THE UNITED REPUBLIC OF TANZANIA

VICE-PRESIDENT'S OFFICE

GUIDELINES ON MANAGEMENT OF LIQUID WASTE

DIVISION OF ENVIRONMENT JUNE 2013

FOREWORD

Liquid waste management is increasingly becoming one of the major social and environmental challenges in the country. This is contributed by factors such as rapid population growth, urbanization and increased demand towards industrial development and limited resources to cater for the growing quantity and pollutants of liquid waste generated. The inadequacies in liquid waste treatments systems have led to water borne diseases such as diarrhoea, cholera as well as deterioration of the environmental quality.

It is estimated that about 90 percent of all liquid waste generated from industry is untreated or partially treated and directly is discharged into rivers, lakes and Ocean. Consequently, over 40 percent of the reported cases of illness are linked to contaminated water. This presents a threat to human health and the environment, with both immediate and long term consequences in our efforts to reduce poverty.

The Environmental Management Act (Cap 191) under section 123 (2) and 230 (2) empowers the Minister responsible for Environment to prescribe specific guidelines to local government authorities or sewerage authorities to be applied during disposal of general or specific types of liquid waste. These guidelines are to be used as a toolkit for local government and black water authorities on how liquid waste from domestic and commercial premises can be treated and finally disposed within and outside the premises.

Finding appropriate solutions to manage liquid waste requires innovation to reduce the volume and contamination of waste generated, treat or even reuse the liquid in an affordable and sustainable way. It is crucial to consider improving liquid waste management as part of the solution. In order to succeed, liquid waste management must be an integral part of the broader rural and urban development planning, across all sectors. Instead of being a source of problems, well-managed liquid waste can be beneficial to the environment. In turn such waste can be used in crop production to improve food security, health and therefore economic gain. It is against this background these guidelines on liquid waste management have been developed.

The Guidelines have been developed to facilitate effective and efficient management of liquid waste in the country through promotion of best practices as well as for awareness raising. The Guidelines cover a wide range of issues which include: a review of current liquid waste management practices; liquid waste management hierarchy; guidelines for selected liquid waste treatment systems including storm water management; black water sludge management; and sampling and monitoring.

I would like to emphasize that, adherence to these guidelines, coupled with sustainable investments in liquid waste management, significant social, economic and environmental benefits will be realised. Addressing the liquid waste challenge is thus essential for public health security and sustainability of natural resources.

Hon. Dr. Terezya Luoga Huvisa (MP)
Minister of State –Environment
Vice President's Office

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ABBREVIATIONS AND ACRONYMS

APHA	American Public Health Association
BOD	Biological Oxygen Demand
Cd	Cadmium
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DO	Dissolved Oxygen
EA	Environmental Assessment
EAC	East African Community
EC	Electrical Conductivity
E.Coli	*Escheria Coliform*
ECOSAN	Ecological Sanitation
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
EWURA	Energy and Water Utility Regulatory Authority
FWSW	Free Water Surface Wetland
HLR	Hydraulic Loading Rate
ISO	International Organization for Standardization
K	Potassium
LGA	Local Government Authority
MoW	Ministry of Water
N	Nitrogen
NAWAPO	National Water Policy
NEMC	National Environment Management Council
Ni	Nickel
NTU	Nephelometric Turbidity Unit
NWSDS	National Water Sector Development Strategy
OLTS	On-site Liquid waste Treatment System
P	Phosphorus
PCB	Polychlorinated Biphenyl
pH	logarithms of Hydrogen ions
SAR	Sodium Absorption Ratio
SS	Suspended Solids
SSFW	Sub-Surface Flow Wetland
SSFCW	Sub-Surface Flow Constructed Wetland
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
UNEP	United Nations Environment Programme
UWSSAs	Urban Water Supply and Sewerage Authorities
VIP	Ventilated Improved Pit Latrine
WHO	World Health Organization
WIOMSA	Western Indian Ocean Marine Science Association
WSDP	Water Sector Development Programme

WSP	Waste Stabilization Ponds
Zn	Zinc

DEFINITION OF TERMS

Aesthetic	A premium attached to the value of natural environment because of its physical appearance or the scenic view that may be enjoyed from the environment.
Anaerobic digestion	Refers to a series of processes in which microorganisms break down biodegradable material in the absence of oxidizing agent. It is used for industrial or domestic purposes to manage waste and/or to release energy.
Bioaccumulation	The accumulation of a substance, such as a toxic chemical, in various tissues of a living organism. Bioaccumulation takes place within an organism when the rate of intake of a substance is greater than the rate of excretion or metabolic transformation of that substance.
Biological Oxygen Demand	A measure of the amount of oxygen used in the biochemical oxidation of organic matter, over a given time and at a given temperature; it is determined entirely by the availability of the material as a biological food and by the amount of oxygen used by the micro-organisms during oxidation.
Biota	Animal and plant life of a particular habitat
Chemical Oxygen Demand	The standard method for indirect measurement of the amount of pollution (that cannot be oxidized biologically) in a sample of water
Composting	Biological process of breaking down of organic waste such as food waste, manure, leaves, grass trimmings, paper, worms, and coffee grounds, etc., into an extremely useful humus-like substance by various micro-organisms including bacteria, fungi and *actinomycetes.*
De-sludging	Removal of sludge from a septic tank, wetlands, waste stabilization ponds, lagoons or black water treatment plant.
Dewatering	Reduction of moisture content of sludge so that it can be handled and/or processed as a semi-solid instead of as a liquid.

