmental Sanitation, Provisional Guideline for Decision-Makers. Water, Sanitation and Hygiene (WASH), 1. Water Supply and Sanitation Collaborative Council, Geneva, 46 pp. URL

6 Wastewater Treatment Technologies

6.1 Objectives

- To understand the basics of wastewater treatment as quality of sewage, quantification of sewage and treatment process involved in the treatment systems.
- To understand the treatment chain and different aspects involved in the treatment stages of the system (Primary Treatment, Secondary Treatment and Tertiary treatment)
- To understand the appropriate treatment system as to understand the purpose, treatability and the parameters involved in the treatment system.

6.2 Duration

60 min

6.3 Key facts

What are the appropriate wastewater treatment technologies?

To design an appropriate treatment system, it is important to combine the technologies in order to achieve the desired overall treatment objectives (e.g. multiple stage configuration for pre-treatment, primary treatment and secondary treatment). It is important to consider the following factors as,

- Type and quantity of products to be treated (including future developments)
- Desired output product (end-use and/or legal quality requirements)
- Financial resources
- Local availability of materials
- Availability of space
- Soil and groundwater characteristics
- Availability of a constant source of electricity
- Skills and capacity (for design and operation)
- Management considerations

6.4 Learning Notes

6.4.1 Wastewater Treatment Basics

Quantification of Sewage

Quantification of sewage is an important aspect in designing of wastewater treatment system. It is considered that the net quantity of sewage involves accounted quantity of water supplied for the daily use from the water supply department and unaccounted private water supplies (e.g. wells, borewells etc). It also involves the infiltration during wet season and water losses from the sewers. It is considered that around 75 - 80% of sewage generated from the total accounted water supply.

Quality of Sewage

It is important to consider the concentration of various parameters while designing the sewage treatment plant. It is pondered that if there is higher water supply, it leads to lower concentration of the sewage.

Item	Per capita contribution (g / c /d)	water supply (L / c / d)	Sewage Generation 80 % of (3)	Concen-tration (mg/L)
(1)	(2)	(3)	(4)	(5)
BOD	27.0	135	108	250.0
COD	45.9	135	108	425.0
TSS	40.5	135	108	375.0
VSS	28.4	135	108	262.5
Total Nitrogen	5.4	135	108	50.0
Organic Nitrogen	1.4	135	108	12.5
Ammonia Nitrogen	3.5	135	108	32.5
Nitrate Nitrogen	0.5	135	108	5.0
Total Phosphorus	0.8	135	108	7.1
Ortho Phosphorous	0.5	135	108	5.0

Illustration BOD = 27 *1000 (mg) / 135 X 0.8 (litres) = 250 mg/L

FIGURE 35: CONCENTRATION OF VARIOUS PARAMETERS IN THE ABSENCE OF DRAIN OR OUTFALL

The raw sewage characteristics are a function of level of water supply and per capita pollution load. Thus, the level of water supply plays a major role in deciding the concentration of pollutants. Other significant factors are settlement and decomposition in sewers under warm weather conditions, partially decomposed sewage from septic tanks, lifestyle of the population, etc. The best way to ascertain the sewage characteristics is to conduct the composite sampling once a week for diurnal variation on hourly basis from the nearby existing sewage outfall or drain. Based on the raw sewage quality monitoring experiences, the following typical concentrations can be taken for design purpose for 135 L/Cap /day water supply.

Wastewater Treatment Processes

The wastewater treatment processes are usually classified as,

- Physical unit operations
- Biological unit processes
- Chemical unit processes
- Photolytic unit processes

Physical Unit Operations: Treatment methods in which the application of physical forces predominates are known as physical unit operations. Most of these methods are based on physical forces, e.g. screening, mixing, flocculation, sedimentation, flotation, and filtration.

Chemical Unit Processes: Treatment methods in which removal or conversion of contaminant is brought by addition of chemicals or by other chemical reaction are known as chemical unit processes, for example, precipitation, gas transfer, adsorption, and disinfection.

Biological Unit Processes: Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes.

- This is primarily used to remove biodegradable organic substances from the wastewater, either in colloidal or dissolved form.
- In the biological unit process, organic matter is converted into gases that can escape to the atmosphere and into bacterial cells, which can be removed by settling.
- Biological treatment is also used for nitrogen removal and for phosphorous and sulphate removal from the wastewater.

Wastewater Treatment Chain

Typical wastewater treatment chain involves the following stages,

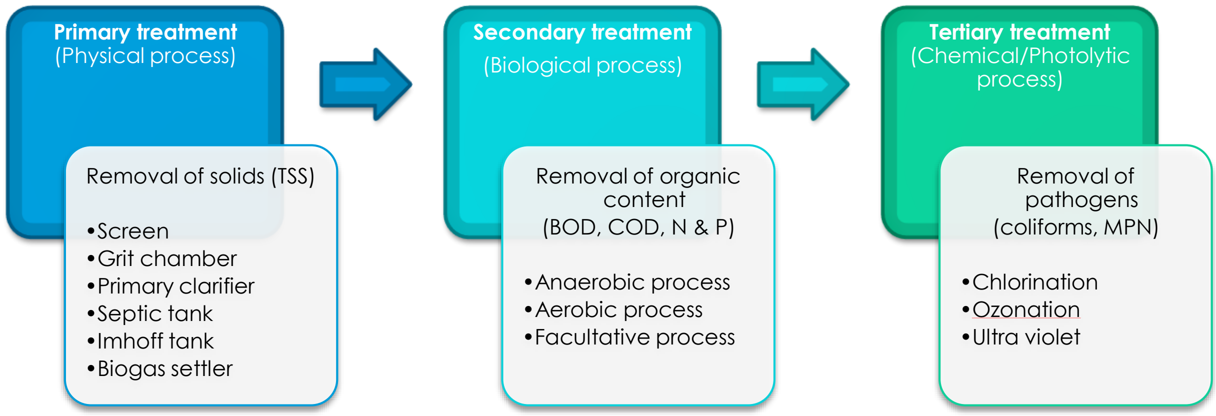


FIGURE 36: WASTEWATER TREATMENT CHAIN

6.4.2 Primary Treatment

A. Screens

Screening aims to prevent coarse solids, such as plastics, rags and other trash, from entering a sewerage system or treatment plant. Solids get trapped by inclined screens or bar racks. The spacing between the bars usually is 15 to 40 mm, depending on cleaning patterns. Screens can be cleaned by hand or mechanically raked. The latter allows for a more frequent solids removal and, correspondingly, a smaller design. The screening may consist of parallel bars, rods, gratings or wire mesh or perforated plates and the openings may be of any shape, although generally they are contrived from circular or rectangular bars. It is recommended that three sequential stages of screens shall be provided being coarse, followed by medium and followed by fine screens

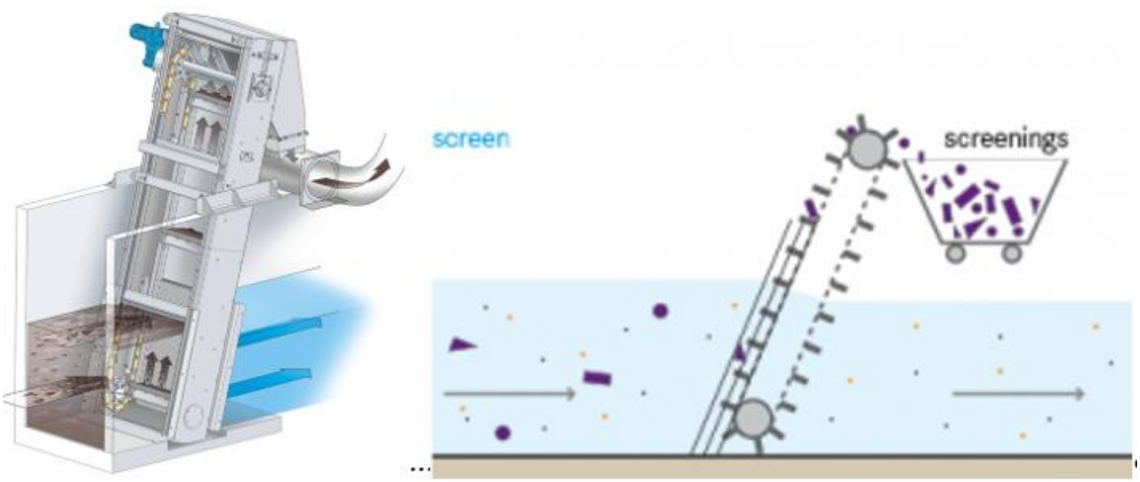


FIGURE 37: SCHEMATIC DIAGRAM OF SCREENS

B. Grit Chamber

Where subsequent treatment technologies could be hindered or damaged by the presence of sand, grit chambers (or sand traps) allow for the removal of heavy inorganic fractions by settling. There are three general types of grit chambers: horizontal-flow, aerated, or vortex chambers. All of these designs allow heavy grit particles to settle out, while lighter, principally organic particles remain in suspension.

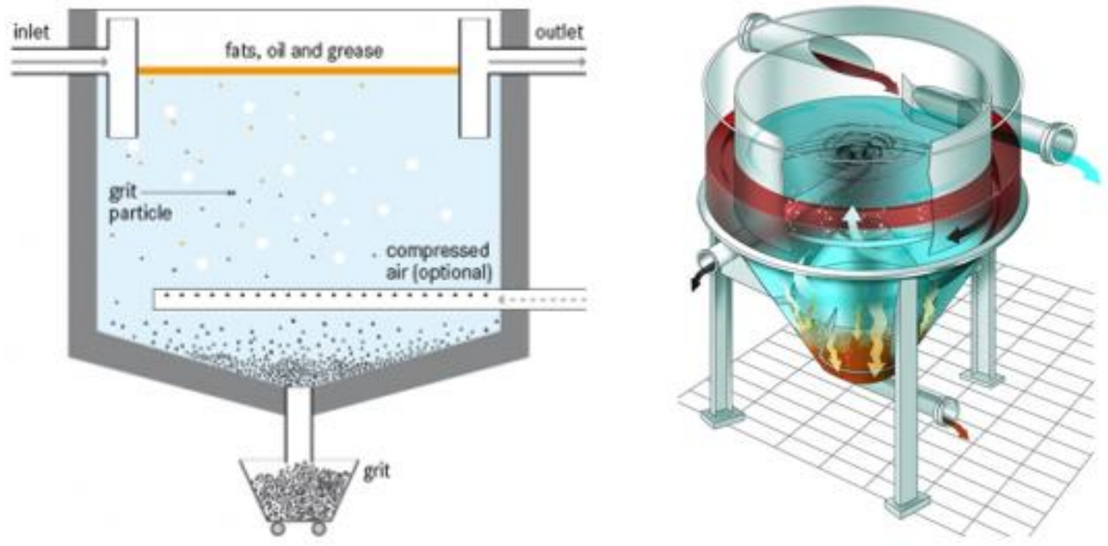


FIGURE 38: SCHEMATIC DIAGRAM OF GRIT CHAMBER

C. Primary Clarifier

The primary clarifier generally removes 30 to 40% of the total BOD and 50 to 70% of suspended solids from the raw sewage. The flow through velocity of 1 cm/sec at average flow is used for design with detention period in the range of 90 to 150 minutes. This horizontal velocity will be generally effective for removal of organic suspended solids of size above 0.1 mm. Primary sedimentation tanks can be circular or rectangular tanks designed using average dry weather flow and checked for peak flow condition. The numbers of tanks are determined by limitation of tank size. The diameter of circular tank may range from 3 to 60 m (up to 45 m typical) and it is governed by structural requirements of the trusses which supports scrapper in case of mechanically cleaned tank. Rectangular tank with length 90m are in use, but usually length more than 40 m are not preferred.

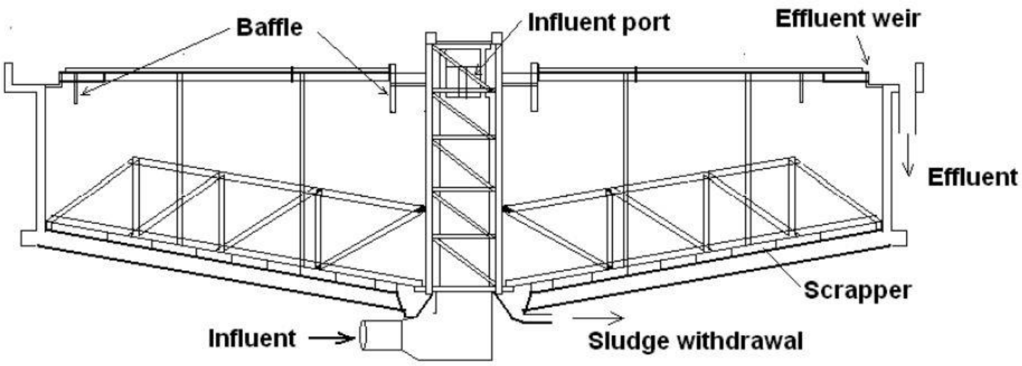


FIGURE 39: SCHEMATIC DIAGRAM OF PRIMARY CLARIFIER

The depth of mechanically cleaned tank should be as shallow as possible, with minimum 2.15 m. The average depth of the tank used in practice is about 3.5 m. The floor of the tank is provided with slope 6 to 16 % (8 to 12 % typical) for circular tank and 2 to 8% for rectangular tanks.

D. Septic Tank

A septic tank is a watertight chamber made of concrete, fibreglass, PVC or plastic, through which blackwater and greywater flows for primary treatment. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

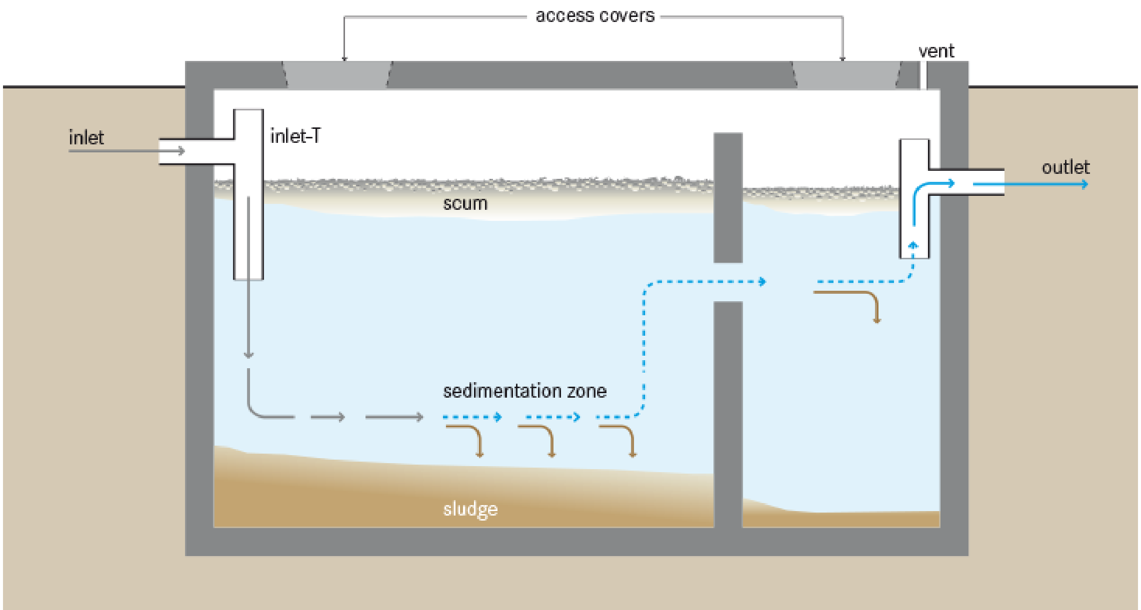


FIGURE 40: SCHEMATIC DIAGRAM OF SEPTIC TANK (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Basically, a septic tank (physical treatment) in which settled sludge is stabilised by anaerobic digestion (biological treatment). Dissolved and suspended matter leaves the tank more or less untreated.**
Capacity/Adequacy	Household and community level; Primary treatment for domestic grey- and blackwater. Depending on the following treatment, septic tanks can also be used for industrial wastewater. Not adapted for areas with high groundwater table or prone to flooding.
Performance	BOD: 30 to 50%; TSS: 40 to 60 %; E. coli: 1 log units HRT: about 1 day
Costs	Low-cost, depending on availability of materials and frequency of de-sludging.
Self-help Compatibility	Requires expert design but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly. Sludge needs to be dug out every 1 to 5 years and discharged properly (e.g. in composting or drying bed). Needs to be vented.
Reliability	When not regularly emptied, wastewater flows through without being treated. Generally good resistance to shock loading.
Main strength	Simple to construct and to operate.
Main weakness	Effluent and sludge require further treatment. Long start-up phase.

E. Imhoff Tank

The Imhoff tank (also known as Emscherbrunnen or Emscher Tank), which works similar to a communal septic tank, is a robust and effective settler that causes a suspended solids reduction of 50 to 70%, COD reduction of 25 to 50%, and leads to potentially good sludge stabilisation – depending on the design and conditions. It is a compact and efficient system for pre-treatment of municipal wastewater. The settling compartment has a circular or rectangular shape with V-shaped walls and a slot at the bottom, allowing solids to settle into the digestion compartment, while preventing foul gas from rising up and disturbing the settling process.

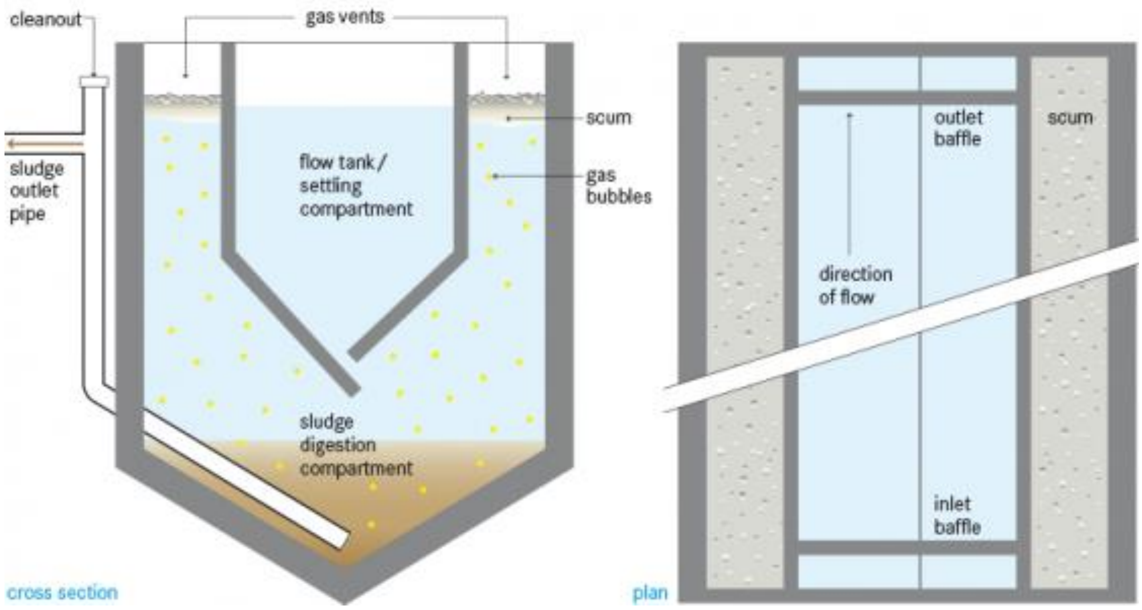


FIGURE 41: SCHEMATIC DIAGRAM OF IMHOFF TANK (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Settling of solids occurs in the upper compartment. Sludge falls through the slot to the bottom of the settling compartment into the lower tank, where it is digested.**
Capacity/Adequacy	Imhoff tanks are used by small communities for primary treatment of grey- and blackwater.
Performance	Removes 25 to 50% of COD. Pathogen removal is low.
Costs	Construction costs are slightly higher than the costs of a septic tank.
Self-help Compatibility	Requires expert design but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly. Sludge needs to be dug out every 1 to 5 years and discharged properly (e.g. in composting or drying bed). Needs to be vented.
Reliability	Reliable if amply designed and desludging carried out routinely. Imhoff tanks are resistant against shock loads.
Main strength	Simple to construct and to operate.
Main weakness	Effluent and sludge require further treatment.