Effluent	Liquid waste – treated or untreated - flowing out of a factory, farm, commercial establishment, or a household into a water body such as a river, lake, or lagoon, or a sewer system or reservoir.
Hydraulic Loading Rate	Refers to the amount of liquid waste applied per day over the surface area of the treatment media in respective liquid waste treatment system.
Liquid Waste Minimization	Minimization of liquid waste at its source to minimize the quantity and pollutants required to be treated and disposed of.
Liquid Waste	Any liquid (and associated sludges) which is discharged into the environment in such a volume, composition and manner likely to cause an alteration of quality of the environment.
Organic Loading Rate	Refers to the amount of organic material (expressed in terms Mass of Biological oxygen Demand – BOD) applied to the liquid waste treatment per day.
Reuse	Refers to the application of appropriately treated liquid waste that could result into direct or indirect social, economic and environmental benefits.
Retention time	Retention time refers specifically to the time spent by a portion of influent or effluent in the liquid waste treatment system.
Sewerage	Human excreta disposal systems relying on water as the waste transporting medium.
Black water	Refers to liquid waste containing faecal matter and urineblack water.
Storm Water Management	Involves both the quantitative and qualitative management of storm water and the functions associated with planning, designing, constructing, operating, maintaining and financing of storm water management systems.
Sludge	Semi - solids accumulated in pit latrines, septic tanks, waste water stabilization ponds and other liquid waste treatment systems after reaching their full capacity.
Grey water	Refers to liquid waste generated from domestic activities

such as kitchen, showering and laundry.

Toxicant Synthetic substance that presents a risk of death, disease, injury, or birth defects in living organisms through absorption, ingestion, inhalation, or by altering the organism's environment. In comparison, a toxin is produced in nature by a living animal or plant.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Liquid waste management is increasingly becoming among the socio-economic environmental challenges in the country. This is a result of rapid growth of population; urbanization; rural development; growing population; climate change; agriculture and increased demand from industry and limited resources to cater for the growing volume and pollutants of liquid waste. The inadequacies in liquid waste treatment systems have led into water related diseases such as diarrhoea and cholera and deterioration of environmental quality. Discharge of untreated or inadequately treated liquid waste from various sources often causes pollution or harmful effects to the environment and human health, including undesirable changes to ecosystems, reduction in the economic value of resources, aesthetic damage and human health risks. In Tanzania, legal framework has been provided to deal with such issues.

The Environmental Management Act (EMA) (Cap. 191) provides for legal and institutional framework for environmental management in the country. Sections 123(2) and 230 (2) (s) of the Act empowers the Minister responsible for Environment to prescribe guidelines to be followed by Local Government Authorities or Urban Sewerage Authorities on management of liquid waste. The Guidelines provides framework for liquid waste management in the country.

1.2 Objective of the Guidelines

The overall objective of these Guidelines is to ensure liquid waste emanating from domestic and commercial sources is handled, treated and disposed off in an environmentally sound manner.

The specific objectives of the Guidelines are to:

a) Promote best practices in liquid waste management;
b) Provide guidance for selected on-site and off-site liquid waste management systems including storm water management;
c) Encourage reuse of liquid waste;
d) Promote black water sludge management; and
e) Enhance awareness raising efforts on issues related to liquid waste management.

1.3 Scope of the Guidelines

The Guidelines takes into account the requirements of the relevant national policies and legislations. It provides guidance for practices of liquid waste management; liquid waste management hierarchy; selected on-site and off-site liquid waste treatment systems; selection criteria for liquid waste management; sludge management options; and general framework for monitoring the environment and effluents.

1.4 Rationale for Developing the Guidelines

Environmental pollution is one of the six priority environmental problems in the country as identified by the National Environmental Policy (1997). The Environmental Management Act No. 20 of 2004 calls for the development of regulations, guidelines, and strategies for proper environmental management.

Liquid waste management in the country is an environmental and public health growing challenge particularly in urban areas due to limited infrastructure and resources to cater for the growing population and urbanization. Indeed, in many instances, raw or partially treated liquid waste is discharged into water bodies. Such indiscriminate discharge of liquid waste threatens productivity and biodiversity of the water bodies. At the same time, it poses serious risks to human health and the environment. For instance, 40% of the cases reported in health facilities in the country are water borne diseases such as diarrhoea, cholera and dysentery.

In response to the daunting challenge in addressing liquid waste management, these Guidelines have been prepared to provide guidance and promote best practices in an attempt to improve liquid waste management. Effective management of the unavoidable liquid waste is crucial in order to reduce adverse effects to human health and the environment.

1.5 Target Audience

These Guidelines are intended to be used by: Water Supply and Sewerage Authorities; Local Government Authorities; Basin Water Offices; Academic and Research Institutions; Media; Civil Societies; Investors and general public.

CHAPTER TWO

OVERVIEW OF CURRENT LIQUID WASTE MANAGEMENT PRACTICES

There is an inadequate capacity for management of liquid waste from different sources in the country. This results into indiscriminate discharge of liquid waste into water bodies and in the environment threatening human health, ecosystem integrity and biodiversity. For instance, a substantial proportion of the population remains without access to basic sanitation facilities. This Chapter provides not only the major categories of liquid waste in the country but also an overview of the current liquid waste management practice. ..

2.1 Major Categories of Liquid Waste

Liquid waste can be categorized as domestic liquid waste, industrial liquid waste, and storm water.

2.1.1 Domestic Liquid Waste

This is generated from domestic and other non-industrial uses mainly from households, institutions and commercial buildings, recreational places, etc. This includes black water (from the toilet) and grey water (water from kitchen and bathroom). Black water has a high content of solids and contributes a significant amount of nutrients (nitrogen and phosphorus).. The latter may have a high content of solids and grease, and depending on its intended reuse/treatment or disposal can be combined with black water. Both grey water and black water may contain human pathogens, though concentrations are generally higher in black water.

2.1.2 Industrial Liquid Waste

This is mainly generated from industrial operations and processes. In most industries, liquid waste effluent results from three main uses of water such as: heat exchange medium; means of transport; and process material. Characteristics of industrial liquid waste depend directly on the nature of industrial process and raw materials for which the liquid has been used.

2.1.3 Storm Water

This results from precipitation run-off. Storm water is generated from house roofs, paved areas and from roads during rainfall events. In addition, storm water is produced from the catchment of a stream or river. The amount of storm water is therefore related to the amount and intensity of rainfall precipitation, and the nature of surfaces, with impervious surfaces producing more run-offs. In general, the pollutant load of storm water is lower than that of domestic liquid waste.

2.2 Current Liquid Waste Management Practices

2.2.1 Industrial Liquid Waste

In Tanzania, most industries fall in the category of small and medium scale. These include textiles, metals, pharmaceuticals, mining, metal, tanneries, printing, painting, automobiles, breweries, food industries, construction industry (such as cement), paper industry and small scale industries e.g. milling, small garage, carpentry, metal works, jewellery and masonry.

Most industries are located in urban areas and in large towns mainly in Dar es Salaam, Arusha, Morogoro, Moshi and Mwanza. However, many of these were established without adequate environmental attention, and as a result they have been operating without liquid waste pre-treatment facilities. Most of industries have setting up of liquid waste disposal although are inappropriate and ineffective.

Some industries have been reported to pollute water bodies including rivers Msimbazi, Kizinga and Mzinga in Dar es Salaam; Themi in Arusha; Ngerengere in Morogoro;Karanga in Kilimanjaro; Mirongo and Lake Victoria in Mwanza.

In general, liquid waste from artisanal mining sites is poorly managed. Artisanal mining has completely no provision for liquid waste management. This implies the absence of adequate treatment provision, and poor operation and maintenance. However, large scale mining has provision for treating and managing resulting liquid waste.

Commonly used industrial liquid waste pre-treatment facilities include screening and aeration. Primary industrial liquid waste treatment is generally provided for mainly in the form of Waste Stabilisation Ponds (WSPs) systems while in a few cases constructed wetland systems have been incorporated in liquid waste treatment systems to provide a polishing secondary treatment stage. Notably, there are also few trickling filter plants.

2.2.2 Domestic Liquid Waste

The technologies used to dispose of domestic liquid waste are mainly pit latrines and septic tank systems. About 90% of the urban population in Tanzania depends on on-site sanitation systems: pit latrines (80%) and septic tanks (10%) as their excreta disposal facility. There is also a relatively smaller proportion of the population which use improved liquid waste disposal systems including Ventilated Improved Pit (VIP) Latrines (1.1%) and eco-san (ecological sanitation) toilets. In most urban centres, only about 10-15% of the population is connected to the central sewerage systems. Treatment of liquid waste from areas served by centralized sewerage systems is accomplished in Waste Stabilisation Ponds (WSP). However, haphazard disposal practices are mostly encountered especially during the rainy season whereby discharges from pit latrines are intentionally released into the environment, partly to avoid disposal cost. Some Local Government Authorities with central sewerage systems discharge their untreated or treated effluents into the Indian Ocean, rivers or lakes.

Currently, only a small proportion of the total liquid waste generated is treated in the available WSP systems or discharged through the installed sea outfalls. This is mainly because most of the urban areas are not covered by existing sewerage systems.

Currently, there are no facilities for proper treatment of faecal sludge from pit latrines and septic tank systems and WSP systems.

In the small towns, responsibility for sewerage and sanitation services rests with the Local Government Authorities and sewerage systems rarely exist. People living in small towns and peri-urban areas primarily depend on cesspits or pit latrines, which are emptied by the local authority or private operators. In rural areas, the coverage of sanitation is about 84%, through the construction of pit latrines by individual households as compared to 98% in urban areas .However, most of the latrines are not in good conditions.

In some areas of the country, open defecation is still practised thus adding into the magnitude of the problem. Moreover, grey water management has not received any attention.

2.2.3 Storm Water

Storm water drainage systems in the country are available almost exclusively in urban areas and they are mainly associated with road developments. In addition, storm water drainage systems are provided to prevent floods as well as control disease vectors, soil erosion and landslides. The storm water drainage system can be classified as open/confined, paved/lined, unpaved/unlined or natural streams depending on the nature of land and rate of runoff. Generally, final disposal of storm water runoff is to the natural streams, rivers, lakes and into the Indian Ocean. However, no treatment of storm water is done except for preliminary treatment to remove bulky floating matter using screens or grit chambers.

The main issues in relation to poor provision of storm water drainage are the following:

i) Inadequate social services particularly in unplanned settlements, which comprise a large proportion of urban households. In the absence of proper social services, (informal) drainage system becomes the recipient of wastes of all kinds including liquid waste, faeces and solid waste. This results into water pollution and *eutrophication* of water bodies;

ii) Reluctance to relocate to better drained areas when settlements are regularly flooded forcing residents to move to temporary shelters until the flooding subsides;

iii) Degradation of urban areas due to erosion and sedimentation;

iv) Inadequate funds allocation for improvement of drainage systems; and

v) Increase in the frequency of floods due to urbanization.

2.2.4 Sludge Management

In general, more efforts on sanitation have concentrated to liquid waste treatment than to sludge management. Consequently, the generated sludge is commonly dealt with as follows:

i) Sludge from septic tanks - upon accumulation of sludge, tenants have to pay for the service of acquiring tankers to withdraw sludge from the septic tanks and transport to nearby waste water stabilization ponds.

ii) Sludge from pit latrines is also a major component requiring adequate management due to several reasons among which are:
   a) Inaccessible or very narrow pathways in unplanned settlements;
   b) Restricted areas within households property inhibiting the construction of new latrines which is not a sustainable solution by itself.

The need to manage the handling and disposal of sludge in an environmentally sound manner taking into consideration the type of hazards such sludge can result in. Informal excavators are widely used to dig the contents of the pit latrines then buried nearby in shallow pits or dumped indiscriminately in gullies or waterways.

iii) Sludge from waste water stabilization ponds, which has accumulated for years, is not regularly de-sludged which is one of the major reason for malfunctioning of the ponds including those found in Dar es Salaam City.

2.2.5 Liquid Waste Reuse
Reuse can produce an obvious benefit if it reduces the demand for water from other sources and systems. In times of water shortage, it provides a scarce resource. While only a very small percentage of effluent is reused in the country, there is increasing interest in using this resource mainly for land application and to a lesser extent for industrial purposes or for the augmentation of domestic supplies. Recent years have witnessed rapid growing interest in re-using raw, partially and treated liquid waste for the urban agriculture. This practice is seen in most of urban centres in the country. The practice is posing potential health risks both on the environment and the public.