F. Biogas Settler

A settler is a primary treatment technology for wastewater; it is designed to remove suspended solids by sedimentation. The main purpose of a settler is to facilitate sedimentation by reducing the velocity and turbulence of the wastewater stream.

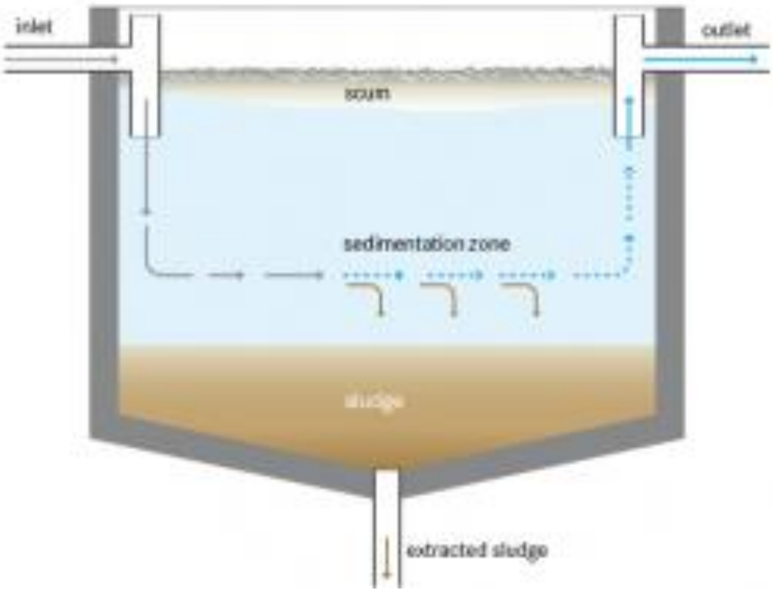


FIGURE 42: SCHEMATIC DIAGRAM OF ANAEROBIC/BIOGAS SETTLER (SOURCE: TILLEY ET AL. 2014)

Settlers are circular or rectangular tanks that are typically designed for a hydraulic retention time of 1.5-2.5 h. Less time is needed if the BOD level should not be too low for the following biological step.

Working Principle	**Biogas settlers are often used as a primary settling treatment and function much like septic tanks, with the difference that biogas is recovered. Wastewater and organic wastes are introduced in an airtight reactor, solids settle to the bottom, where they are decomposed by anaerobic digestion and transformed to biogas and fertilising slurry. The supernatant flows to further treatment steps or the storage tank to be reused for irrigation.**
Capacity/Adequacy	Biogas settlers are most suited for decentralized wastewater treatment systems at household, community or institutional level. They are applicable in both urban and rural areas as long as the wastewater contains sufficient organic matter and is biodegradable.
Performance	80 to 85 % BOD; Relatively high pathogen removal; N and P remain in the sludge; HRT of some days; SRT of several years

Costs	Low capital and low operating costs
Self-help Compatibility	Expert design is required and the construction needs to be supervised; operation staff needs to receive training to understand the functioning. Can be constructed with locally available material.
O&M	De-sludging every 2 to 5 years; Checking for gas-tightness should be done regularly.
Reliability	Resistant to shock loading. Reliable if operated and maintained well.
Main strength	High removal of organic pollutants without any requirement for energy; Generation of biogas and fertiliser (compost).
Main weakness	Expert design is required; The organic and solid content in the influent needs to monitored.

6.4.3 Secondary Treatment

A. Anaerobic Baffle Reactor

An anaerobic baffled reactor (ABR) is an improved Septic Tank with a series of baffles under which the wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment. The upflow chambers provide enhanced removal and digestion of organic matter. BOD may be reduced by up to 90%, which is far superior to its removal in a conventional Septic Tank.

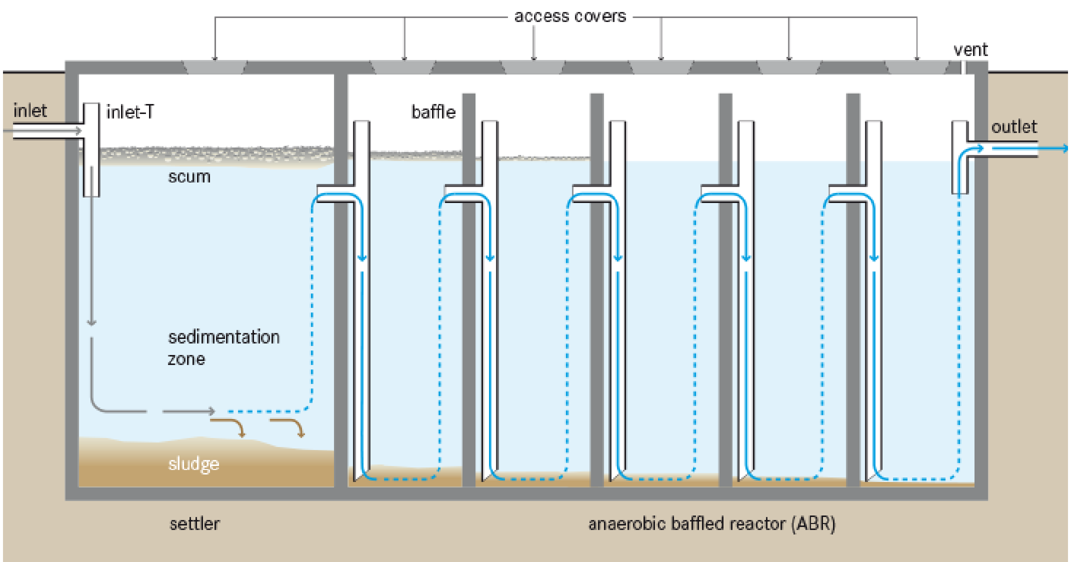


FIGURE 43: SCHEMATIC DIAGRAM OF ANAEROBIC BAFFLED REACTOR (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Vertical baffles in the tank force the pre-settled wastewater to flow under and over the baffles guaranteeing contact between wastewater and resident sludge and allowing an enhanced anaerobic digestion of suspended and dissolved solids; at least 1 sedimentation chamber and 2–5 up-flow chambers.**
Capacity/Adequacy	Community (and household) level; For pre-settled domestic or (high-strength) industrial wastewater of narrow COD/BOD ration. Typically integrated in DEWATS systems; Not adapted for areas with high ground-water table or prone to flooding.
Performance	70- 95% BOD; 80% - 90% TSS; Low pathogen reduction. HRT: 1 to 3 days
Costs	Generally low-cost; depending on availability of materials and economy of scale.
Self-help Compatibility	Requires expert design but can be constructed with locally available material.
O&M	Should be checked for water tightness, scum and sludge levels regularly; Sludge needs to be dug out and discharged properly (e.g. in composting or drying bed); needs to be vented.
Reliability	High resistance to shock loading and changing temperature, pH or chemical composition of the influent; requires no energy.
Main strengths	Strong resistance; built from local material; biogas can be recovered.
Main weakness	Long start-up phase.

B. Anaerobic Filter

An anaerobic filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, particles are trapped and organic matter is degraded by the active biomass that is attached to the surface of the filter material. An anaerobic filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, particles are trapped and organic matter is degraded by the active biomass that is attached to the surface of the filter material.

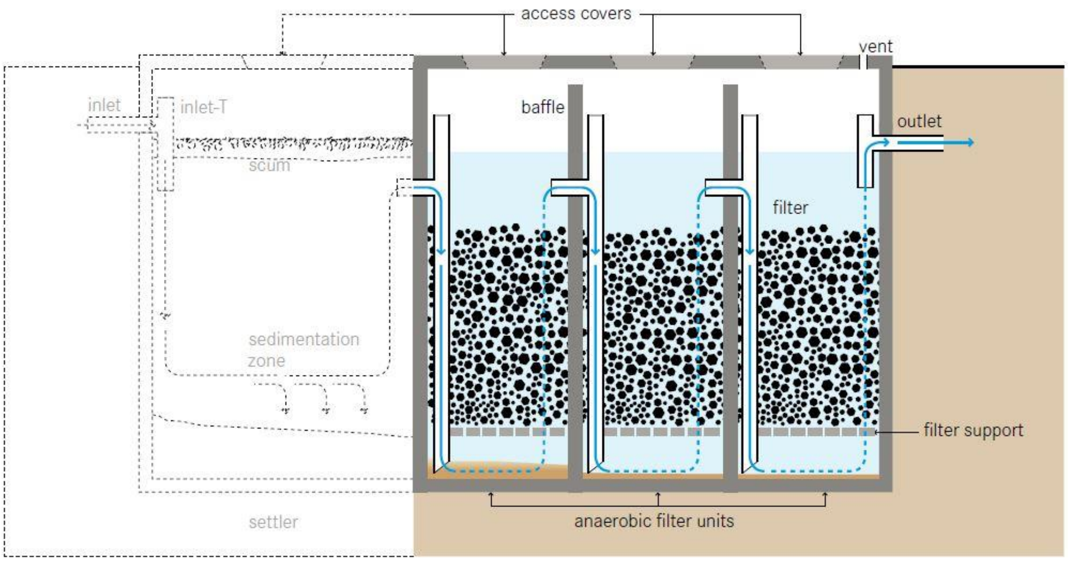


FIGURE 44: SCHEMATIC DIAGRAM OF ANAEROBIC UP FLOW FILTER (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Dissolved and non-settleable solids are removed by anaerobic digestion through close contact with bacteria attached to the filter media**
Capacity/Adequacy	Household and community level; as secondary treatment step after primary treatment in a septic tank or an anaerobic baffled reactor; effluents can be infiltrated into soil or reused for irrigation; not adapted if high ground-water table or in areas prone to flooding.
Performance	BOD: 50 to 90%; TSS: 50 to 80 %; Total Coliforms: 1 to 2 log units. HRT: about 1 day
Costs	Generally low-cost; depending on availability of materials and frequency of back flushing and desludging.
Self-help Compatibility	Requires expert design but can be constructed with locally available material.
O&M	Regularly backflush to prevent clogging (without washing out the biofilm); desludging of the primary settling chambers; needs to be vented if biogas not recovered.
Reliability	Reliable if construction is watertight and influent is primary settled; Generally good resistance to shock loading.
Main strength	Resistant to shock loading; High reduction of BOD and TSS.
Main weakness	Long start-up phase.

C. Constructed Wetlands (Horizontal Flow)

A horizontal subsurface flow constructed wetland is a large gravel and sand-filled basin that is planted with wetland vegetation. As wastewater flows horizontally through the basin, the filter material filters out particles and microorganisms degrade the organics. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach, and a base for the vegetation. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter.

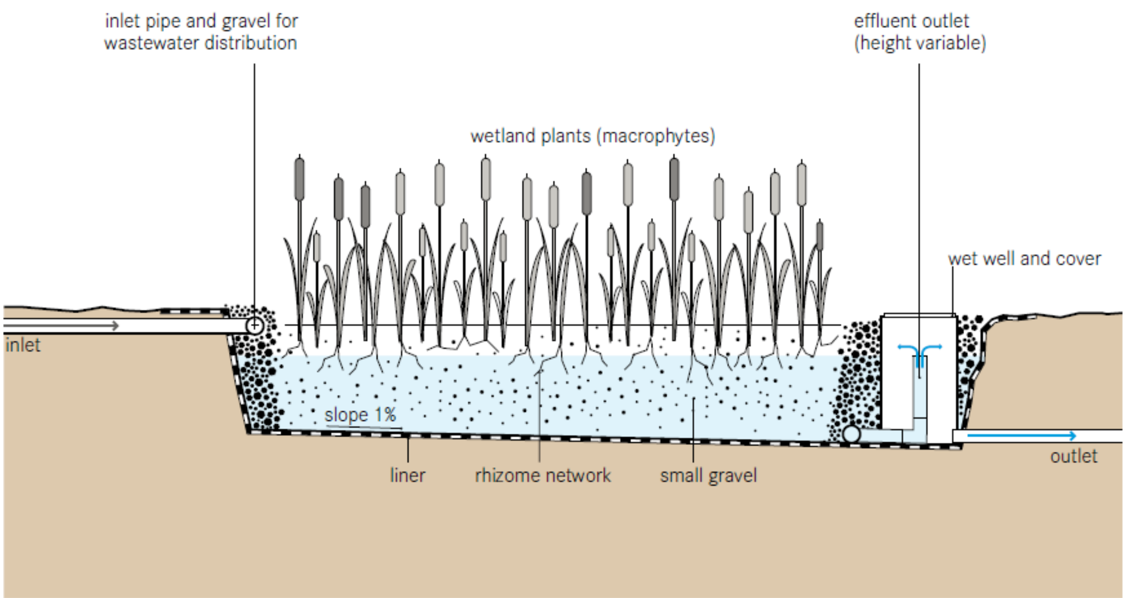


FIGURE 45: SCHEMATIC DIAGRAM OF HORIZONTAL FLOW CONSTRUCTED WETLANDS (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Pre-treated grey or blackwater flows continuously and horizontally through a planted filter bed. Plants provide appropriate environments for microbiological attachment, growths and transfer of oxygen to the root zone. Organic matter and suspended solids are removed by filtration and microbiological degradation in aerobic anoxic and anaerobic conditions (MOREL and DIENER 2006).**
Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water (MOREL and DIENER 2006).

Performance	BOD = 80 to 90 %; TSS = 80 to 95 %; TN = 15 to 40 %; TP = 30 to 45 %; FC ≤ 2 to 3 Log; LAS > 90 %
Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low (MOREL and DIENER 2006).
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design.
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory.
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose (MOREL and DIENER 2006).
Main weakness	Permanent space required; risk of clogging if wastewater is not well pre-treated, high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (MOREL and DIENER 2006).

D. Constructed Wetlands (Vertical Flow)

A vertical flow constructed wetland is a planted filter bed that is drained at the bottom. Wastewater is poured or dosed onto the surface from above using a mechanical dosing system. The water flows vertically down through the filter matrix to the bottom of the basin where it is collected in a drainage pipe. The important difference between a vertical and horizontal wetland is not simply the direction of the flow path, but rather the aerobic conditions. By intermittently dosing the wetland (4 to 10 times a day), the filter goes through stages of being saturated and unsaturated, and, accordingly, different phases of aerobic and anaerobic conditions. During a flush phase, the wastewater percolates down through the unsaturated bed. As the bed drains, air is drawn into it and the oxygen has time to diffuse through the porous media. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach and a base for the vegetation. The top layer is planted and the vegetation is allowed to develop deep, wide roots, which permeate the filter media. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics. However, the primary role of vegetation is to maintain permeability in the filter and provide habitat for microorganisms. Nutrients and organic material are absorbed and degraded by the dense microbial populations. By forcing the organisms into a starvation phase between dosing phases, excessive biomass growth can be decreased and porosity increased.

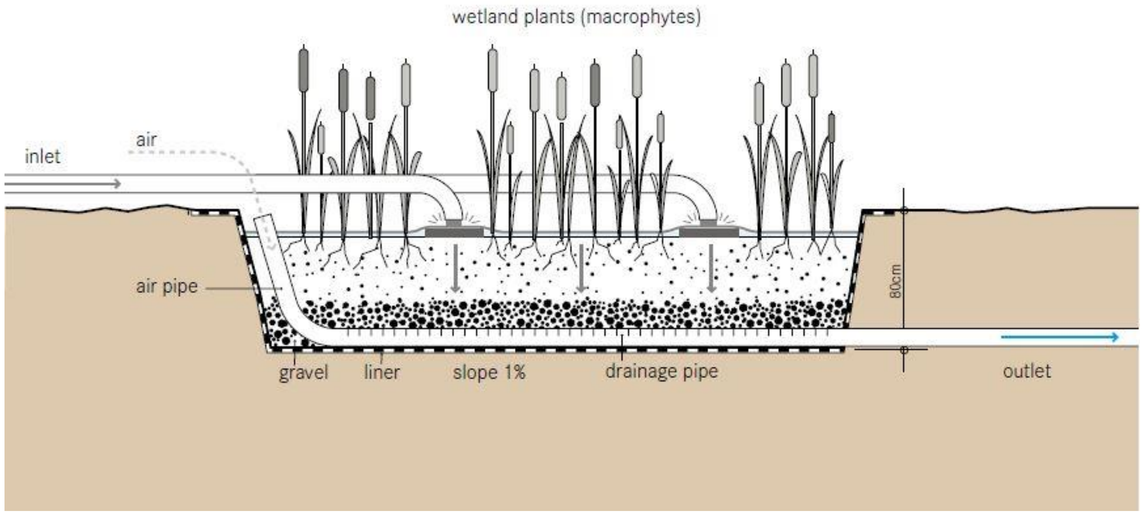


FIGURE 46: SCHEMATIC DIAGRAM OF VERTICAL FLOW CONSTRUCTED WETLANDS (SOURCE: TILLEY ET AL. 2014)

Working Principle	**Pre-treated grey- or blackwater is applied intermittently to a planted filter surface, percolates through the unsaturated filter substrate where physical, biological and chemical processes purify the water. The treated wastewater is collected in a drainage network (adapted from MOREL and DIENER 2006).**
Capacity/Adequacy	It can be applied for single households or small communities as a secondary or tertiary treatment facility of grey- or blackwater. Effluent can be reused for irrigation or is discharged into surface water (MOREL and DIENER 2006).
Performance	BOD = 75 to 90%; TSS = 65 to 85%; TN < 60%; TP < 35%; FC ≤ 2 to 3 log; MBAS ~ 90%; (adapted from: MOREL & DIENER 2006)

Costs	The capital costs of constructed wetlands are dependent on the costs of sand and gravel and also on the cost of land required for the CW. The operation and maintenance costs are very low (MOREL and DIENER 2006).
Self-help Compatibility	O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design. Electricity pumps may be necessary.
O&M	Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.
Reliability	Clogging of the filter bed is the main risk of this system, but treatment performance is satisfactory.
Main strength	Efficient removal of suspended and dissolved organic matter, nutrients and pathogens; no wastewater above ground level and therefore no odour nuisance; plants have a landscaping and ornamental purpose (MOREL and DIENER 2006).
Main weakness	Even distribution on a filter bed requires a well-functioning pressure distribution with pump or siphon. Uneven distribution causes clogging zones and plug flows with reduced treatment performance; high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (MOREL and DIENER 2006).

E. Waste Stabilization Pond

Waste Stabilization Ponds (WSPs) are large, manmade water bodies. The ponds can be used individually or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three or more with effluent flowing from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep pond is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the sludge. Anaerobic bacteria convert organic carbon into methane and, through this process, remove up to 60% of the BOD. In a series of WSPs, the effluent from the anaerobic pond is transferred to the facultative pond, where further BOD is removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.