2.3 Institutional Framework
The current institutional framework for the provision of water supply and sanitation services is based on a separation between urban water supply and sewerage services, and rural water supply services. The ultimate responsibility for the provision of these services rests largely with the Ministry of Water.

Role of Government, through the Ministry responsible for Water includes, coordination; policy making; regulations and guideline formulation while and the responsibilities for the provision of water supply and sanitation services rest to successor organisations. Based on the National Water Policy (NAWAPO) (2002), six basic principles have been derived and applied to the development of the future institutional framework for water supply and sanitation:

- Government's role will be limited to co-ordination, policy and guideline formulation, and regulation.
- Regulatory and executive (i.e. service provision) functions will be separated.
- Responsibility for executive functions will be decentralized to the lowest appropriate level, whilst balancing consumer representation/participation with economies of scale.
- Responsibility for regulation will be separated from the prioritization and allocation of capital investment funds.
- Autonomous entities will be established to manage water supply and sewerage services in urban areas.
- Community organizations will own and manage water supply schemes.

Ministry/Institution	Functions and Responsibilities
Ministry responsible for Water	• Lead authority in provision of water supplies, management of water resources and liquid waste management in the country • Policy and strategy development. • Advise EWURA in formulation of technical guidelines and standards. • Co-ordinates planning for projects of national importance. • Secures finance for projects of national importance. • Provides technical guidance to Councils. • Water resources development policy, rural and urban water supply, sewerage and drainage • Formulating policies on water and sewerage • Issuing of liquid waste discharge permit/consent for industries that discharges their liquid waste unto receiving water bodies • Issuing water use permit • Monitoring compliance of liquid waste discharges to water bodies
Water Supply and Sanitation Authorities (UWSSAs)	• Own, manage and develop water supply and sanitation assets. • Prepare business plans to provide water supply and sanitation services, including capital investment plans. • Secure finance for capital investment, and relevant subsidies. • Contract and manage Service Providers. • Provide services not contracted out. • Formulate by-laws for service provision.
Energy and Water Utilities Regulatory Authority	• Approves business plans of UWSSAs. • Issues operating licences to UWSSAs. • Approves service tariffs. • Publishes technical guidelines and standards. • Monitors water quality and performance of UWSSAs. • Collects and publishes comparative performance data.
Prime Minister's Office Regional Administration and Local Government Authority	• Co-ordinates planning of projects from local government authorities. • Co-ordinates local government authority budgets. • Co-ordinates capacity building for local government authorities.
Regional Secretariat	• Advise UWSSA Boards. • Provides technical advice to local government authorities.
Municipal and District Councils	• Management of both liquid and solid waste implementation of sector policies • Enforcement of sectors legislations and regulations • Formulation of by laws • Infrastructure development • Insuring of Building permits • Regulation and enforcement of sanitary and Industrial waste water • Implementation of land use planning
Ministry of Health and Social Welfare	• Develop policy, guidelines and strategies for sanitation. • Provides technical assistance to councils for sanitation.

	• Prepares Acts, Regulations and Standards for sanitation. • Monitors, regulates and provides support and advice to councils and other stakeholders on sanitation issues.
Tanzania Bureau of Standards (TBS)	• Establish and review environmental quality standards including liquid waste discharge limits • Assist industries in setting up environmental management standards and systems
Ministry responsible for Environment	• Develop policy and strategies for addressing environmental pollution. • Prepare strategies aiming at public participation in conservation and control of environmental pollution. • Coordinate the implementation of international conventions dealing with pollution prevention and control
National Environment Management Council (NEMC)	• Enforce and ensure environmental quality standards in relation to liquid waste • Provide advice and technical support on liquid waste management • Environmental education and public awareness on environmentally sound management of liquid waste

CHAPTER THREE

HIERARCHY OF LIQUID WASTE MANAGEMENT

This chapter describes the options available for liquid waste management hierarchy. The options should address the management of the liquid waste as a whole and each of the aspects individually. The aspects are:

i) Liquid waste minimization;
ii) managing the collection of liquid waste;
iii) treatment of liquid waste;
iv) effluent reuse;
v) discharge of the remaining effluent

3.1 Liquid Waste Minimization

The application of good liquid waste minimization practices will keep the volume of liquid waste and potential pollutants to a minimum. It is the first aspect which should be addressed. Major areas for consideration are:

- reduction of contaminants in industrial wastes discharged to the sewerage system;
- minimization of water use by applying water conservation and demand management principles to industrial, commercial and domestic sources;
- management of domestic products that may add contaminants to the liquid waste flow; and
- management of sewerage systems to exclude infiltration and storm water

Waste minimization can also be enhanced by a combination of actions in the areas of:

- incentives, such as quantity and quality based charges for major industrial dischargers and user pays for domestic black water; and
- education, such as providing information on the use of water efficient appliances (such as low flow shower heads and low water use taps) and environmentally friendly products and practices.

3.2 Collection of Liquid Waste

Collection of liquid waste is by use of sewer system. The principle of using gravity as the driving force for conveying liquid waste in a sewerage system should be applied wherever possible, because this will minimise the cost of pumping. Other options for managing liquid waste collection system include:

- minimise odour emissions;
- minimise infiltration (leakage of groundwater into the pipes) and illegal discharges of storm water to keep liquid waste volumes to a minimum;
- deliver liquid waste as fresh as possible to the treatment plant so that it is easy to treat and minimise energy usage;
- avoid deposition and blockage in the sewer; and
- minimize leakages of liquid waste.

3.3 Treatment Levels of Liquid Waste

A number of factors are considered in selecting a particular liquid waste treatment technology from a wide range of technologies available of which the selection of liquid waste treatment technology depends on the characteristics of the liquid waste and the national discharge standards that have to be maintained Liquid waste treatment involves various levels either used individually or in parallel or in series to obtain the required effluent quality. In normal sequence, the principal levels are:

i) pre-treatment level which removes gross solids, coarse suspended and floating matter;
ii) primary treatment level which removes readily settleable solids, usually by sedimentation;
iii) secondary treatment level which removes most of the remaining contaminants including fine suspended solids, colloidal and dissolved organic matter usually by biological aerobic processes or chemical treatment (where chemical treatment produces an effluent of similar quality to that achieved by biological processes);
iv) nutrient removal level which further reduces the levels of nitrogen and phosphorus following secondary treatment;
v) disinfection of effluent level which reduces pathogens to levels acceptable for the reuse or discharge of the treated liquid waste; and
vi) advanced level of liquid waste treatment which further improves the quality of effluent by processes such as sand filtration, ion exchange and microfiltration.