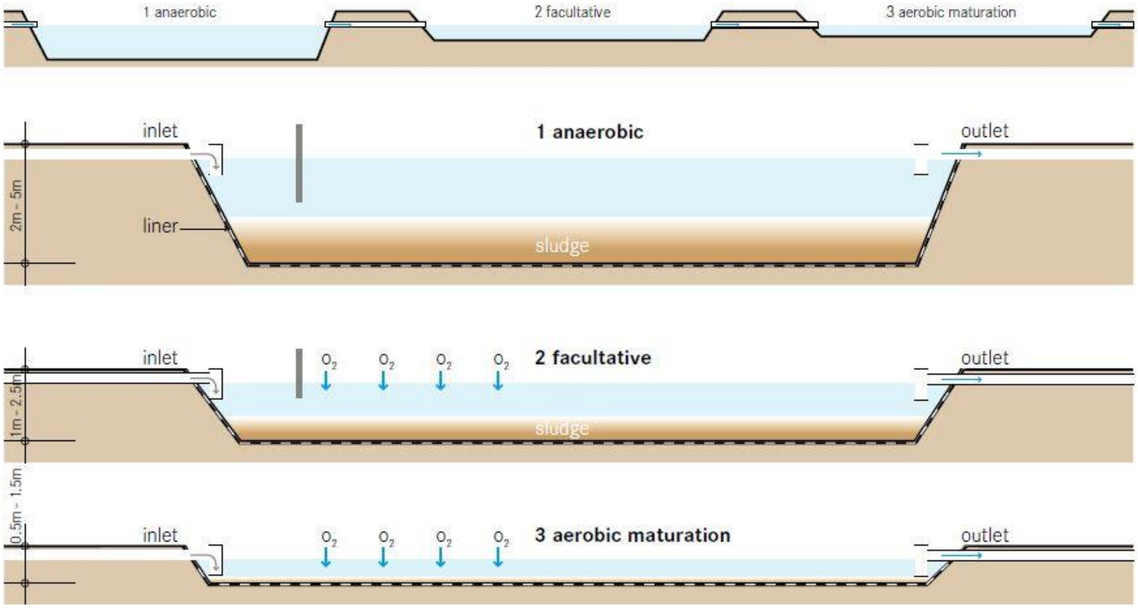


FIGURE 47: SCHEMATIC DIAGRAM OF WASTE STABILIZATION POND (SOURCE: TILLEY ET AL. 2014)

Working Principle	**In a first pond (anaerobic pond), solids and settleable organics settles to the bottom forming a sludge, which is, digested anaerobic by microorganism. In a second pond (facultative pond), algae growing on the surface provide the water with oxygen leading to both anaerobic digestion and aerobic oxidation of the organic pollutants. Due to the algal activity, pH rises leading to inactivation of some pathogens and volatilisation of ammonia. The last ponds serves for the retention of stabilised solids and the inactivation of pathogenic microorganisms via heating rise of pH and solar disinfection.**
Capacity/Adequacy	Almost all wastewaters (including heavily loaded industrial wastewater) can be treated, but as higher the organic load, as higher the required surface. In the case of high salt content, the use of the water for irrigation is not recommended.
Performance	90% BOD and TSS; high pathogen reduction and relatively high removal of ammonia and phosphorus; Total HRT: 20 to 60 days

Costs	Low capital costs where land prices are low; very low operation costs
Self-help Compatibility	Design must be carried out by expert. Construction can take place by semi- or unskilled labourers. High self-help compatibility concerning maintenance.
O&M	Very simple. Removing vegetation (to prevent BOD increase and mosquito breath) scum and floating vegetation from pond surfaces, keeping inlets and outlets clear, and repairing any embankment damage.
Reliability	Reliable if ponds are maintained well, and if temperatures are not too low.
Main strength	High efficiency while very simple operation and maintenance.
Main weakness	Large surface areas required and needs to be protected to prevent contact with human or animals

F. Advanced Integrated Ponds

Advanced Integrated Ponds, involves the complete treatment using combination of anaerobic, aerobic, oxygen transfer process and photolytic disinfection process. Through this system, it removes upto 90 – 100% BOD, 90 – 100% TSS, 60 – 90% Nitrogen, 90 – 100% Ammonia, 60 – 100% Phosphorus and 6 log units of E. coli.

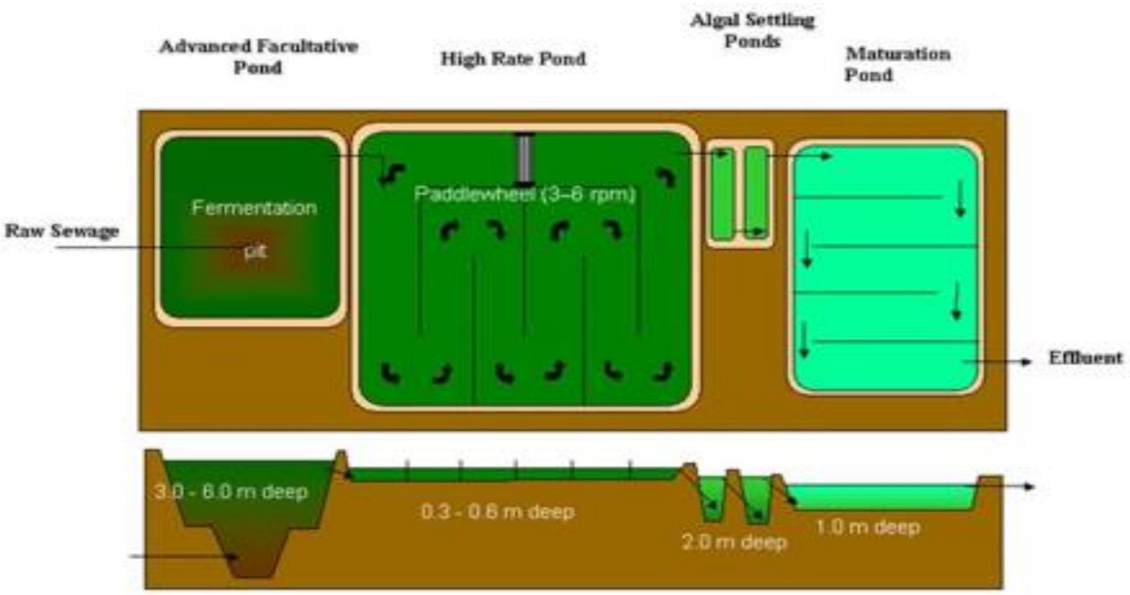


FIGURE 48: SCHEMATIC DIAGRAM OF ADVANCED FACULTATIVE POND (SOURCE: RAMADAN ET AL. 2009)

Working Principle	**In a primary advanced facultative pond (AFP) containing a digester pit on its bottom, solids and organic are trapped and degraded via anaerobic digestion and aerobic degradation. In a high rate algae pond (HRP) BOD is further aerobically degraded and taken up by growing microalgae. In the next step, algae are settled in the algal settling pond (ASP) and can be harvested (and used as fish fodder or fertiliser). A final maturation pond (MP) enhances pathogen abatement.**
Capacity/Adequacy	Due to the complexity of the system it is adapted for community or large-scale application, but almost every wastewater can be treated.
Performance	90 to 100 % BOD; 90 to 100 % TSS; 60 to 90 % nitrogen; 90 to 100 % ammonia; 60to 100 Phosphorus; 6 log units E. coli
Costs	Compared to the high BOD, TSS and pathogen removal, AIWPS are cost-effective. However, investment costs are high and expert skills for design and construction are required.
Self-help Compatibility	Presently, no clear guidelines for the design are available and planning and construction supervision. Operation and maintenance need to be carried out by technical experts; the community may contribute during construction.
O&M	Large objects and coarse particles need to be screened; The algal settling pond needs to be desludged once to twice a year. HRPs are sensitive and require skilled maintenance.
Reliability	High reliability and good resistance to shock loading.
Main strength	High removal efficiency and almost no sludge produced.
Main weakness	Not well experienced yet and expert skills required since the system is somehow complicated.

G. Up flow Anaerobic Sludge Blanket (UASB) Reactor

The up flow anaerobic sludge blanket reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it.

The sludge blanket is comprised of microbial granules (1 to 3 mm in diameter), i.e., small agglomerations of microorganisms that, because of their weight, resist being washed out in the upflow. The microorganisms in the sludge layer degrade organic compounds. As a result, gases (methane and carbon dioxide) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls. After several weeks of use, larger granules of sludge form which, in turn, act as filters for smaller particles as the effluent rises through the cushion of sludge. Because of the Upflow regime, granule-forming organisms are preferentially accumulated as the others are washed out.

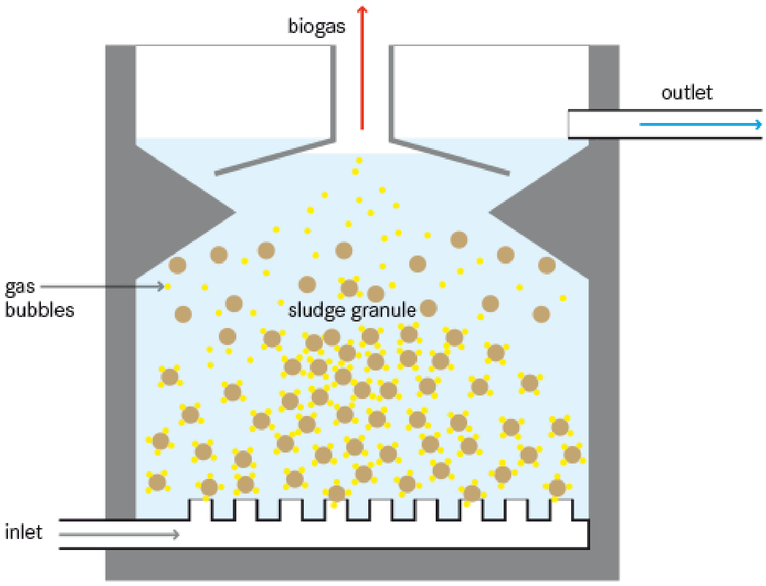


FIGURE 49: SCHEMATIC DIAGRAM OF UASB REACTOR (SOURCE: TILLEY ET ALL. 2014)

Working Principle	**Industrial wastewater or blackwater flows into the bottom of an anaerobic Upflow tank. Accumulated sludge forms granules. Microorganisms living in the granules degrade organic pollutants by anaerobic digestion. The sludge blanket is kept in suspension by the flow regime and formed gas bubbles. A separator at the top of the reactor allows to recover biogas for energy production, nutrient effluent for agriculture and to retain the sludge in the reactor. Sludge accumulation is low (emptying is only required every few years) and the sludge is stabilised and can be used as soil fertiliser.**

Capacity/Adequacy	Centralised or decentralized at community level, for industrial wastewater or blackwater. The system requires a continuous and stable water flow and energy.
Performance	60 to 90 % BOD; 60 to 80 % COD and 60 to 85 % TSS; low pathogen reduction minimal removal of nutrient (N and P) HRT: minimal 2 hours, generally 4 to 20 hours
Costs	Investment is comparable to baffled reactors. For operation usually, no costs arise beneath desludging costs and operation of feeding pump.
Self-help Compatibility	Can be constructed with locally available material but requires skilled staff for construction, maintenance and operation.
O&M	Desludging is not frequent but feeder pump and control of organic loads requires skilled staff for operation and maintenance.
Reliability	Not resistant to shock loading and sensitive to organic load fluctuations.
Main strength	High removal of organics and solids (BOD and TSS) with low production of sludge and the possibility to recover biogas; only little land required.
Main weakness	Requires skilled staff, electricity and is sensitive to variable flows.

H. Trickling Filter

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material. The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass. The incoming pre-treated wastewater is 'trickled' over the filter, e.g., with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass and the inner layers may be anoxic or anaerobic.

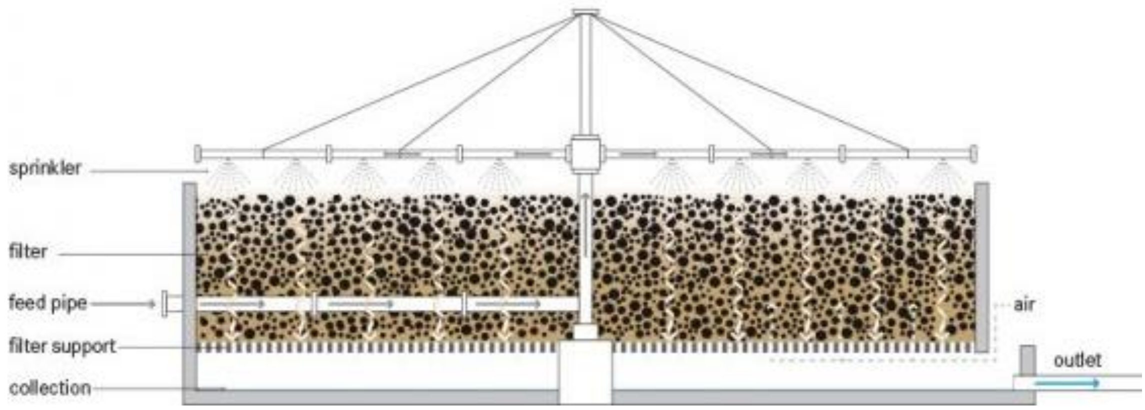


FIGURE 50: SCHEMATIC DIAGRAM OF TRICKLING FILTER

Working Principle	Wastewater trickles vertically through a porous media (e.g. a stone bed) with high specific surface. The biofilm growing on the media removes organic matter under aerobic conditions.
Capacity/Adequacy	Semi-centralised to centralised. The system is usually applied in urban areas for treatment of domestic wastewater. It can be applied for bigger and smaller communities.
Performance	BOD: 65 to 90 %. Low TSS removal. Total Coliforms: 1 to 2 log units, N: 0 to 35%. P: 10 to 15 %.
Costs	Medium; investment costs depend on type of filter materials and feeder pumps used; operational costs determined by electricity consumption of feeder pumps.
Self-help Compatibility	Low. Design, planning and implementation by expert consultants; no community labour contribution possible; feeder pumps required; permanent staff required for operation.
O&M	Civil engineer needed for construction, professional service providers required
Reliability	Resistant to shock loadings but the systems does not work during power failures.
Main strength	High treatment efficiency with lower area requirement compared to wetlands or ponds; resistant to shock loading.
Main weakness	Requires expert skills, pumps and continuous electrical power, as well as ample and continuous wastewater flow required

I. Activated Sludge Process

An activated sludge process refers to a multi-chamber reactor unit that makes use of highly concentrated microorganisms to degrade organics and remove nutrients from wastewater to produce a high-quality effluent. To maintain aerobic conditions and to keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required.

Different configurations of the activated sludge process can be employed to ensure that the wastewater is mixed and aerated in an aeration tank. Aeration and mixing can be provided by pumping air or oxygen into the tank or by using surface aerators. The microorganisms oxidize the organic carbon in the wastewater to produce new cells, carbon dioxide and water. Although aerobic bacteria are the most common organisms, facultative bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment, and wastewater characteristics.

The flocs (agglomerations of sludge particles), which form in the aerated tank, can be removed in the secondary clarifier by gravity settling. Some of this sludge is recycled from the clarifier back to the reactor. The effluent can be discharged or treated in a tertiary treatment facility if necessary for further use.

Activated sludge processes are one part of a complex treatment system. They are usually used after primary treatment (that removes settleable solids) and are sometimes followed by a final polishing step (see POST, p.136). The biological processes that occur are effective at removing soluble, colloidal and particulate materials. The reactor can be designed for biological nitrification and denitrification, as well as for biological phosphorus removal. The design must be based on an accurate estimation of the wastewater composition and volume. Treatment efficiency can be severely compromised if the plant is under- or over-dimensioned. Depending on the temperature, the solids retention time (SRT) in the reactor ranges from 3 to 5 days for BOD removal, to 3 to 18 days for nitrification. The excess sludge requires treatment to reduce its water and organic content and to obtain a stabilized product suitable for end-use or final disposal. It is important to consider this step in the planning phase of the treatment plant.

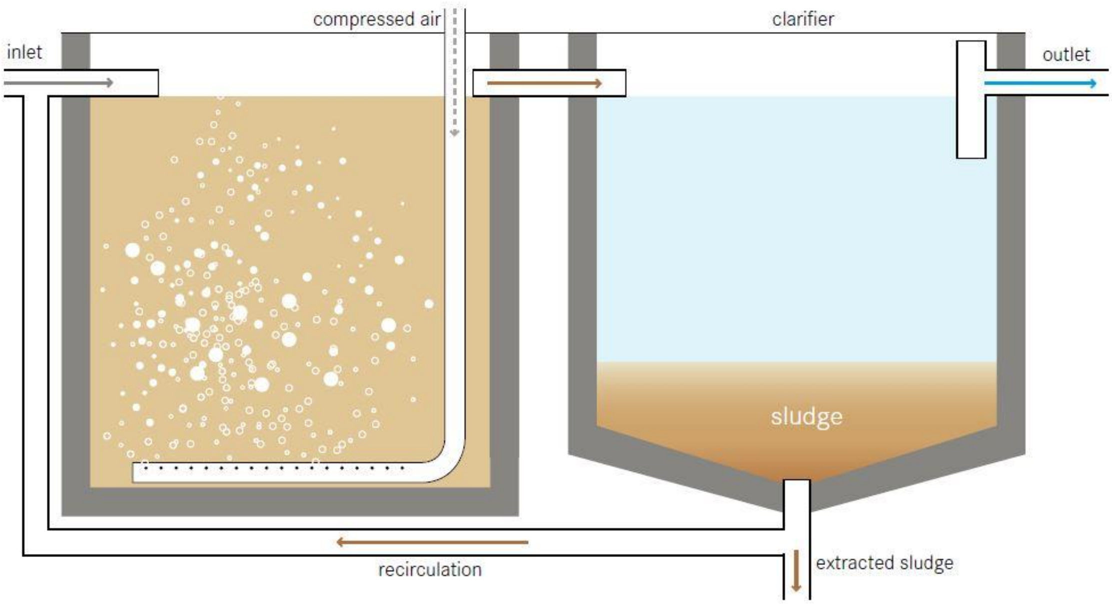


Figure 51: Schematic diagram of activated sludge process (Source: Tilley et al. 2014)

J. Sequential Batch Reactor (SBR)

The Sequencing Batch Reactor (SBR) is a different configuration of the conventional activated sludge systems, in which the process can be operated in batches, where the different conditions are all achieved in the same reactor but at different times. The treatment consists of a cycle of five stages: fill, react, settle, draw and idle. During the reaction type, oxygen is added by an aeration system. During this phase, bacteria oxidise the organic matter just as in activated sludge systems. Thereafter, aeration is stopped to allow the sludge to settle. In the next step, the water and the sludge are separated by decantation and the clear layer (supernatant) is discharged from the reaction chamber (ASANO et al. 2007). Depending on the rate of sludge production, some sludge may also be purged. After a phase of idle, the tank is filled with a new batch of wastewater (UNEP and MURDOCH UNIVERSITY 2004). At least two tanks are needed for the batch mode of operation as continuous influent needs to be stored during the operation phase. Small systems may apply only one tank. In this case, the influent must either be retained in a pond or continuously discharged to the bottom of the tank in order not to disturb the settling, draw and idle phases. SBRs are suited to lower flows, because the size of each tank is determined by the volume of wastewater produced during the treatment period in the other tank (UNEP and MURDOCH UNIVERSITY 2004). Pollutants removal efficiency: BOD_5: 95%, COD: 90%, TSS: 95%, Pathogen: N/A.

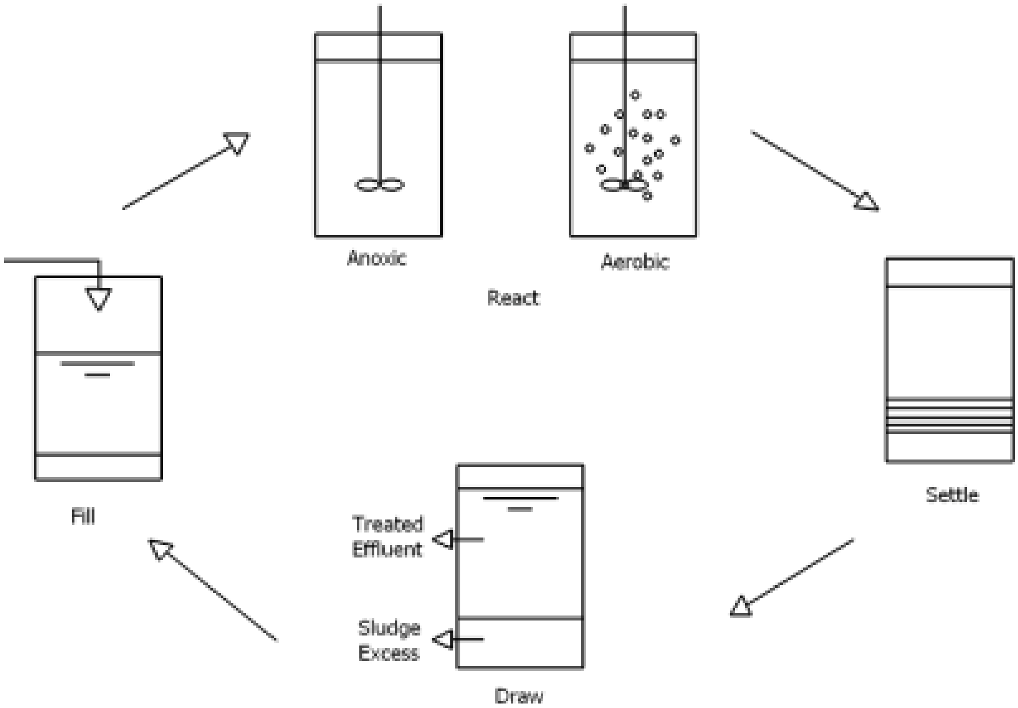


FIGURE 52: PROCESS DIAGRAM OF SBR

K. Membrane Bio Reactor (MBR)

The Membrane Bioreactor (MBR) process (membrane activated sludge process) is an advanced wastewater treatment technology and constitutes a suspended growth activated sludge system, which instead of secondary clarifiers utilises low-pressure membranes for solid/liquid separation. As opposed to secondary clarification, the quality of solids separation is not dependent upon the mixed liquor suspended solids concentration, or the settling characteristic. Hence, the fact that MBRs can operate with much higher mixed liquor suspended solid concentrations, which provides an intensified biological process. Accordingly, the two major benefits of the MBR process are substantially reduced land and space requirements, and the reclamation of water (permeate) of excellent quality, which is a valuable source for higher demand reuse applications (LAHNSTEINER et al. 2007). There are five types of membrane configuration, which are currently in operation: Hollow fibre (HF), Spiral-wound, Plate-and-frame (i.e. flat sheet - FS), Pleated filter cartridge and Tubular. To provide optimal aeration and scour around the membranes, the mixed liquor is typically kept in the 1.0-1.2% solids range, which is 4 times that of a conventional plant. Pollutants removal efficiency: BOD_5: 99%, COD: 95%, TSS: 99%, Pathogen: 99.99% (FITZGERALD 2008).