In designing and operating liquid waste treatment systems to meet the effluent and sludge management requirements, the following should be considered:

- balancing energy usage and performance through use of systems such as ponds, energy efficient aeration systems, use of methane for energy recovery etc;
- recycling effluent for filling tanks, washing down, etc;
- minimizing odours and noise;
- judicious use of chemicals;
- minimizing overflows;
- removing solids to maintain the quality of the effluent; and
- developing effluent and sludge (bio-solids) as nutrient for agriculture uses.

3.4 Reuse of Treated Liquid Waste

Treated liquid waste is being used for various purposes. Typical liquid waste reuse is mostly practiced in a number of manufacturing industries with a view of reducing operational costs. For example industry's requirement for water quality ranges widely, from very pure water for boilers for electricity generation to lower water quality for cooling towers. In addition, treated liquid water reuse can be practiced to a limited extent in households for toilet flushing, watering of gardens and for suppressing dust in adjacent unpaved roads.

Indirect and environmental reuse options may include reuse via surface waters and ground water. The options include: irrigation; direct potable; indirect potable; nonpotable urban; municipal; agricultural; aquaculture; tree growing; recreational; environmental; and industrial.

For the larger effluent discharges, reuse options reduce the total discharge but rarely totally eliminate the need for discharge.

3.5 Disposal of Treated Liquid Waste

Where effluent is discharged to water bodies or land, the aim is to maintain water quality that protects the water body's environmental values. Factors which influence the impact of effluent on a specific water body include:

- quality of the water body before effluent is mixed;
- quality and quantity of the effluent;
- dilution in the mixing zone;
- hydrodynamics of the water body;
- interactions between the effluent and the receiving environment; and
- sensitivity of the receiving environment

CHAPTER FOUR
GUIDELINES FOR LIQUID WASTE COLLECTION

Small Bore Sewer System

Brief Description

Small bore sewer systems are designed to receive only the liquid portion of black water for off-site treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewers are separated from the waste flow in interceptor tanks installed upstream of every connection to the sewers (Figure 9). The accumulated solids are removed periodically for safe disposal.

Collecting only settled wastewater in this manner has four principal advantages:

i) Reduced water requirements. Since the sewers are not required to carry solids, large quantities of water are not needed for solids transport;
ii) Reduced excavation costs: With the troublesome solids removed, the sewers may be laid with a variable or inflective gradient. This reduces excavation costs, since the sewer can follow the natural topography more closely than conventional sewers and avoid most obstructions within its path.
iii) Reduced materials costs: Peak flows which the small bore sewers must be designed to handle are lower than those experienced with conventional sewers because the interceptor tanks provide some surge storage which attenuates peak flows. Therefore, the sewer and any pumping equipment can be reduced in size (and pumps handling only liquids are simpler).
iv) Reduced treatment requirements: Screening, grit removal and primary sedimentation or treatment in anaerobic ponds are not needed at the treatment works, since these unit processes are performed in the interceptor tanks.

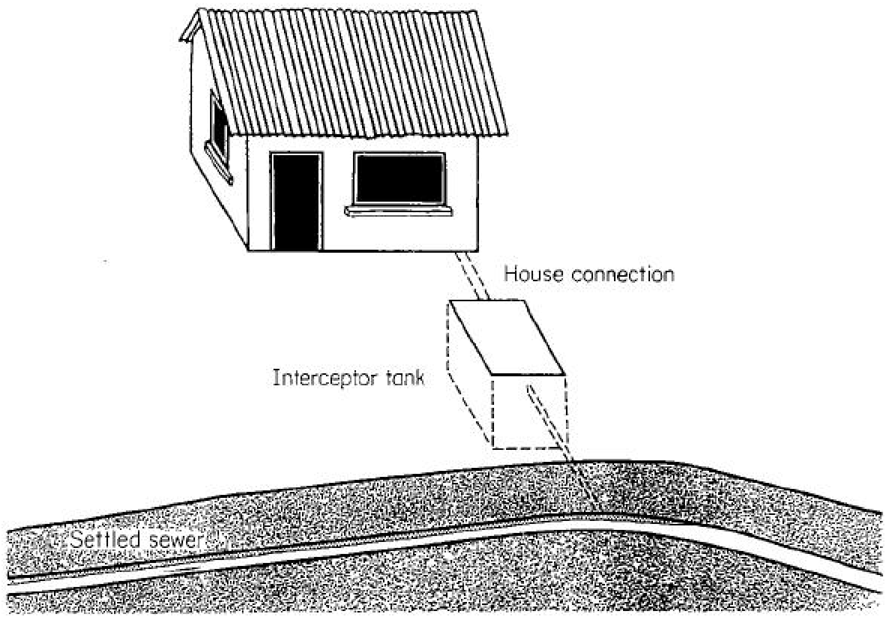


Figure 1: schematic diagram of small bore sewerage system..

Sitting of an Interceptor Tank

i) The tanks should be located where they can be reached easily for routine removal of solids. The tanks should be clear of vehicular traffic areas unless the cover is adequately reinforced to withstand live traffic loads.