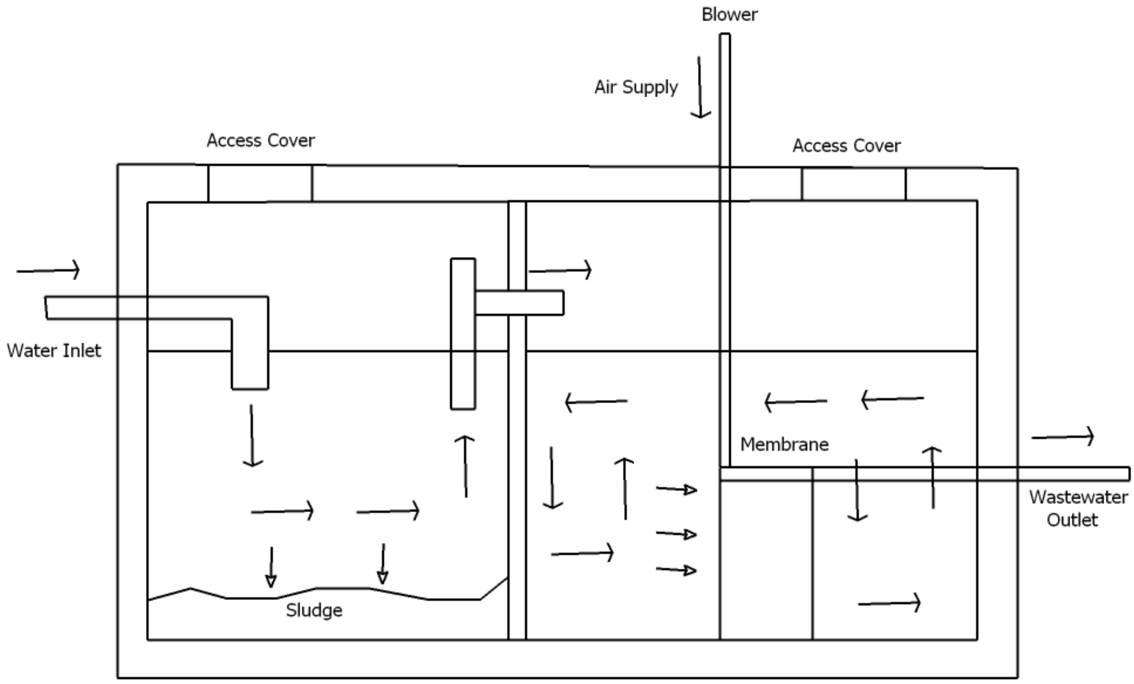


FIGURE 53: SCHEMATIC DIAGRAM OF MBR

Working Principle	Membrane Bioreactors (MBRs) combine conventional biological treatment (e.g. activated sludge) processes with membrane filtration to provide an advanced level of organic and suspended solids removal.
Capacity/Adequacy	Applicable in conventional wastewater plants.
Performance	High
Costs	High capital and operational costs.
Self-help Compatibility	Low
O&M	Membranes need to be cleaned regularly.
Reliability	High if membranes are maintained correctly.
Main strength	Secondary clarifiers and tertiary filtration processes are eliminated, thereby reducing plant footprint.
Main weakness	High operation and capital costs (membranes).

6.4.4 Tertiary Treatment

A. Chlorination

The destruction, inactivation, or removal of pathogenic microorganisms can be achieved by chemical, physical, or biological means. Due to its low cost, high availability and easy operation, chlorine has historically been the disinfectant of choice for treating wastewater.

Chlorine oxidizes organic matter, including microorganisms and pathogens. Concerns about harmful disinfection by-products (DBP) and chemical safety, however, have increasingly led to chlorination being replaced by alternative disinfection systems, such as (UV) radiation and ozonation (O3).

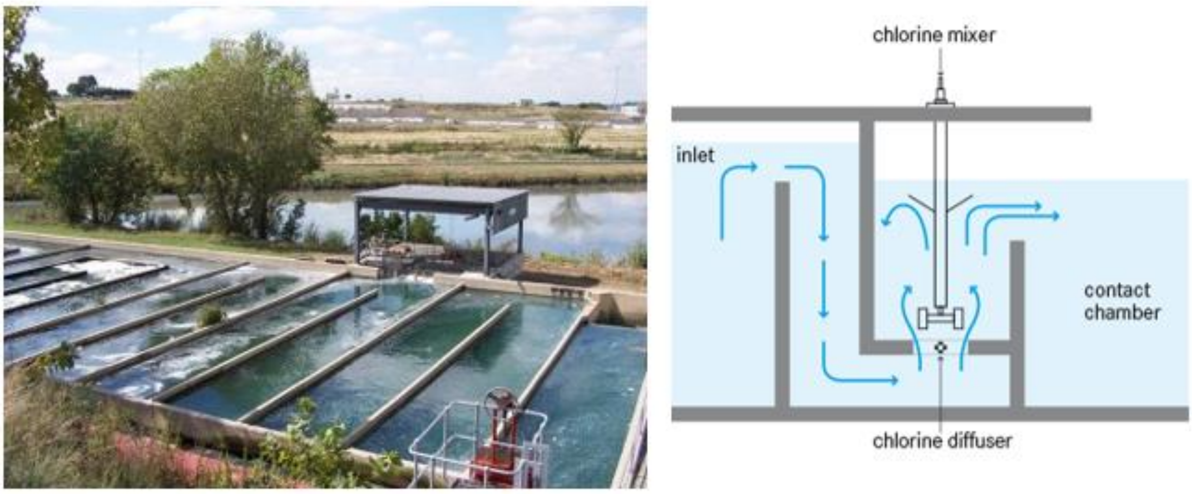


FIGURE 54: CHLORINATION BASIN AND SCHEMATIC DIAGRAM OF CHLORINE DOSING AND MIXER

B. Ozonation

Ozonation is an efficient treatment to reduce the amounts of micropollutants released in the aquatic systems by wastewater treatment plants (MARGOT et al. 2011). Although no residual by-products are generated by ozone itself, some concerns are raised regarding oxidation by-products when water containing both organics and ions, such as bromide, iodide and chlorine ions, are treated with ozonation. A typical ozonation system consists of an ozone generator and a reactor where ozone is bubbled into the water to be treated.

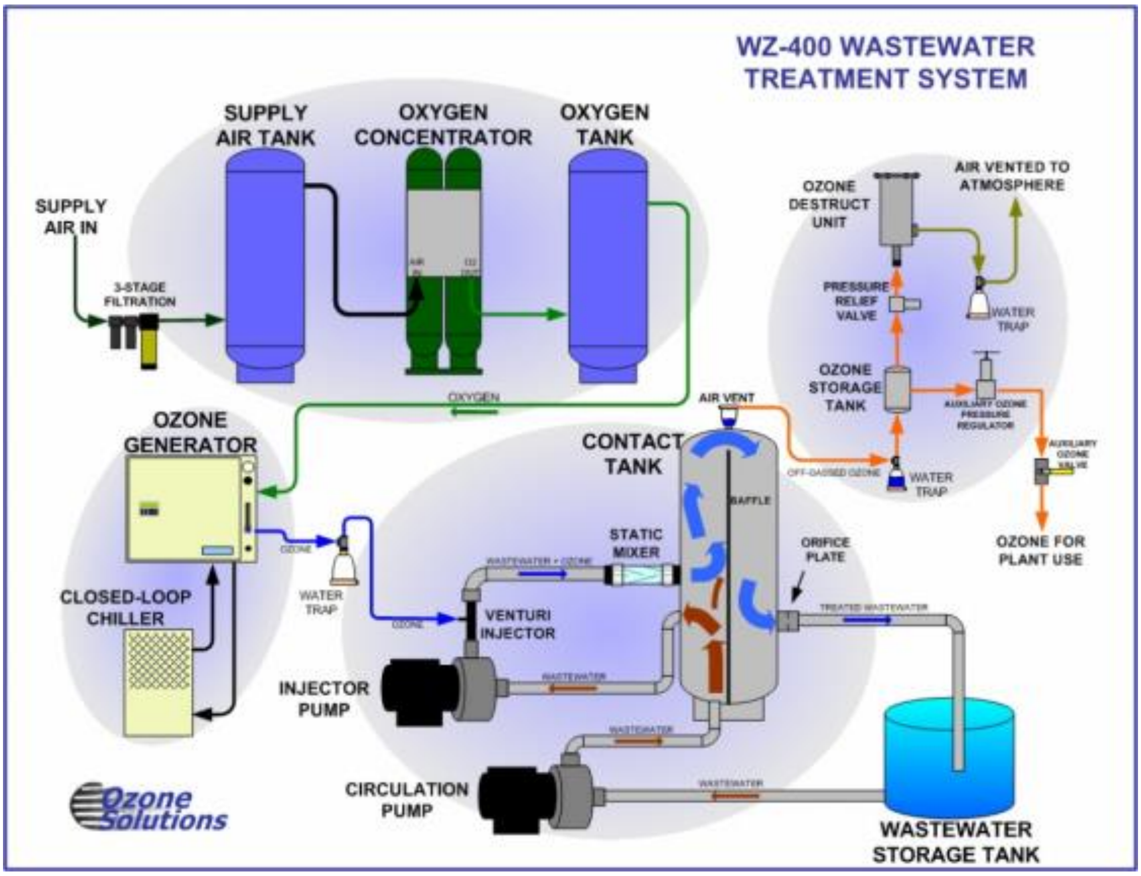


FIGURE 55: SCHEMATIC DIAGRAM OF OZONATION (SOURCE: OZONE SOLUTIONS)

Working Principle	Infusion of ozone, a gas produced by subjecting oxygen molecules to high electrical voltage, which reacts with microorganisms and pollutants
Capacity/Adequacy	High tech equipment required
Performance	High efficiency
Costs	Relatively high operation costs
Self-help Compatibility	Engineers are required for the design
O&M	Continuous input of electrical power required
Reliability	Reliable if operating conditions are scaled taking into account wastewater content
Main strength	Very efficient and fast method for disinfection and as a AOP
Main weakness	Requires complicated equipment as well as large amounts of energy and qualified operators

6.4.5 Appropriate Treatment System

It is important to understand the appropriate treatment technologies while designing the system as per the scenario. As appropriate treatment system is important to reduce the quantity of pollutants going in to the natural environment. Specific purpose of the appropriate treatment system is,

- Reuse of by-products in the Industry (cement industry, manufacturing industry etc)
- To reduce eutrophication of surface water bodies
- Reuse in the agricultural (in drought prone areas)
- Reuse in indirect aquifer recharge

Treatability

For wastewater, the treatability study should also factor in local discharge regulations and whether you release your waste to a local municipality or to the environment. Treatability depends on the following factors,

- Treatment system with various scales (various volumes, capacity etc)
- Different waste streams (e.g. black water, grey water, mixed water etc)
- Robustness of the system for the shock loading (volume or organic load etc)

Important Parameters

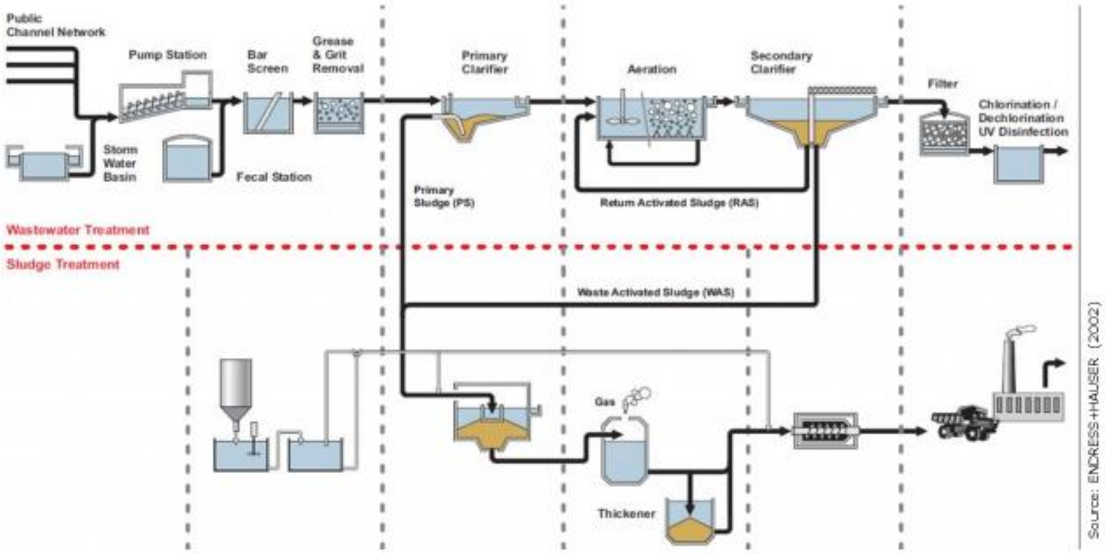
In the selection of appropriate treatment system for the current scenario, it is important to consider the following parameters,

- Capital expenditure – initial investment can be huge but it can save the direct and indirect expenses in future
- Operational expenditure – it's important to spend bit more money upfront to reduce the ongoing costs
- Demonstrated experience – Its necessary to visit the demonstrated sites or pilot sites and ensure about the appropriateness of the treatment system
- Local services and support – the local services available for the troubleshooting the system if needed.

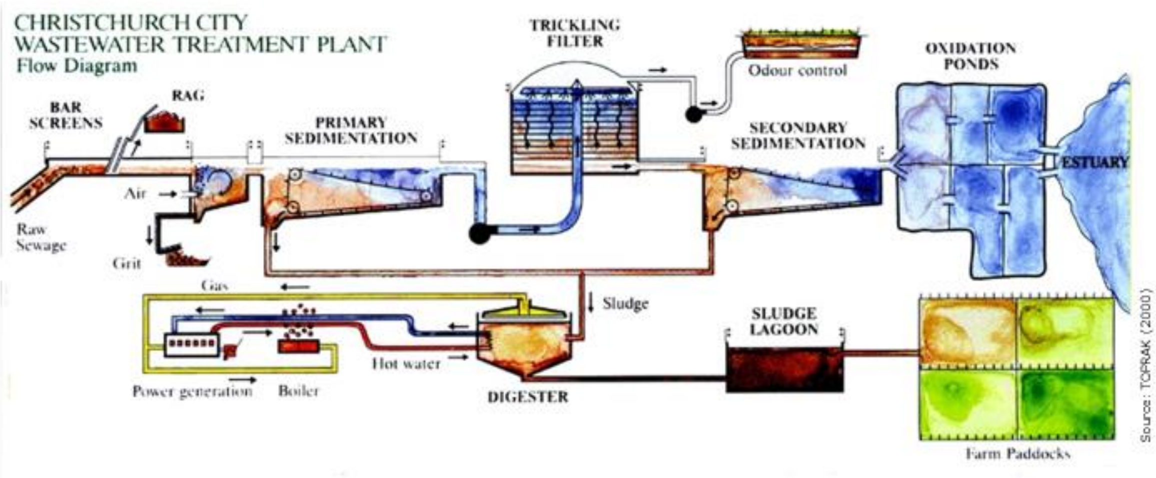
6.4.6 Treatment Chain

To design the system for the statement given by the facilitator. To under the suitability of the treatment system for the defined scenario. There are few examples are given below for the reference.

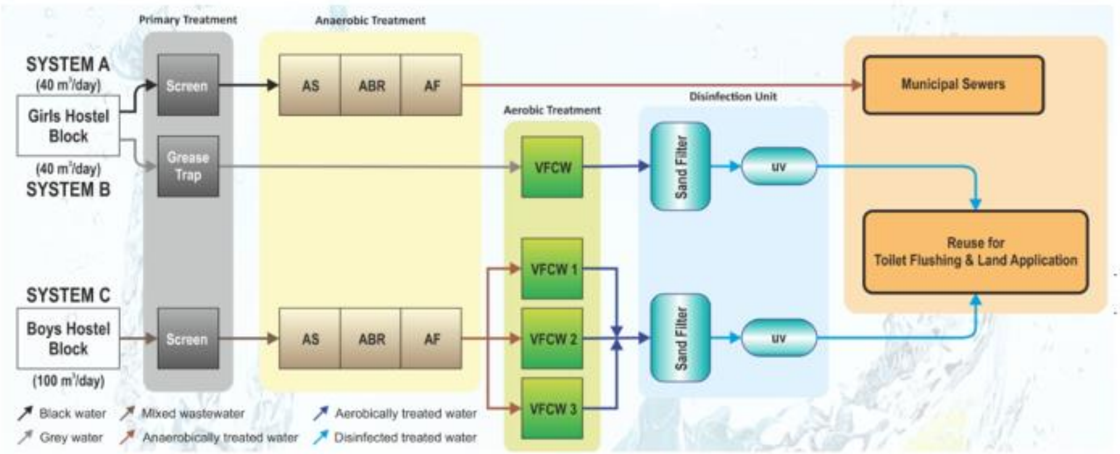
Case I: ASP



Case II: Trickling filter



Case III: DTS



6.5 Key readings

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7 Need of FSSM

7.1 Objectives

- To understand the sanitation facts in India.
- To gain knowledge on National programs and policies (like Swachh Bharat Mission, National policy on Faecal Sludge and Septage Management, FSSM in AMRUT).
- To understand the basics of Faecal Sludge and Septage Management. Needs and challenges in FSSM.

7.2 Duration

60 min

7.3 Key facts

I. What are the sanitation facts in India?

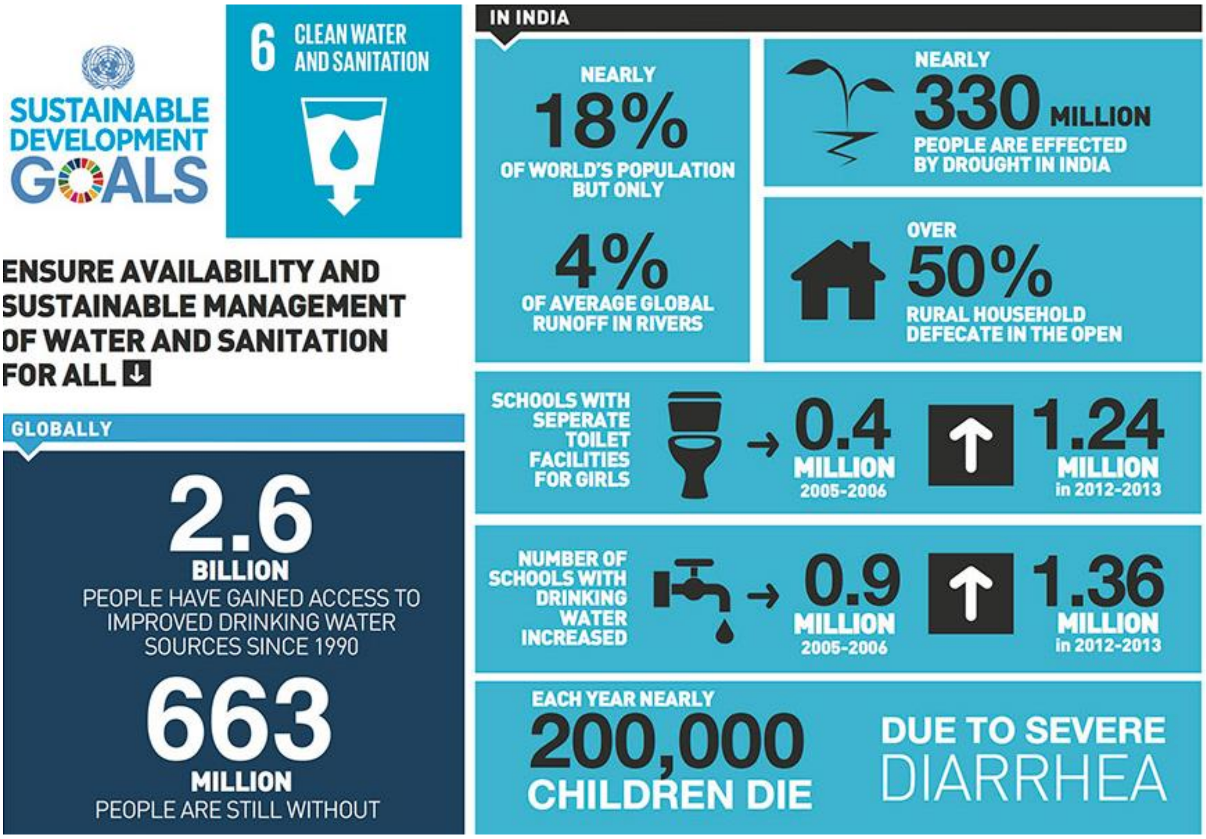


FIGURE 56: SANITATION FACTS: SDG 6 AND INDIA

II. What are the National Programs and Policies?

In 2012, 59% of rural households and 8% of urban households did not have access to improved sanitation facilities. As per census 2011, 37 million people practice open defecation in urban India. 28 million people with individual toilets use insanitary methods of disposal of waste. 43,117 MLD of untreated wastewater is discharged in water bodies or on land. Improving sanitation is a key priority of the government which has introduced several flagship programmes including the Swachh Bharat Abhiyan to clean India, National policy on Faecal Sludge and Septage Management (FSSM), FSSM in AMRUT Program and Namami Gange, which aims at the conservation of the River Ganga.

III. What are the needs and challenges in Faecal Sludge and Septage Management?

In the absence of adequate safe and sustainable sanitation, many Indian cities are already suffering the consequences, in the form of health ailments and serious pollution of water and soil resources. There are many factors which define the need of FSSM,

- Insufficient infrastructure
- Health and environmental implications
- Government policy and regulations
- Resource recovery

7.4 Learning Notes

7.4.1 Sanitation Facts in India

According to Census 2011, India's urban population is 377 million or 31% of the total population, which is expected to increase to 600 million by 2031. The Census 2011 also showed that in 4,041 statutory towns, 7.90 million households (HHs) do not have access to toilets and defecate in the open. Under the Swachh Bharat Mission (SBM), it is envisaged that nearly 80% of these 7.90 million HHs (or nearly 6.3 million HHs) will meet their sanitation needs through newly-built individual household toilet (IHHT) and the remaining 20% (or nearly 1.6 million HHs) will rely on existing or newly-built community toilets. Weak sanitation has significant health costs and untreated faecal sludge and septage from cities is the single biggest source of water resource pollution in India. Human waste has clearly been identified as the leading polluter of water sources in India, causing a host of diseases including diarrhoea, agricultural-produce contamination and environmental degradation.

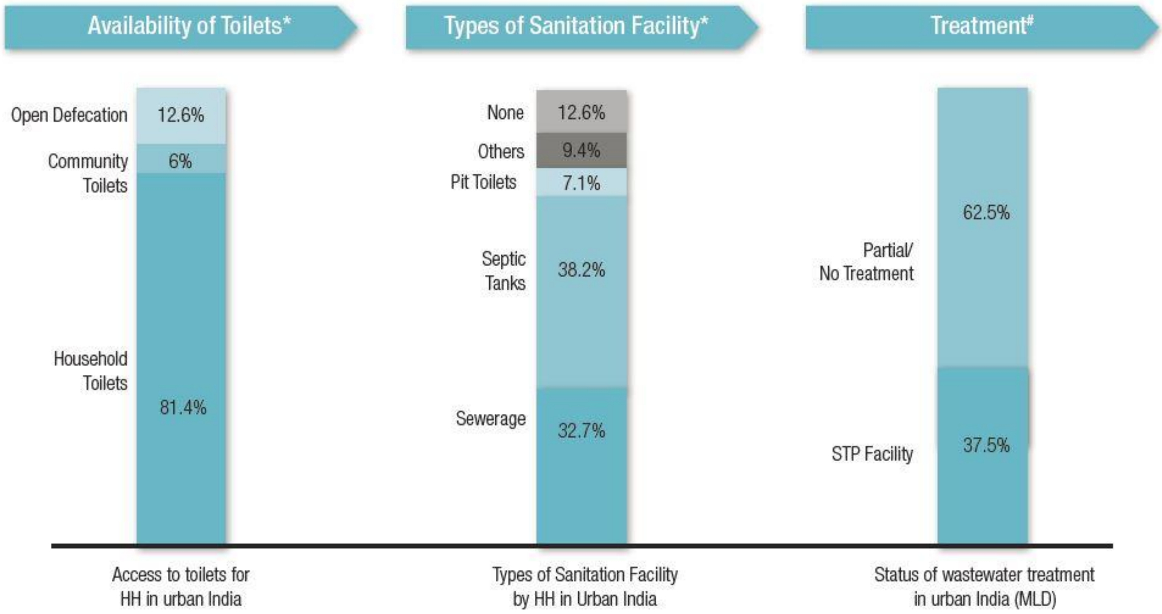


FIGURE 57: STATUS OF SANITATION IN URBAN INDIA

According to the report "Inventorization of Sewage treatment plants, 2015" by the Central Pollution Control Board, out of the 816 municipal sewage treatment plants (STPs) listed across India, 522 are operational (only 64% are functioning), 79 STPs are Non-Operational, 145 STPs are under construction and 70 STPs are proposed. The treatment capacity that is available is only for 37% of the total 62,000 MLD (million litres per day) of human waste that is generated in urban India.

7.4.2 National program and policies

Swachh Bharat Mission – Urban

For ensuring hygiene, waste management and sanitation across the nation, a "Swachh Bharat Mission" will be launched on 2nd oct, 2014. SBM is being implemented by the Ministry of Housing and Urban Affairs (M/o HUA) and by the Ministry of Drinking Water and Sanitation (M/o DWS) for urban and rural areas respectively. As per the vision of the mission, it is envisioned that India will be open defecation free till 2nd oct 2019.

Objectives

- Elimination of open defecation
- Eradication of Manual Scavenging
- Modern and Scientific Municipal Solid Waste Management
- To effect behavioural change regarding healthy sanitation practices
- Generate awareness about sanitation and its linkage with public health

- Capacity Augmentation for ULBs to create an enabling environment for private sector
- participation in Capex (capital expenditure) and Opex (operation and maintenance)

Components

- Household toilets, including conversion of insanitary latrines into pour-flush latrines
- Community toilets,
- Public toilets and urinals
- Solid waste management
- IEC & Public Awareness
- Capacity building and Administrative & Office Expenses (A&OE)

National Faecal Sludge and Septage Management (FSSM) Policy

MoUD and a host of research and civil society organisations jointly drafted and signed a National Declaration on Faecal sludge and Septage management (FSSM) on 9th September, 2016. The National policy on Faecal sludge and Septage management is declared by MoUD in February, 2017.

The vision for Faecal Sludge and Septage Management in urban India is that all Indian cities and towns become totally sanitized, healthy and liveable and ensure sustenance of good sanitation practices with improved Onsite Sanitation Services together with faecal sludge and septage management to achieve optimum public health status and maintain clean environment with special focus on the poor.

Objective

The key objective of the urban FSSM Policy is to set the context, priorities, and direction for, and to facilitate, nationwide implementation of FSSM services in all ULBs such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town and city

Specific Milestones

- Leveraging FSSM to achieve 100% access to safe sanitation - Promoting access for households, community-planned and managed safe FSSM facilities

- Achieving Integrated Citywide Sanitation: Mainstreaming Sanitation - Mainstream thinking, planning and implementing measures related to FSSM, Strengthening national, state, city and local institutions
- Sanitary and Safe Disposal - Promoting proper functioning of FSSM systems and ensuring proper collection, transportation and disposal or recycle/reuse of the faecal sludge
- Awareness Generation and Behaviour Change

FSSM Implementation Approach

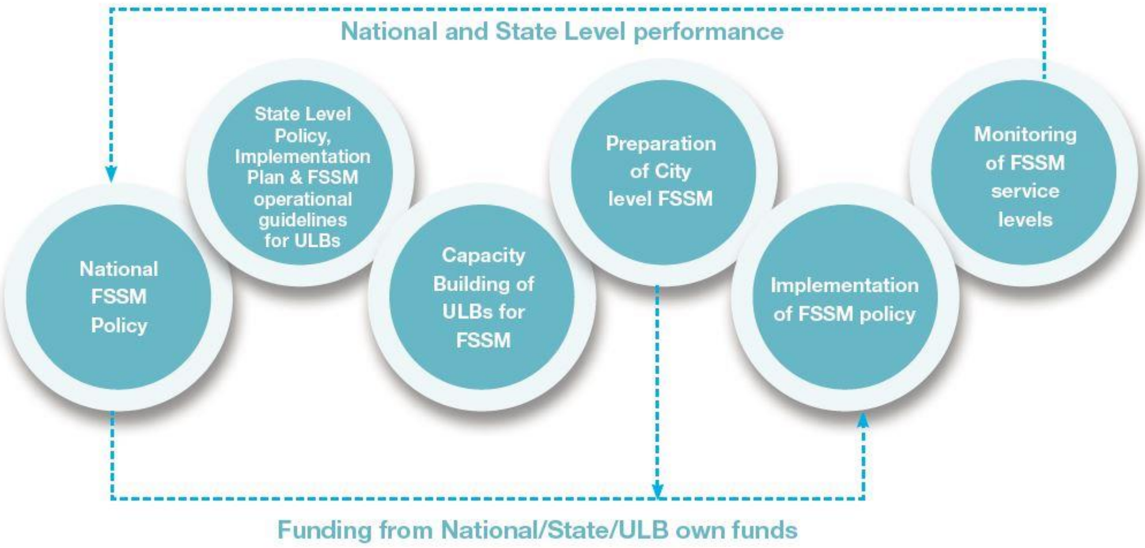


FIGURE 58: FSSM IMPLEMENTATION APPROACH

Faecal Sludge and Septage Management in AMRUT Program

- It focuses on Sanitation services delivery to the citizens
- Under AMRUT, incentives will be provided for the achievement of reforms
- State has to develop their own state level FSSM policy
- Financial allocations should include under AMRUT for FSSM related projects.

7.4.3 Introduction of Faecal Sludge and Septage Management

What is Faecal Sludge and Septage?

Faecal sludge comprises all liquid and semi-liquid contents of pits and vaults accumulating in on-site sanitations installations, namely un-sewered public and private latrines or toilets, aqua privies and septic tanks. These liquids are normally several times more concentrated in suspended and dissolved solids than wastewater.

Septage comprises of liquid and solid material pumped from a septic tank, cesspool or other primary treatment source

What is Faecal Sludge and Septage Management?

Faecal sludge and septage management deals with on-site sanitation systems, while wastewater management is concerned with sewered sanitation. Faecal Sludge and Septage may be treated in separate treatment works or co-treated with sludges produced in wastewater treatment plants.

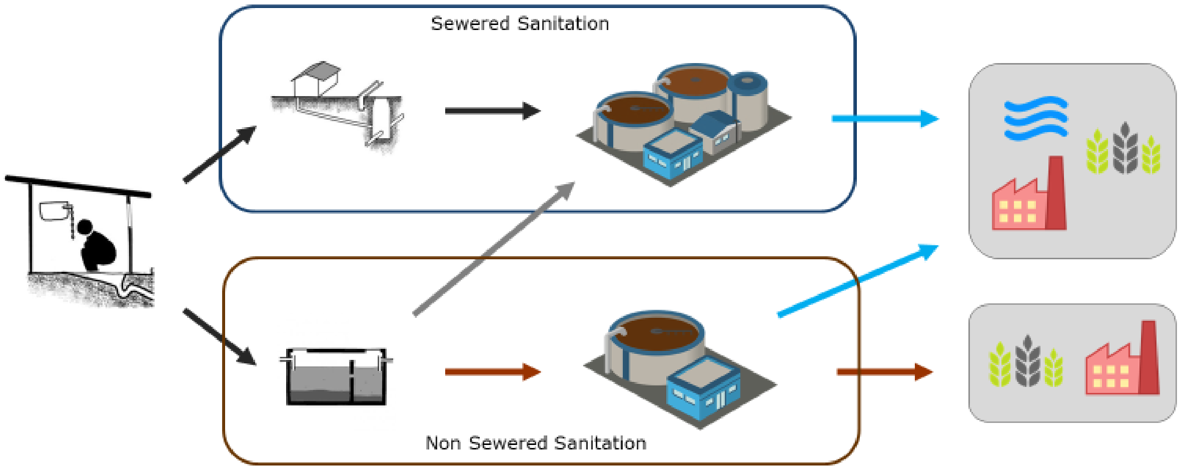


FIGURE 59: SANITATION AROUND US: SEWERED AND NON-SEWERED

Faecal Sludge Sanitation Value Chain

Faecal sludge management value chain is concerned with the movement of the faecal sludge from containment to disposal or reuse. Faecal sludge management specifically includes the following components,

- **Capture –** any type of latrine or tank which is used to capture and store faecal sludge;
- **Emptying –** any type of device used to empty storage devices;
- **Transport –** physically moving the sludge from the storage device to the treatment plant;
- **Treatment –** treating sludge so that it is safe to disposed of or, ideally, reused;
- **Reuse –** regaining value from the sludge by making it's nutritional or calorific content available for agriculture, energy, etc.

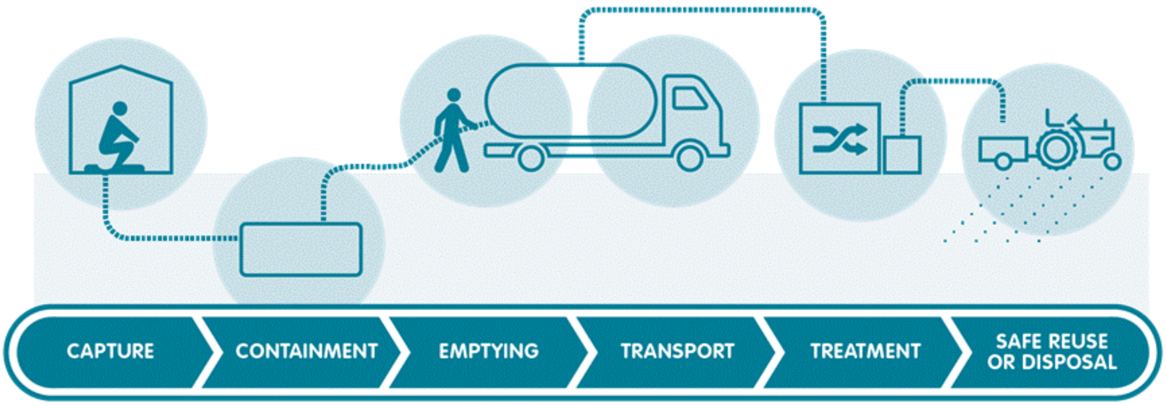


FIGURE 60: SANITATION VALUE CHAIN

7.4.4 Needs and Challenges in FSSM

Need of Faecal Sludge and Septage Management (FSSM)

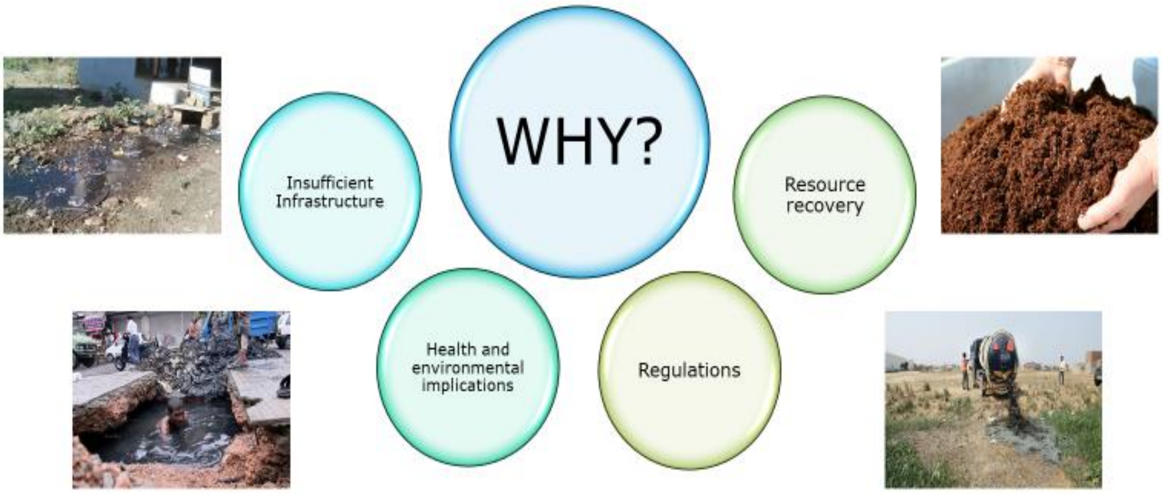


FIGURE 61: NEED OF FAECAL SLUDGE AND SEPTAGE MANAGEMENT (FSSM)

Insufficient infrastructure

There is a challenge with respect to sanitation infrastructure in India. Sanitation infrastructure does not pose a challenge only in the form of lack of sewerage network lines, but also in the case of emptying of OSS and treatment of effluent let out by them. Achieving SBM objective, there is need of conveyance facilities for emptying the OSS, which currently be catered through illegal manual scavenging or through the use of vacuum tankers. There is a need of treatment systems and proposal disposal management.

Regulations

The legislative framework in India has adequate provisions at the national-, state- and city-level to protect water and environment. Public health and sanitation is a part of the ‘constitutional responsibility’ of the municipalities under the 12th schedule of the Constitution (74th Amendment, 1992). Some of the key provisions in different laws and regulations that deal with septage management are given in *Table 3: Legislative and regulatory provisions for septage management*. Municipal acts and regulations normally refer to management of solid and liquid waste, but do not provide detailed rules for septage management. Inadequacy in the implementation and enforcement of regulations worsens the problem. We need a better regulatory framework focused on septage management as well as more robust implementation. In February 2017, MoUD issued the National FSSM Policy. The policy aims to set the context, priorities, and direction for, and to facilitate nationwide implementation of, FSSM services in all ULBs such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town and city in India

Resource recovery

In India, still faecal sludge has been considered as a social taboo and practices of resource recovery are minimal. Resource recovery is an important aspect in septage management if we can look it as a wealth. It can be seen as a resource containing nutrients such as nitrogen and phosphorus and, in some cases, varying amounts of micro-nutrients such as boron, copper, iron, manganese, molybdenum and zinc. Urine contains 90 % nitrogen, 50–60 % phosphorus and 50–80 % potassium, which are very valuable in agricultural applications. Septage can reduce reliance on chemical fertilizers and in combination with them, it can meet the requirements of nutrients for crop production. In some experiments, septage has also been used to generate energy through biogas systems and bio-methanization process. The methane thus produced can be used as fuel for cooking or for generation of electricity.