General Design of the Small Bore Sewer System

i) The house connection is made at the inlet to the interceptor tank. Storm water must be excluded from entering the system;
ii) The interceptor tank should be designed to detain the liquid flow for 12 to 24 hours and to remove both floating and settle able solids from the liquid stream.
iii) The sewers are small bore plastic pipe (minimum diameter of 100 mm) which is trenched into the ground at a depth sufficient to collect the settled liquid waste from most connections by gravity.
iv) Manholes should be provided to access the sewers for inspection and maintenance.
v) Each household is usually served by its own solids interceptor tank. In many instances this may be the optimal solution, but consideration should be given to the feasibility of connecting more than one household to each interceptor tank. This is likely to be a lower-cost solution in many situations, especially in high-density, low-income urban areas.

vi) The preferred shape of interceptor tank is rectangular with a length to breadth ratio of 2 to 1, or higher, in order to reduce short-circuiting of the raw wastewater across the tank, and so improve suspended solids removal.

vii) Single-compartment interceptor tanks are sufficient to remove settle able solids, since the suspended solids carried out in the effluent are not likely to settle in the sewer.

Maintenance

i) Scheduled maintenance for the interceptor tanks is generally limited to yearly inspection and solids removal when necessary.

ii) Small bore sewers require very little maintenance. The only routine maintenance which must be performed is the removal of sludge from each of the interceptor tanks.

iii) Occasional flushing of the sewer mains is recommended to insure against blockages. Flushing should begin at the upstream terminal ends of the sewers, and each section between manholes should be flushed successively downstream. Each manhole should be flooded with water from a tank truck.

CHAPTER FIVE

GUIDELINES FOR SELECTED LIQUID WASTE TREATMENT SYSTEMS

5.1. Onsite Liquid Waste Treatment Systems (OLTS)

On-site treatment systems rely on decomposition of the organic wastes by bacteria. This can take place in a simple pit in the ground or in specially designed tanks to promote the bacterial decomposition of the wastes. The liquid waste from the pit or tank is allowed to soak into the ground. Further bacteriological decomposition and soil filtration, absorption and purification processes take place in the soil. The potential for groundwater pollution, however, exists with on-site treatment and disposal systems, because not all pollutants (e.g. nitrate) are removed by these processes.

5.1.1 Simple Pit Latrine

5.1.1.1 Brief System Description

A pit latrine collects excreta in a pit dug in the ground beneath the toilet structure. If the soil is loose the pit needs to be lined with, for example, loose bricks to prevent the wall from collapsing. During storage in the pit decomposition of the organic substances takes place under anaerobic conditions. The anaerobic decomposition releases gases (carbon dioxide, methane and sulphuric gases) and reduces the volume of sludge.

Seepage of water into the surrounding soil takes place through the sides and bottom of the pit. During seepage further decomposition of organic matter by soil bacteria takes place reducing the BOD of the water. There will also be die-off of bacteria and viruses during storage and as the water percolates through the soil. Bacteria under these conditions do generally not remove nutrients, so pollution of groundwater may occur.

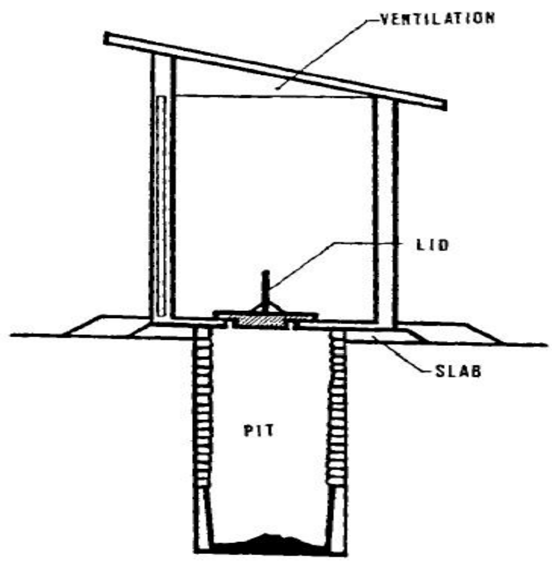


Figure 2: Cross-section of a simple pit latrine

Advantages of a Pit Latrine include low cost; can be built easily; and requires minimal amount of water. However, some of the disadvantages include fly and mosquito nuisance; waste cannot be recycled; smell problem; lack of space for relocating new ones when full; potential for ground water pollution; children may feel unsafe to use the latrine; and difficulty of construction in rocky soil.

A pit latrine should be properly constructed not only to isolate faeces but also to give comfort (no smell, give privacy); prevent accident, pollution and fly breeding; and not spoiling the living environment.

5.1.1.2. Sitting of a Pit Latrine

i) The site where pit latrine is to be constructed should never be flooded.
ii) A pit latrine should be located down slope from water sources such as wells, springs or surface water. It should also be located a minimum distance of 6 meters away from kitchen and the living house but not more than 50m away. This is from the fact that flies that may have access to the pit may travel to the kitchen to contaminate the food and the odour that may emanate from the pit could be nuisance for people inside the house. It will also be easy to reach the toilet during bad weather.
iii) If there is a well in the compound, the latrine should be located as far away from it as possible on the downhill side to avoid possible seeping and contamination of groundwater. A minimum distance of about 30–60 m is recommended with an absolute minimum of 15 m, otherwise the well has to be abandoned.

5.1.1.3.General Design Considerations

i) Depending on the soil formation and distance to the ground water near the site, the pit should be as deep as possible and not less than 1.5 meters otherwise flies will breed and cause a lot of trouble.
ii) The pits can be square, rectangular or circular, usually 1.0-1.5 m wide. Deep pits (deeper than about 1.5 m) are usually circular, whereas shallow pits are commonly square or rectangular. As the pit gets deeper the load applied to the pit lining by the ground increases. At shallow depths, normal pit linings (concrete, brick masonry, etc.) are usually strong enough to support the soil without a detailed design. Also square or rectangular linings are easier to construct. At greater depths, the circular shape is structurally more stable and able to carry additional loading.
iii) If a circular pit is to be dug the diameter should be at least 0.90 meters (otherwise workers will not be able to move around) and not more than 1.50 meters (there is an increased risk of collapse, especially in sandy soils; and it will be expensive to cover the pit).
iv) The presence of solid rock or a high water table near the ground surface generally prevents the construction of pit latrines. In such circumstances, the latrine can be built on a mound as shown in Figure 2. The pit walls need to be built at least 1.2m before the mound is constructed. The pit should be fully lined with stone, brick or concrete and this lining continued above the ground to the top of the mound. Steps should be built up the outside of the mound.