Health and environment implications

Septage contains elements that may produce bad odour, risk public health and create serious environmental hazards. Since septage is highly concentrated, discharging it into a water body may cause immediate depletion of dissolved oxygen and increase nutrients levels in the water, leading to eutrophication and increase in the number of pathogens, thus creating risk of health hazards. Knowledge of septage characteristics and variability is important in determining acceptable disposal methods. There is a direct discharge of collected septage by the private operators into drains, waterways, open land and agricultural fields, which in turn poses a larger threat to the environment and health.

Challenges in FSSM

TABLE 6: CHALLENGES IN FSSM

Components of value chain	Challenges
User Interface	• Availability of the space to construct sanitation facilities • Affordability of the construction cost • Non-availability or limited access of water, electricity • Less operation and maintenance of the sanitation facilities • Quality of the material used for the construction of the sanitation facilities
Collection	• Access for the on-site systems, Congested locations for the movement of desludging trucks • No provisions for secondary effluent disposal units in the form of piped sewer network, leach pits or drain fields, thus directly discharging septic effluent into drains. • Most of the septic tanks present are not constructed as per the standard specifications, leading to varying sizes, partial lining, frequent failures, leakages/contamination of water bodies or soil etc
Conveyance	• Most households only call for septic tank cleaning services when the tank is overflowing or on the verge. The frequency of desludging typically varies from 5 - 10 years due to irregular sizes and usage pattern, which far exceeds the prescribed interval of 2-3 years as recommended by CPHEEO Manual, MoUD advisory on Septage management (2013) • Unsafe handling of faecal sludge by the private operators • Desludging operators and Service providers are not properly trained and do not use safety equipment during operations
Treatment	• Requirement of scientific treatment facilities
Disposal	• Private operators practice the direct discharge of desludged faecal sludge/septage in the open drains, open land, SWM landfill sites etc.

7.5 Further Readings

I. EAWAG/SANDEC (2008): (Sandec Training Tool 1.0, Module 5). Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC) URL

II. STRANDE, L.; RONTELTAP, M.; BRDJANOVIC, D. (2014): Systems Approach for Implementation and Operation. London: IWA Publishing URL

III. Ministry of Housing and Urban Affairs, Government of India: National Policy on Faecal Sludge and Septage Management (FSSM) (2017) URL

8 FSSM Planning Process

8.1 Objectives

- To understand the process of assessment of initial situation
- To understand the role of stakeholders and their engagement in the FSSM activities
- To understand the planning process of Integrated Faecal Sludge Management systems

8.2 Duration

60 min

8.3 Key facts

IV. What is the importance of initial situation assessment?

It is necessity to understand baseline information at the beginning stage of the Faecal sludge management planning process and to identify the data needs to be collected. It is important to identify the shortcomings and challenges of an existing Faecal sludge management system and able to describe an enabling environment.

V. What is the importance of Stakeholders Analysis?

It is obligatory to understand the key stakeholders which will be involved in the faecal sludge management projects and their main interest and constraints. Stakeholders analysis is the process of identifying and characterising stakeholders, investigating relationship between them and planning for their participation. It is a vital tool for understanding the social and institutional context of a project or a policy.

8.4 Learning Notes

8.4.1 Assessment of initial situation

The assessment of the initial situation, which is the first step in the planning process is crucial, as it provides the baseline information for decision making. The main goals of the assessment of the initial situation are to set the scene, understand the context, get to know stakeholders and provide enough information to start elaborating the Faecal sludge management scenarios, including context specific design parameters and therefore this characterized mainly by data collection via different options. Data collection needs to be carried out step by step during the exploratory investigation, preliminary studies and feasibility study.

Tools and Methods of data collection

The collection of good quality data is not an easy process, especially in contexts where data is scarce, not collected or analyzed properly, or hidden or manipulated for political or personal reasons. Governmental agencies usually have the reports, statistics and maps that can serve as a preliminary introduction.

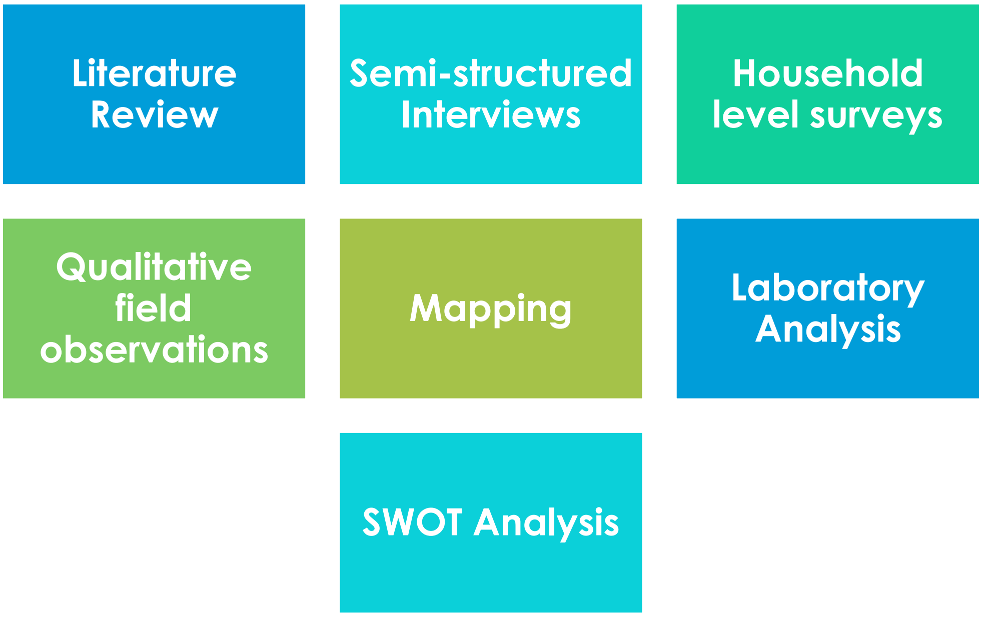


FIGURE 62: TOOLS AND METHOD OF DATA COLLECTION

Literature review

The literature review consists of searching data that already exists (grey literature i.e. reports, maps or white literature i.e. publications). Data quality (especially with statistics) is always questionable, and, in very dynamic contexts, may become quickly outdated. The main source of the information are always the different governmental agencies as well as non-governmental organizations (NGOs) and institutional organizations.

Semi-structured interviews

Semi-structured interviews are one way to structure discussions aimed at collecting information. The interviewers are the process leaders, usually with facilitators ad the interviewees are the FSM stakeholder. Semi structured interviews can be held with individuals or in focus groups. They require time and experienced interviewers but they help to build a solid basis for further work. Semi structured interviews are conducted with a fairly open framework which allows for focused two-way communication. They can be used for both to give and collect information.

Household level surveys

Surveys or questionnaire are a way of collecting information systematically, so that data collected from different sources can be easily compared and analyzed quantitatively e.g. using statistics. In FSM, they are used to collect data at the household level in order to assess the practices, perceptions and sanitation status.

The following aspects need to be part of the household-level survey in a FSM planning process,

- Characterization of the interviewee: status, family, cultural background, household size
- Water supply: water sources, water quality, service quality, water consumption, costs
- Hygiene and sanitation:
    - Type of on-site sanitation technology (or open defecation), numbers of users
    - Type of emptying services (what happens when the pit is full) – if no sewers: mechanical/manual, public/private, frequency (winter/summer or dry/rainy season), cost, perception of cost and service, willingness to pay for improved services
    - If sewer network: type of sewers, problems encountered, discharge point
    - Greywater management
    - Solid waste management: disposal/endues practices
    - Stormwater management
    - In rural areas: animal manuare management – disposal/endsue practices
- Institutional/organizational aspects: who is responsible for each service, positive/negative aspects
- Environmental awareness: perception of cleanliness and health impacts, willingness to improve
- Communications channels: main information sources, information on consumption habits

Qualitative field observations

While field visits are a powerful tool to expose all the stakeholders or reality, they are also a good way for the process leaders to understand the reality better, to cross-check the available information by observing and discussing with people, and to build trust onsite with the main stakeholders. They provide an introduction to the existing sanitation services and an initial understanding of conditions from the perspective of local residents. Quantitative household – level surveys are essential for good quantitative data, but freer observation is also important.

Mapping

Mapping is essential for a clear and extensive analysis of the existing situation, especially when it comes to understanding the city structure and identifying the treatment sites. Mapping is much easier in recent years with the democratization of satellite images (e.g. google earth) and geographical information systems (GIS). A participatory mapping is also recommended, as it is good way to involve selected stakeholders. Particularly important is the identification of key elements, such as existing disposal sites or obstacles for emptying trucks (e.g. road segments prone to traffic jams and poor quality of roads).

Laboratory Analysis

In FSM, where a comprehensive database on FS characteristics does not yet exist, it is usually necessary to carry out the sapling campaigns and analyses in order to be able to characterize the sludge on a site-specific basis. Sludge characteristics vary significantly between and even within the cities, and it is important to obtain first hand data.

SWOT Analysis

When carrying out the initial assessment, it is important to clearly determine what are the strengths, weakness, opportunities and threats (SWOT) of the environment in which the FSM system has to be developed, especially the organizational and institutional framework, as well as the key stakeholders. The SWOT matrix shows the positive and negative factors that have to be dealt with, setting them out clearly in this way makes it possible to take action in order to maximize the potential of the strengths and opportunities while minimizing the impact of the weakness and threats.

FIGURE 63: SWOT MATRIX

FIGURE 64: EXAMPLE OF SWOT MATRIX

Data to be collected

The most important data to be collected is,

- Population and demography: number of inhabitants, number of people per household, population density and growth rate, type of housing
- Water and hygiene: drinking water coverage and infrastructure, drinking water sources, types of supply (e.g. networks, taps in houses, fountains, trucks), operators (public/private), prevalence of diseases related to faecal matter

- Physical characteristics: geomorphology, hydrologic basins, areas prone to flooding, types of soil, ground water table
- Climatic data
- Stormwater management
- Main elements of the city structure
- Local economy: main economic activities in the city, main sources of household revenue, average income

Latrines and onsite treatment	
Water availability	Information on existing water supply services (including daily consumption per household) can be used to estimate daily wastewater production
Sanitation facilities	Current levels of service (household and shared facilities) including approximate household coverage and number and location of communal or public toilets
Onsite treatment	Types of onsite sanitation system serving households with households connections
Waste collection and conveyance	
Existing sewerage infrastructure	Coverage of sewerage and proportion of household with household connections
Faecal sludge and septage collection services	Coverage and frequency of servicing
Offsite wastewater treatment and reuse	
Wastewater treatment	Location and types of wastewater treatment infrastructure (if any exists)
Discharge or enduse	Location where wastewater and faecal sludge is disposed or endused

FIGURE 65: RELEVANT INFORMATION OF EXISTING SANITATION SERVICES

8.4.2 Stakeholders analysis

Managing faecal sludge at city level in an efficient and sustainable way requires the involvement and support of all concerned key stakeholders. Stakeholders is mean that any group, organization or individual that can influence or be influenced by the project. In order to understand and engage stakeholders, stakeholder analyses should be performed. Stakeholders analysis is the process of identifying and characterizing the stakeholders, investigating the relationships between them, and planning for their participation. It is vital tool for understanding the social and institutional context of a project or a policy. Its findings can provide early and essential information about who will be affected by the project and who could influence the project, which individuals, groups or agencies need to be involved in the project and whose capacity needs to be built to enable them to participate.

Stakeholders analysis process is important in order to,

- Identify who to involve and at what level of participation, at different stages of the planning and implementation process
- Understand who has what interest and who is influential in supporting or in blocking/delaying/rejecting the project
- Identify conflicts of interests between stakeholders
- Identify relations between stakeholders that should be improved and strengthened
- Structure the knowledge about the project stakeholders and share it with others
- Understand how to deal with the different people; for example, it should be clear who needs to be empowered, who needs to be informed and who should be dealt with in a particularly careful way (potential threats)
- In partnership with governments and implementing agencies, assess how best to harness the positive aspects of the informal sector, minimize the negative aspects, and look for genuinely effective ways of creating effective links between the formal and the informal

Identification of Stakeholders

Stakeholders identification is one of the first tasks when starting a new project. Collaboration with local facilitators is essential to get the situation under control quickly. Identifying stakeholders is an iterative process, during which additional stakeholders are added as the analysis develops

FIGURE 66: KEY STAKEHOLDERS

Characterization of Stakeholders

Characterization of stakeholders provides the necessary information on how to best involve each stakeholder and at the end process, how to best attribute roles and responsibilities.

Information to be collected

Main interest: Consultation with stakeholders should be carried out in order to determine how each interest can be taken into account in the future FS systems.

Strength: Establish what the process leader can count on.

Weakness: Establish where information, empowerment and capacity building is needed.

Opportunities/threats: Characterise the potential positive (negative) perspective of the project.

Relationship between stakeholders: Hierarchy, friendship, competition or professional link. Good, bad can decide which working groups can be built.

Impacts: Type of impact of the project on the stakeholder determines the measure needed to maximise positive impact and mitigate negative impact.

Involvement needs: The action required, results mainly from identified interest, weakness and potential.

Involvement needs (including training needs): the action required results mainly from identified interests, weakness and potentials

Stakeholders	Interests	Strengths	Weaknesses	Opportunities/ threats	Relationships	Impacts	Involvement needs
Stakeholder a							
Stakeholder b							
Stakeholder c							
...							

FIGURE 67: EXAMPLE OF STAKEHOLDERS ANALYSIS

It is important to differentiate between two different types of the opportunities and threat; the influence over the project and the interest in the project.

Influence: is the power that stakeholders have on the project i.e. to control which decisions are made facilitate their implementation or affect the project negatively.

Interest: characterise stakeholders whose needs constraints and problems are a priority in the strategy, e.g. sludge service providers, end users, households and sanitation authorities.

INFLUENCE FACTORS	
Within and between formal organisations	**For informal groups**
Hierarchy (command and control, budget holders)	Social, economic and political status
Leadership (formal and informal, charisma, political, familial)	Degree of organisation, consensus and leadership in the group
Control of strategic resources for the project	Degree of control of strategic resources significant for the project
Possession of specialist knowledge (e.g. engineering staff)	Informal influence through links with other stakeholders
Negotiating position (strength in relation to other stakeholders in the project) - personal connections to ruling politicians	Degree of dependence on other stakeholders

FIGURE 68; VARIABLES AFFECTING STAKEHOLDERS RELATIVE INFLUENCE

	Low influence	*High influence*
Low interest	Stakeholders are unlikely to be closely involved in the project and require not more than information-sharing aimed at the 'general public' *Information*	Stakeholders may oppose the intervention; therefore, they should be kept informed and their views acknowledged to avoid disruption or conflict *Consultation - Information*
High interest	Stakeholders require special effort to ensure that their needs are met and their participation is meaningful *Consultation - Empowerment*	Stakeholders should be closely involved to ensure their support for the project *Consultation - Collaboration Empowerment / Delegation*

FIGURE 69: INFLUENCE-INTEREST MATRIX TO IDENTIFY INVOLVEMENT NEEDS AND PARTICIPATION LEVELS

TABLE 7: TYPICAL CHARACTERISTICS OF THE MAIN STAKEHOLDERS AND ACTIONS TO BE UNDERTAKEN

Stakeholder categories	Main interests	Opportunities	Involvement needs and required actions
Municipal authorities	▪ Public health ▪ Cleanliness of the city ▪ Collection and management of sanitation fees	▪ Power for enforcement through regulatory framework and police ▪ Management of treatment units ▪ Link with other stakeholders, existing contracts and authorisations ▪ Development of social services	▪ Sensitisation, need for capacity building, collaboration ▪ Institutional and regulatory frameworks often need to be developed and their application enforced ▪ Often lack financial, human resources and land ▪ Involve them in the financing scheme
Regional and national authorities	▪ Respect for laws and regulations ▪ Capacity building ▪ Master plans	▪ Collaboration between agencies, development of synergies ▪ Support for baseline data	▪ Sensitisation, information
Utilities	▪ Sufficient revenues ▪ Municipal, regional or national priorities	▪ Collection, transport and treatment under the same umbrella ▪ Cross-subsidy to allow social service	▪ Collaboration, sensitisation ▪ Ensure that they act as 'public services' reaching low-income areas and not only upper-class neighbourhoods
Traditional authorities	▪ Public health	▪ Support and land property	▪ Consultation, information, sensitisation
Small-scale FS businesses ▪ Mechanical service providers	▪ Sufficient revenues ▪ Disposal sites close to working area ▪ Clarification of legal status, better image	▪ Increase in quality of service ▪ Lower emptying price ▪ Collaboration with manual service providers	▪ Organise in association (empowerment) ▪ Organise the market ▪ Control the respect for rules ▪ Contracts/licenses should be issued by municipal authorities
▪ Manual service providers	▪ Sufficient revenues ▪ Gain status, social recognition ▪ Reduce risk at the workplace	▪ Improvement of working conditions	▪ Organise in association (empowerment) ▪ Empowerment ('give them a voice') and capacity building ▪ Organise a service of collection and transport or transfer of sludge
Organisations active in sanitation	▪ Wellbeing of citizens ▪ Clean environment ▪ Capacity building ▪ Visibility	▪ Experience in sanitation advocacy ▪ Existing structures, human resources and competencies ▪ Contact with households ▪ Capacity to obtain funding	▪ Some organisation can be of great help (facilitation, experience, and international funding). ▪ Their relationship with the authorities should be investigated
Potential endusers	▪ Affordable and safe products ▪ Yield increase	▪ Increase WWTP's revenue through selling of endproducts	▪ Create enduser groups (empowerment) ▪ Market study, and willingness and capacity to pay
Households (users and owners)	▪ Affordability of collection service ▪ Clean environment	▪ Pressure on municipal authorities and service providers ▪ Pay more for a better service ▪ Better management of onsite systems	▪ Information, sensitisation for behaviour change, especially management of onsite systems ▪ Assessment of willingness and capacity to pay ▪ Advice for latrine construction

8.4.3 Stakeholders engagement

Stakeholder engagement or stakeholder involvement is key for the successful implementation of faecal sludge management (FSM) projects. It is the art of including stakeholders in the planning process in order to take into account their needs, priorities and interests, to achieve consensus and to remove opposition. Stakeholder engagement is largely about defining the participation level of people in the process and how to best answer their needs (e.g. through awareness raising or training and capacity building).

Stakeholders Participation Levels

The level of participation depends on what needs to be achieved with the targeted stakeholders e.g. households may be informed about the process or consulted to understand their collection needs. Collection and transportation operators may be consulted about their routes and to help define optimal disposal sites or collaborate on regulation definition.

Aspects should be considered when developing the involvement strategy,

- Perception of involvement: indicates how involved stakeholders feel
- Willingness to contribute to the project
- Expected benefit from the project
- Level of obligation which the stakeholder feels towards their responsibilities in the project
- People influencing the willingness of the stakeholder and extent of the peer pressure

Stakeholders Participation Matrix

- **Information**: Objective is to enable the stakeholders to understand the situation, the different options and their implications. This is one-way flow of communication.
- **Consultation**: Objective is to have stakeholders' feedback on the situation, options, scenarios and / or decisions.
- **Collaboration**: Objective is to work as a partner with the stakeholder on various aspects such as creating scenarios and identification of preferred solution.
- **Empowerment / Delegation**: Objective is to build capacities of the stakeholders so that they can make informed decision, take responsibility of final decision making, and assume their roles and responsibilities in the FSM system.

TABLE 8: STAKEHOLDERS PARTICIPATION MATRIX

		Participation levels			
		Information	Consultation	Collaboration	Empowerment / delegation
Planning	*Launch of the planning process*	All stakeholders		Municipality, utilities	
	Detailed assessment of current situation		Key stakeholders[1]	Municipality, utilities	
	Identification of service options		Key stakeholders[1]	Municipality, utilities	
	Development of an Action Plan	All stakeholders	Endusers	Municipality, utilities, FS operators, NGOs	Empower weak and non-organised groups
Implementation		Households, traditional authorities and opinion leaders	Endusers	Municipality, utilities, FS operators, NGOs	Empower and delegate to municipality, utilities, FS operators, NGOs
Monitoring & Evaluation		Key stakeholders	Households, FS operators, endusers	Municipality, utilities, selected NGOs	

TABLE 9: STAKEHOLDERS INVOLVEMENT TECHNIQUES AND PARTICIPATION LEVELS

	Information	Consultation	Collaboration	Empowerment / delegation
Personal meetings	▪	▪	▪	▪
Focus groups		▪	▪	▪
Workshops	▪	▪	▪	▪
Site visits	▪	▪		
Media campaigns	▪			
Household surveys		▪		
Advocacy / lobbying	▪		▪	▪
Mediation		▪	▪	▪
Logical framework		▪	▪	

Milestones and Cross-cutting tasks

The way in which participation level evolve is context specific and the process is marked out by the milestones corresponding to the end of phases, where the participation levels are formally re-thought and important changes can be decided for the next step.

In parallel, the planning process is marked by two participatory cross-cutting tasks, i) awareness raising to a wide audience and ii) capacity building

Main milestones in the participatory process

There are three milestones identified for the involvement strategy,

- **Initial launching workshop:** including a field visit with all the stakeholders. This consist mainly of an information workshop, aiming to communicate the plans, activities and current stage of the process. Afterwards, all the stakeholders have the common understanding
- **Validation workshop of selected options by all the stakeholders:** This event brings all the key stakeholders together publically and officially seal the decisions taken up to this point. The technical options and management options are presented, discussed and validated.
- **Validation workshop of the action plan:** This workshop seals the agreements reached on the validation options and how to proceed further. The roles and responsibilities of the different stakeholders in the project are defined in a common understanding, which will facilitate the coordination of the various tasks.

Cross-cutting Tasks

- **Raising Awareness:** Enabling people to make informed choices and adopt good practices. It is critical to reach a common understanding of existing problems and to ensure that the stakeholders agree on the goals.
- **Training and capacity building:** Skills and capacities are important components of the enabling environment. When it comes to implementation, the capacities at the technical, managerial, financial, commercial and social levels are crucial. Several tools and activities such as workshops, practical exercises, participative document elaboration and field visits can be used for training.

Roles and Responsibilities

Once the technical options and organizational modes have been chosen, the roles and responsibilities need to be distributed and formalised. According to the particular situation and the stakeholders who are involved formalisation documents can take different forms such as licenses, contracts, partnership agreements, standards and laws. These different types of documents are described below,

- **Licences:** Issued by authorities for services throughout the whole supply chain. Licence document should contain list of requirements, activities allowed and validity of the licence.
- **Contracts:** Contracts can be signed between the stakeholders involved in the FSM supply chain for specific activities or services. (1) contracts linking a service provider to its customers (2) contracts linking two operators undertaking different activities in the supply chain (3) contracts between one operator and the authorities.

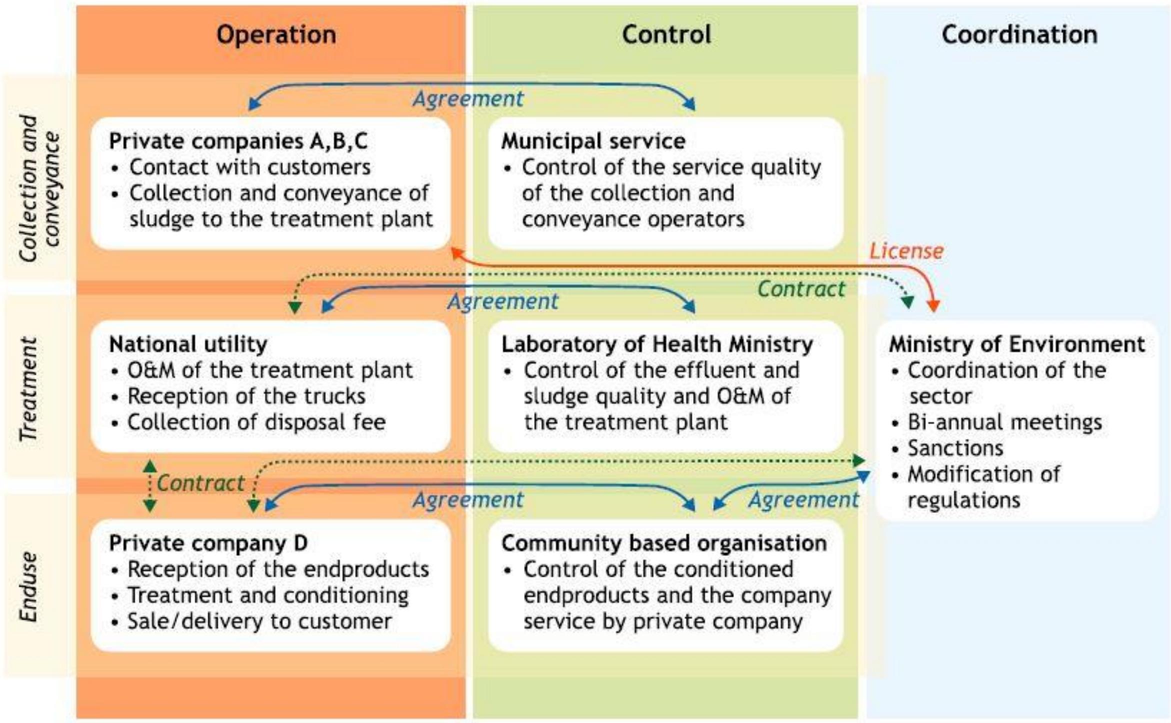


FIGURE 70: RELATIONSHIPS WITH FORMAL LINKS BETWEEN STAKEHOLDERS

- **Partnership agreements:** Agreements can be signed between two stakeholders to provide a collaborative framework for the institutional or technical management of any component of FS supply chain. Public private partnership where stakeholders from the public and the private sector collaborate to provide services to the population.

8.4.4 Planning of Integrated Faecal Sludge Management system

Need for an Integrated Approach

In the past, many water and sanitation projects have failed because of the lack of an integrated approach. The development of physical infrastructure is only one component of a functioning FSM program which also depends upon sustained public-sector commitment and funding, effective policies, appropriate implementation and compliance enforcement. Common reasons for failure are the implementation of infrastructure without consulting the main stakeholders or without planning adequate operation and maintenance (O&M) and financial schemes. Lack of institutionalisation of the system, lack of skills, insufficient organisational capacity and lack of cost-recovery mechanisms are also recognised as major factors in failure.

Enabling Environment

The major barriers to progress in sanitation coverage lie within the institutions, policies and realities of low and middle-income countries. The public sector is often weak in terms of skills, structure, planning capacity and bureaucratic procedures and mechanisms are not always in place to recover investment, operation or management costs, leading to a degradation of service provision or even system failure. An enabling environment is critical for the success of any type of investment, whether this is for the improvement of a single public latrine or a city-wide FSM system. Understanding the conditions necessary in a particular context for the environment to be enabling is part of an integrated approach.

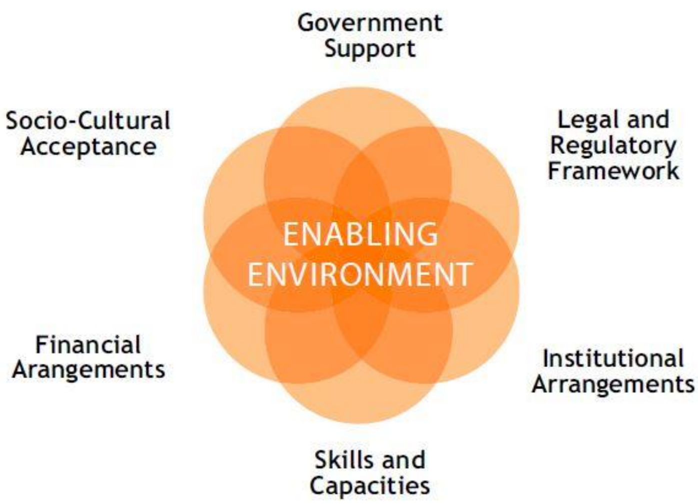


FIGURE 71: COMPONENTS OF ENABLING ENVIRONMENT

Government Support: Conflicting political priorities and therefore, a lack of explicit political support is often the initial cause for project failure. Enabling government support includes not only relevant national policy frameworks and sector strategies, but also receptive local authorities and decision makers.

Legal and regulatory framework: The technical norms and standards that influence the types and service that are put in place are clearly important. Typical problems include regulatory inconsistencies, lack of regulations or unrealistic standards. A further issue in many countries is the poor enforcement of existing regulations. For the legal framework to contribute to the enabling environment, it must be transparent, realistic and enforced.

Institutional arrangements: Public institutions and private actors are integral to an enabling environment and getting the institutional environment right is a key ingredient for the sustainable delivery of sanitation services. This encompasses the correct understanding of roles and responsibilities and capacities of each stakeholder, as well as their influence and interest in improving service provision. A potential obstacle may be overlapping mandates between different institutions.

Skills and capacities: Developing the required skills and capacities at all levels is a key requirement and an issue that can take considerable time to develop. Identifying capacity gaps, particularly at district and municipal level, and then filling the gaps with tailored training courses, on the job training etc is a prerequisite.

Financial Arrangements: Implementing and maintaining environmental sanitation services is costly and requires an enabling financial environment. Financial contributions and investments are required from users, from government agencies and from the private sector.

Socio cultural acceptance: Achieving socio cultural acceptance depends on matching each aspect of the proposed sanitation system as closely as possible to the users preferences. Failure to ensure that the implemented solution is socio-culturally embedded is one of the most common reasons for past projects.

Selecting context-appropriate technical options

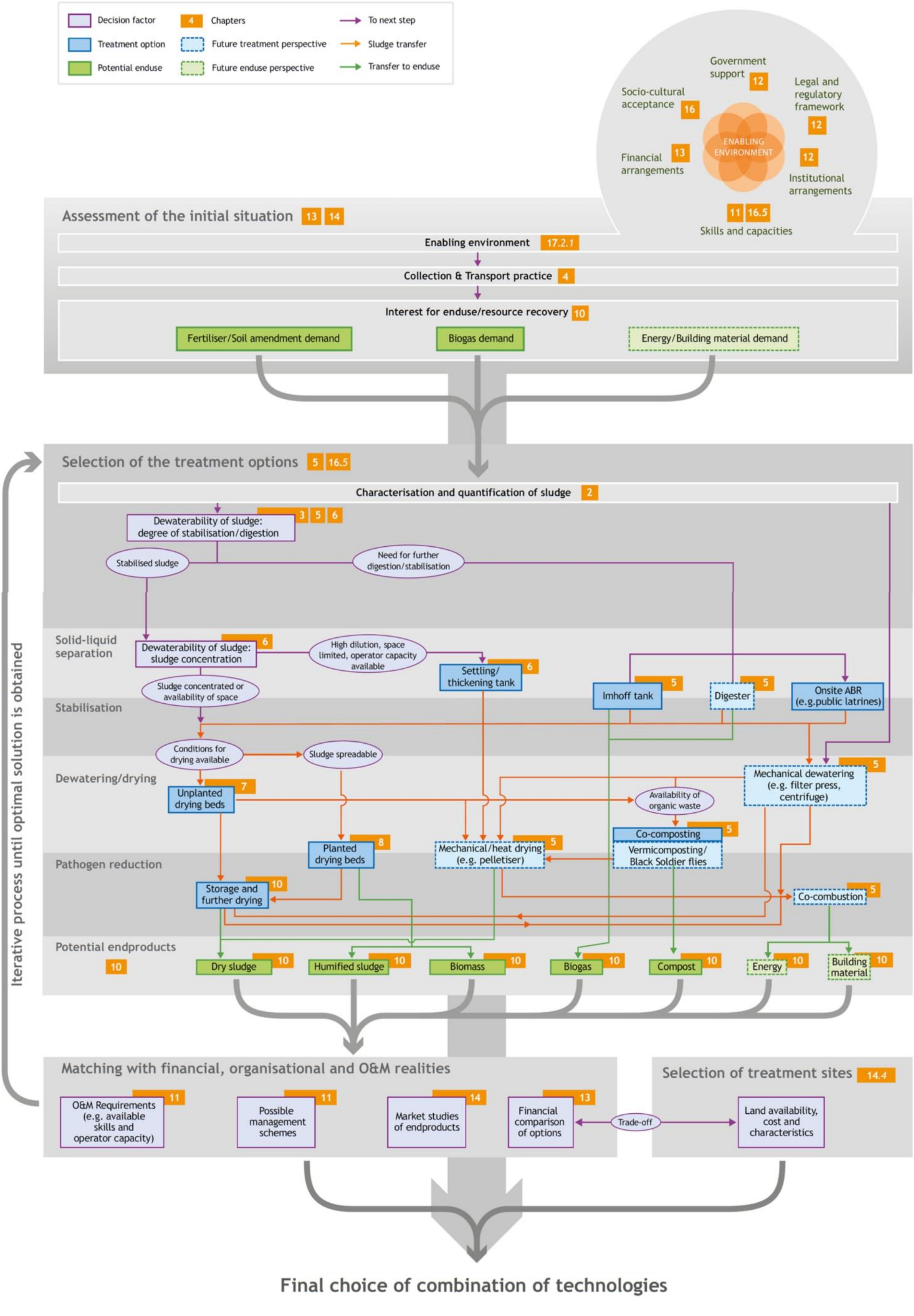
Setting up a FSM system is not only about the selection of single technological options, but about finding a sustainable combination of services that guarantees the appropriate collection, conveyance, treatment and disposal or endues of FS, in a way that ensures household satisfaction, broad coverage and cost recovery.

A FSM system should be efficient and flexible, i.e. able to function normally and adapt to the frequency of sludge delivery and sludge quantities and characteristics, cope with climatic variations, produce end-products that are safe for use, be able to guarantee that the investment and O&M costs are acceptable and that are skilled employees for operation. Eleven criteria for the selection of a combination of technologies are proposed, divided into four categories: treatment performance, local context, O&M requirements and costs,

TABLE 10: CRITERIA FOR SELECTION OF TREATMENT OPTIONS

Treatment performance	Local context	O&M requirements	Costs
• Effluent and sludge quality according to national standards	• Characteristics of sludge (dewaterability, concentration, degree of digestion, spreadability) • Quantity and frequency of sludge discharged at the FSTP • Climate • Land availability and cost • Interest in enduse (fertiliser, forage, biogas, compost, fuel)	• Skills needed for operation, maintenance and monitoring available locally • Spare parts available locally	• Investment costs covered (land, infrastructure, human resources, capacity building) • O&M costs covered • Affordability for households

Selecting a context-appropriate combination of faecal sludge treatment technologies



8.5 Further Readings

I. STRANDE, L.; RONTELTAP, M.; BRDJANOVIC, D. (2014): Systems Approach for Implementation and Operation. London: IWA Publishing URL.

II. EAWAG/SANDEC (2008): (Sandec Training Tool 1.0, Module 5). Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC) URL

9 Financing of FSSM

9.1 Objectives

- To understand the assessment of financial requirements and potential sources of financing.
- To understand the stakeholder's involvement in financial transfers.
- To understand the types of financial transfers and financial flow models.

9.2 Duration

60 min

9.3 Key facts

VI. What are the types of financial transfers?

In FSM system, money is exchanged for different activities (e.g. emptying, transport, processing) at different orders of magnitude and with different frequency. Common financial transfers are,

- Budget Support
- Capital investment
- Discharge fee
- Discharge incentives
- Discharge license
- Emptying fee
- Fines
- Operation and Maintenance
- Purchase price
- Sanitation tax

VII. What are the different financial models?

There is no single FSM model that has proven to be effective in all situations; indeed, service delivery models are constantly modified and restructured depending on the economic, legal, and environmental conditions. Furthermore, the responsibilities within the system are constantly changing and as such, the financial transfers between stakeholders can take several forms. Different financial models are,

- **Model 1:** Discrete collection and treatment model showing the responsibility of each stakeholder and the related financial transfers.

- **Model 2:** Integrated collection, transport and treatment model.
- **Model 3:** Parallel tax and discharge fee model.
- **Model 4:** Dual licensing and sanitation tax model
- **Model 5:** Incentivised discharge model

9.4 Learning Notes

9.4.1 Assessment of financial requirements

One of the reasons that faecal sludge management (FSM) systems have not been widely implemented is because of the financial and political complexity involved. This is not only due to the number of stakeholders who have a financial interest in the system, but also to the diversity of the interests each stakeholder has. Unlike other types of infrastructure (e.g. electricity) where a single utility is usually responsible for the generation, delivery, operation, maintenance and billing, a faecal sludge (FS) system is more commonly a collection of stakeholders, each of whom is responsible for a different part of the treatment chain. Consequently, payments must be made each time responsibility is transferred from one stakeholder to another. Only a special set of political and financial conditions can foster an environment that allows each essential stakeholder to perform their task and permit a complete treatment chain to take form.

Financial requirement of Integrated FSM

The financial requirements as capital Investment and O+M costs of FS collection and treatment must be determined on a case-to-case basis as local conditions are decisive

- Economic indicators (land price, labour cost, interest rates, petrol prices).
- Possible income from the sale of treatment products (e.g. hygienised biosolids or compost, biogas).
- Site conditions (permeability, ground water table).
- Haulage distances and traffic conditions.
- Economy of scale (plant size).
- Legal discharge standards.

FSM component wise financial requirements are given in the following table,

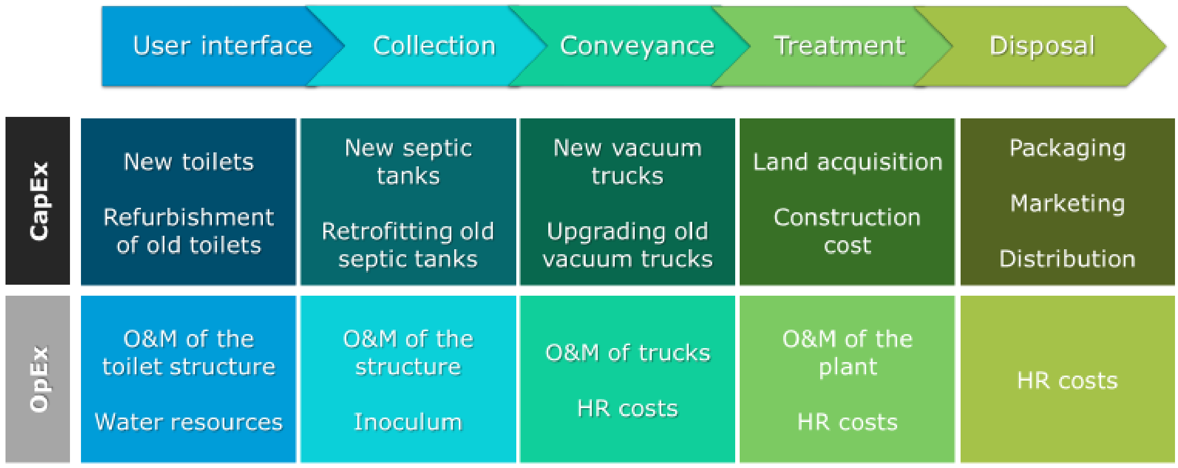


FIGURE 72: FSM COMPONENT WISE FINANCIAL REQUIREMENTS

9.4.2 Potential sources of financing

This section describes the potential sources of financing in each component of the Faecal sludge management system. There are some major sources which are crucial in the proper financial fulfillment of the system e.g. central or state government grants, government subsidy, local level service taxation, CSR fundings etc.