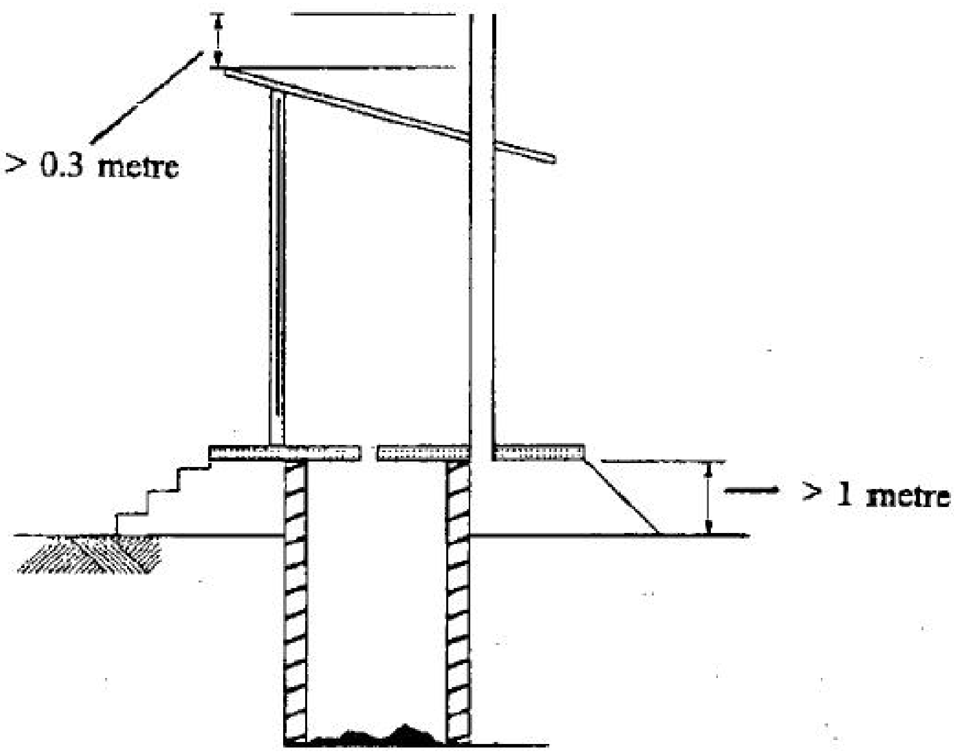


Figure 3: Cross-section of a mound-built latrine

v) Lining the pit is important to prevent it from collapsing and provides support to the superstructure. The bottom of the pit should remain unlined to allow the percolation of liquids out of the pit.
vi) There should be a superstructure made from local material such as cement blocks, bricks, or stone with cement or mud blocks, corrugated iron sheet; or a wooden structure covered with timber, bamboo, grass, leaves, twigs; or mud blocks. The superstructure should be well ventilated and should be made fly-proof with wire mesh. It should have a well fitting door. The superstructure should help in keeping the inside dark to discourage flies entering the pit.
vii) A pit latrine should have mound all around the pit so that surface water will not enter the pit.
viii) Whenever concrete or other impervious material is used for latrine slab, the surface should be smooth, with a slight slope from all sides toward the hole in the centre to let urine flow into the pit.

ix) Two adjoining pits can be used alternately. Further decomposition of sludge in a full pit takes place while the adjacent pit is in use. Its content after further decomposition can be manually removed.

5.1.1.4. Upgrading to a Ventilated Improved Pit Latrine

i) For fly control and to improve odour problems, a ventilation pipe should be installed. This converts the simple pit latrine to a Ventilated Pit Latrine (VIP) latrine (Fig. 3).

ii) The minimum diameter of the ventilation pipe is 100mm and the most convenient to use is PVC. Other materials may be used such as bamboo or a square chimney made from bricks (internal diameter of 225mm). In general, the vent pipe should be located on the outside of the superstructure, since it is more difficult and expensive to ensure a rainproof and wind-tight seal between the roof and a vent pipe going through it.

iii) It is important that the vent pipe extends at least 0.5m above the peak of the roof. This will draw air up the vent pipe and carry odours away. The end of the vent pipe needs to be covered with a fly screen.

iv) The latrine should be well away from tall buildings to ensure that ventilation works efficiently.

v) The VIP latrine should not have a lid over the squat hole, which must be left open to allow circulation of air into the pit.