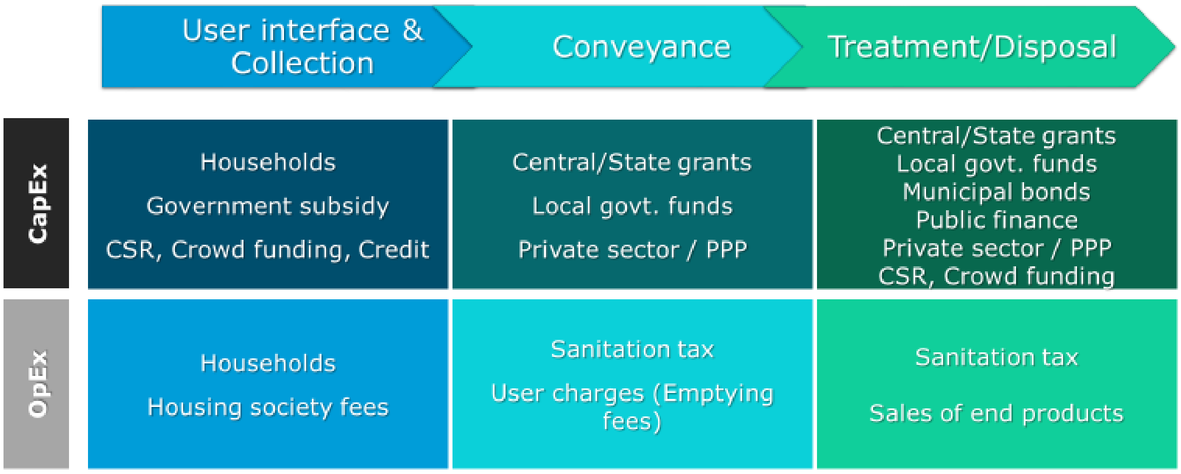


FIGURE 73: POTENTIAL SOURCES OF FINANCING

9.4.3 **Stakeholders involved in financial transfers**

Every stakeholder in a FS system is involved in some kind of financial interaction. Stakeholders are those people, institutions or enterprises that send or receive payment in exchange for taking responsibility for one or more processes in the FS treatment chain. The stakeholders and their financial responsibilities are described below,

- **Enduse industries** are those stakeholders that make use of the inherent nutrients, energy potential, and bulking properties of treated FS. The enduse(s) of FS should be considered when designing the entire FSM service chain to ensure the appropriate design of treatment technologies; i.e. so that the best quality FS can be generated for its specific final use. With a growing need for low-cost, locally sourced, sustainable nutrients, the agricultural industry will likely emerge as an important enduse stakeholder. FS is also a promising sustainable energy source. In the future, the financial benefits and environmental necessity of enduse may become drivers for improved FSM and influence the design of FS systems. The demand for sludge, as well as the legal framework for its application, will have an increasingly powerful impact on how FS is managed through the entire process chain.

- **Government authorities** are responsible for the rules and regulations to which private enterprises and public utilities must adhere. Government authorities may allocate budgets to utilities and outsource work to private enterprises but may also plan and manage their own FS programs internally. Government authorities are responsible for collecting taxes in order to cover, or partly cover their budgets. Authorities may also be recipients of foreign aid, which may be allocated to the construction, operation or maintenance of public infrastructure.
- **Household-level toilet users** are those people who are responsible for removing FS from property that they own or rent. These people have some type of onsite sanitation technology that requires periodic FS removal. Technologies that require periodic emptying include septic tanks, pit latrines, anaerobic baffled reactors (ABRs) (for clusters of houses) or other similar, water-based storage technologies.
- **Non-Governmental organisations (NGOs)** are enterprises that operate on a not for profit basis and which are not funded or supported directly by government, although they are often sub-contracted by government for specific tasks. NGOs operate in the social-service niches left where governments and private enterprise are unwilling or unable to operate effectively.
- **Private enterprises** are organisations that operate on a for-profit basis by providing goods or services in exchange for payment. Private enterprises are bound by the laws of the state and may accept contracts to work for the state. However, private enterprises are not wholly or in part, associated with government at any level and do not receive guaranteed government funding (though they may apply for subsidies, loans, etc.).

- **Public utilities** are responsible for operating and maintaining public infrastructure (e.g. water or electricity). They are extensions of government authorities, and as such, are funded by government budgets. Depending on how well the public utility (PU) is run, and how users are billed, the PU may operate at a loss. Public utilities provide a useful service, which may not otherwise exist in a free market (e.g. sludge treatment) but have typically operated as monopolies.

9.4.4 Financial transfers

In FSM system, money is exchanged for different activities (e.g. emptying, transport, processing), at different orders of magnitude (e.g. small service payments, massive construction costs), and with different frequency (e.g. daily transfer frees, annual taxes). To achieve a financially sustainable business model, a prudent selection of the transfer types must be implemented.

Budget support

- Cash transfers between stakeholders to partly or fully cover one stakeholder's operating budget.
- Government authority would provide a public utility
- Usually long-term and non-conditional

Capital investment

- Paid once, at the beginning of the project to cover all expenses needed to build the facility

Discharge fee

- Charged in exchange for permission to discharge FS at some type of facility.
- Responsibility transfer to a stakeholder who has the legal and technical ability to safely process and/or transfer FS to another responsible stakeholder.
- Highly influences and collection and transport and treatment stage in FSSM. (per trip, per volume)

Discharge incentive

- To reward the C&T business for discharge the sludge in a designated location
- Other means of meeting their costs (sanitation tax)
- Highly effective, more of "carrot" than the "stick" approach!

Discharge license

- Used to control the number and quality of collection and transport enterprises
- Unwanted effect of creating parallel black market.

Emptying fees

- Charged at the household level for removing FS from the onsite sanitation technology
- The emptying fee can be paid once the service is provided, but this type of payment model does not encourage the household to arrange for the emptying until it is absolutely necessary or long overdue.
- Emptying fees vary depending on country, region, currency, market, volume, road condition and a host of other criteria.

Fines

- tools used by the government, or other legal authorities to control and discourage undesirable behaviour.
- fines should be high enough, and enforced often enough, to present a genuine threat to illegal/informal practices
- However, there should be an alternative option to fines that is a functional FSTP which is easily accessible.

Operation and maintenance

- expenses that must be paid regularly and continually until the service life of the infrastructure/equipment has been reached.
- Proper O&M reduces the frequent replacement cost of the equipment and machinery

Purchase price

- the price paid by one stakeholder to another in exchange for becoming the sole owner of a good.
- The purchase price is dependent on supply, demand, and any subsidies that may be available.

Sanitation tax

- fee collected either once, or at regular intervals, and which is paid in exchange for environmental services such as a water connection, a sewer connection / removal of FS, or any combination of these services.
- provides a steady source of income allowing treatment and upgrade activities to be more easily planned.

9.4.5 Financial flow models

There is no single FSM model that has proven to be effective in all situations; indeed, service delivery models are constantly modified and restructured depending on the economic, legal, and environmental conditions. Furthermore, the responsibilities within the system are constantly changing and as such, the financial transfers between stakeholders can take several forms.

Model 1: Discrete collection and treatment model showing the responsibility of each stakeholder and the related financial transfers.

In Model 1, each of the stakeholders is responsible for a single technology in the FSM chain, and consequently, money is exchanged each time responsibility is handed over (emptying and transport are identified here as a single technology). The household-level toilet user pays a private enterprise (PE) an emptying fee to remove the sludge and the PE is responsible for the emptying and transportation of the sludge. The PE is then charged a discharge

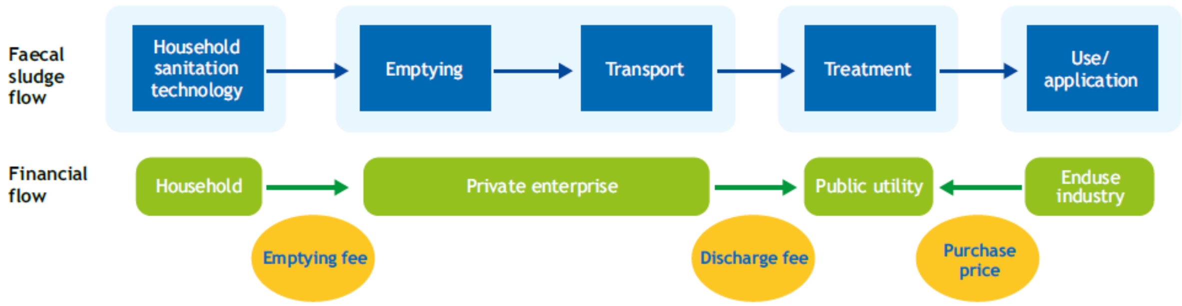


FIGURE 74: MODEL 1: DISCRETE COLLECTION AND TREATMENT MODEL SHOWING THE RESPONSIBILITY OF EACH STAKEHOLDER AND THE RELATED FINANCIAL TRANSFERS

fee by the public utility for accepting and treating the sludge. The utility is also paid a purchase price by an end-use industry in exchange for treated FS or sludge-grown products (e.g. fodder). In this model, the utility operates independently from the government authority and must cover all costs by collecting sufficient discharge and purchase fees.

PROS	CONS
• *Households are free to choose the most competitive price on offer for emptying;* • *Timing of emptying is flexible and can be done when financially feasible* • *The household is not committed to a fixed sanitation tax*	• *The utility's operating expenses must be covered by the discharge fee*

Model 2: Integrated collection, transport and treatment model

In model 2 the operator responsible for treatment is not subject to the sludge or payment irregularities of the PE responsible for emptying. The model 2 appears similar to model 1, but the financial implications are significantly different. In model 2, a single private enterprise or non-governmental organisation (NGO) is responsible for the emptying, transport and treatment, thus eliminating the need for a discharge fee between the stakeholder responsible for C&T and the stakeholder responsible for treatment.

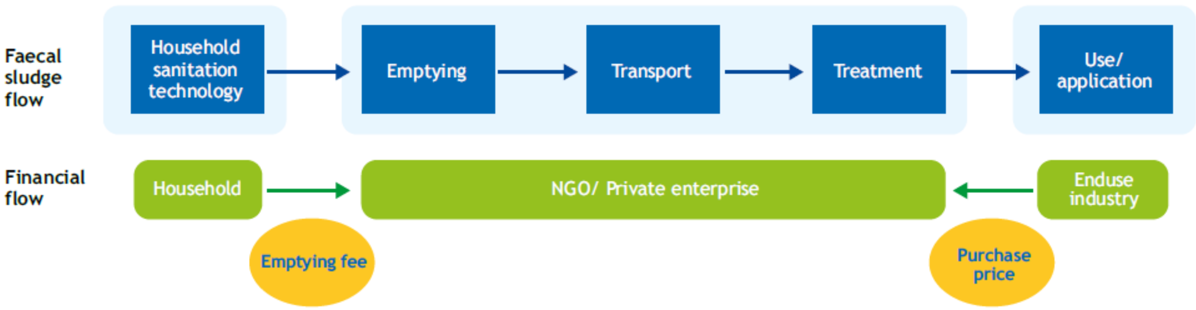


FIGURE 75: MODEL 2: INTEGRATED COLLECTION, TRANSPORT AND TREATMENT MODEL

PROS	CONS
• *A single operator is able to optimise the business model and improve efficiency;* • *Less potential for illegal discharge as the single entity will discharge at the self-run treatment works*	• *High fees may be passed onto the household*

Model 3: Parallel tax and discharge fee model

In model 3, a sanitation tax is paid directly to the government authority by the toilet user, either through water, sewer, or property taxes. The utility is given budget support from the government authority that collects the sanitation tax. The utility therefore does not need to rely entirely on the discharge fee and could lower it (in comparison to Model 1) thus reducing the total costs of the private enterprise. The discharge fee must therefore be high enough, such that operator can hold the PEs accountable for what they dump, but not so high that the toilet users are unable to afford the high emptying fees passed onto them by the C&T operators, or that the sludge is dumped illegally. This system is prone to corruption and under-servicing if the government authority is not competent or transparent in how it allocates it money. Furthermore, the financial balance is very much dependent on the consistent collection of the sanitation tax. Unstable land tenure, poor record keeping, corruption, transient populations and other features of fast-growing urban centres threaten the collection of a steady stream of user-based revenue. Fee collection is notoriously low in many government authorities and fluctuations in the sanitation fees can significantly affect the ability for the utility to make long term O&M decisions if there are not reserves available from the authority to buffer the variation.

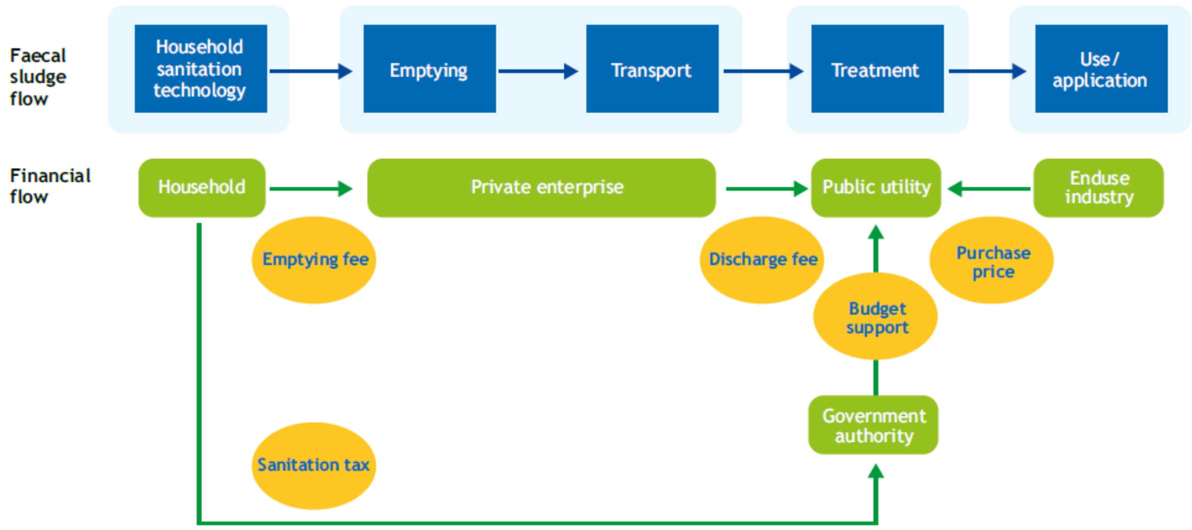


FIGURE 76: MODEL 3: PARALLEL TAX AND DISCHARGE FEE MODEL

PROS	CONS
• *Low-income households' that are not connected to the sewer may have lower C&T costs from cross subsidies;* • *C&T operators may benefit from lower discharge fees* • *Collection and coverage increases*	• *C&T businesses may avoid discharge fees by discharge illegally*

Model 4: Dual licensing and sanitation tax model

In the dual licensing and sanitation tax model, the private entrepreneur who is responsible for C&T is not penalised with a discharge fee for each discharge at the FSTP, but instead is granted unlimited (or semi-limited) access to dump through a discharge license, thus reducing illegal discharge by those C&T operators who may not be able to afford the discharge fee. Having to pay a discharge license, no matter how nominal, ensures that the government has more administrative control over the industry. Data on the number of operators, the revenue that is generated, the distances travelled etc. can be collected and used to advise policy.

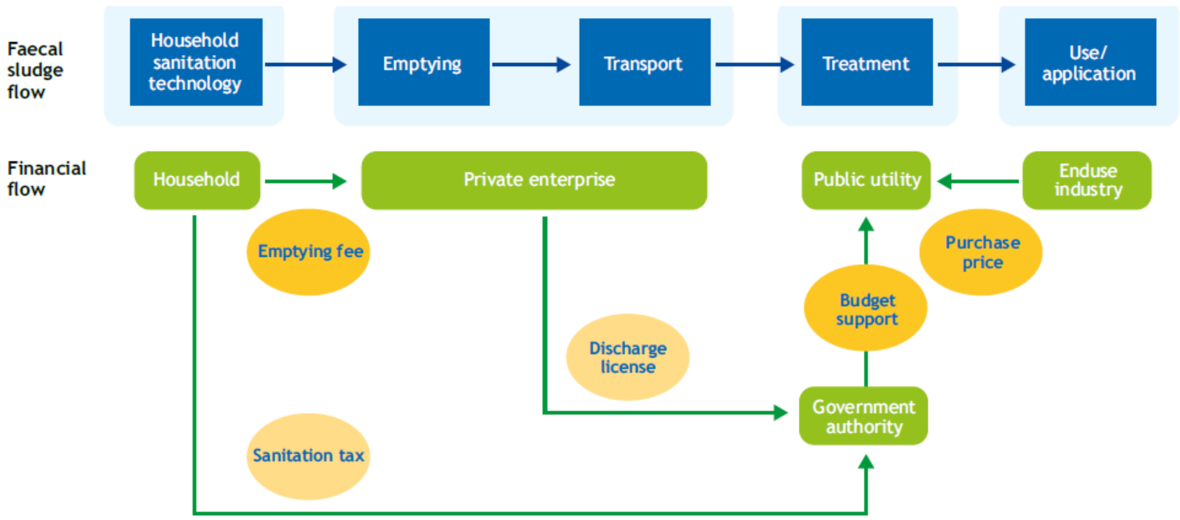


FIGURE 77: MODEL 4: DUAL LICENSING AND SANITATION TAX MODEL

PROS	CONS
• *Industry regulation and legitimisation through licensing* • *Improvement in health and safety conditions;* • *Unlimited discharges minimise risk of illegal dumping*	• *The management of too many aspects of the service chain by one entity could prove difficult for a new business or NGO*

Model 5: Incentivised discharge model

An important feature of the model 5 is the direction of the financial transfer from the public utility to the private entrepreneur. In this model, the FSTP operator pays the stakeholder responsible for C&T a discharge incentive to dump sludge at the FSTP. A financial model that includes discharge incentives could take a variety of forms. As financial incentives can be used to encourage socially desirable behaviour. In the case of discharge incentives, the payment is used to encourage sludge collection and reduce illegal discharge.

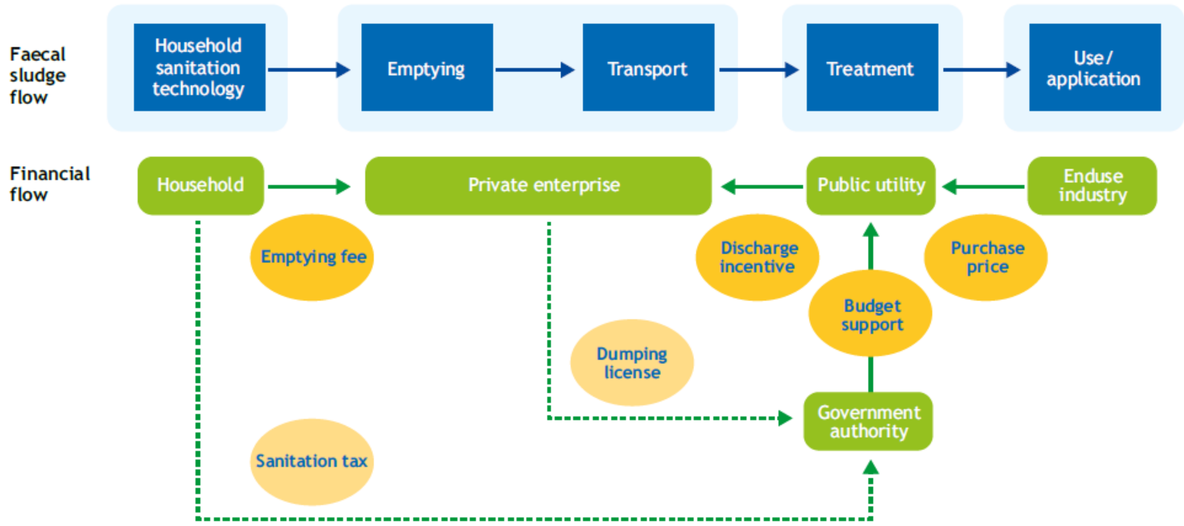


FIGURE 78: MODEL 5: INCENTIVISED DISCHARGE MODEL

This model is built on the theory that C&T stakeholders cannot afford the discharge fees charged by FSTP operators and so dump indiscriminately, causing damage to public and environmental health. Working under this scheme, the C&T operator would only have to recover a portion of the total operating costs from the emptying fee (the other portion would be made up by the discharge incentive). As a result, the collection service would be more affordable for poorer households, more sludge would be collected, less sludge would be discharged to the environment and the community as a whole would benefit.

PROS	***CONS***
• *Emptying fees for households may be reduced;* • *Households that are difficult to access, or located far from the treatment plant, may become attractive to C&T operators because of incentives*	• *Incentives must be corruption proof (e.g. not given for diluted sludge etc.)* • *FSTP operator requires significant budget support to function budget support to function*

9.5 Further Readings

I. STRANDE, L.; RONTELTAP, M.; BRDJANOVIC, D. (2014): Systems Approach for Implementation and Operation. London: IWA Publishing URL.

II. EAWAG/SANDEC (2008): (Sandec Training Tool 1.0, Module 5). Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC) URL

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