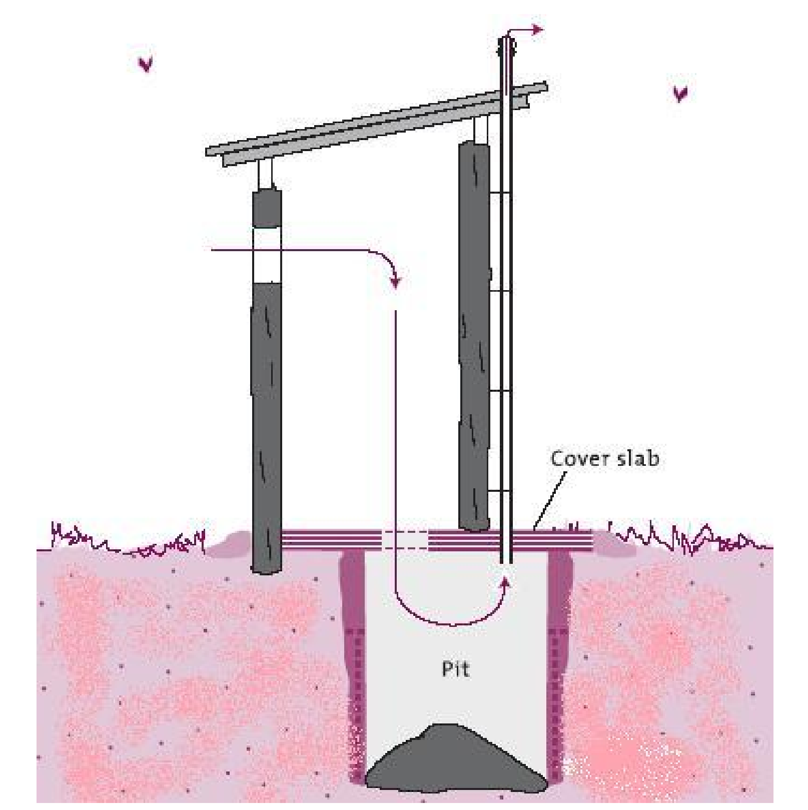


Figure 4: Cross-section of a Ventilated Improved Pit (VIP) Latrine

5.1.1.5 Emptying Pit Latrines

The emptying of single pits containing fresh excreta presents problems because of the active pathogens in the sludge. In rural areas, where land availability is not a constraint, it is often advisable to dig another pit for a new latrine. The original pit may then be left for several years and when the second is filled it may be easy to re-dig the first pit rather than to excavate a new hole in a hard ground.

Emptying and removal of sludge is by no means the only option for the management of pit latrine sludge. Other options include alternating pit latrine, composting latrine and eco-san (urine diversion) latrine. All these options in some way recognize the value of faecal waste as a soil conditioner or compost. By encouraging users to manage their own feacal waste, this can save the cost of pit emptying and associated health risks while users can make productive use of the compost they produce.

Regarding sludge disposal, by far the most economical option is to bury the contents on the site where they are generated. Where the contents must be removed due to a lack of space for on-site disposal, then Local Government Authorities have the following options:

i) The sludge can be disposed of at waste stabilization ponds; or
ii) The sludge can be buried at dedicated landfill sites designed for this purpose.

5.1.1.6 Operation and Maintenance

i) A suitable brush is needed inside the latrine superstructure for cleaning the slab
ii) The latrine slab or seat has to be cleaned regularly with a little water to remove any excreta or urine
iii) There should be a container with ashes, soil, or saw dust to sprinkle over the excreta in order to reduce odour and insect breeding
iv) Proper anal cleaning material should be placed inside the latrine.
v) Tight fitting lid over the latrine hole should be replaced after each use (this applies to a simple pit latrine only)
vi) The latrine should be inspected periodically for cracks in the slab, structural damage
vii) Throwing of non-biodegradable materials such as bottles, tins, glass or plastics should be prohibited as it reduces the lifespan of the pit.
viii) During an epidemic, the floor of the latrine should be cleaned daily with a disinfectant

5.1.2 Ecological Sanitation (ECOSAN) Toilet

5.1.2.1 Brief System Description

Ecological Sanitation (ECOSAN) is an environment friendly sustainable sanitation system which regards human waste as resource for agricultural purposes and food security. ECOSAN is based on the following three fundamental principles:

a) Preventing pollution rather than attempting to control it after we pollute;
b) Sanitizing the urine and faeces; and
c) Using the safe products for agricultural purposes

One of the ECOSAN toilets in use is Urine diversion/separation toilet that is characterized by a special seat or squat plate which separates the urine and faeces, ideally preventing any mixing of the two. Urine can be collected and used in agriculture or compost production or it can be drained into an underground soak away. Faeces falls into the chamber below the toilet, which can either be a removable receptacle or a vault that is emptied only after long intervals of storage. ECOSAN toilets are not the same as VIP latrines as they do not require a deep pit like VIP latrines because urine is diverted allowing faeces to compost faster.

The main benefits urine diversion toilet include reduction of odours and flies by reducing the moisture of the wastes; reduction in the amount of cover material needed; reduction in the volume of wastes needing to be removed from the toilet and treated; and facilitation of pathogen die off through desiccation of the faeces.

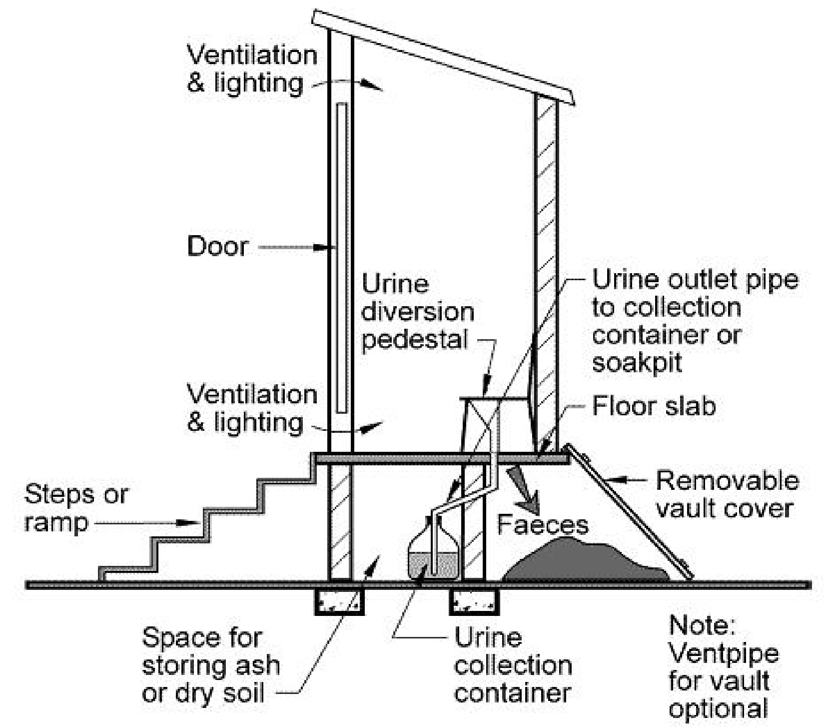


Figure 5: Cross-section of a urine diverting ECOSAN toilet

5.1.2.2 Sitting of an ECOSAN Toilet

i) Position the toilet in shade to stay cool during the day is recommended.
ii) The toilet should be sited in such a location as to allow privacy for the user.

5.1.2.3 General Design Considerations

i) Urine diversion is always recommended to reduce the amount of faecal material to be handled and lower the risk for disease transmission. This also reduces odours and flies;
ii) Faecal collection should occur above ground in closed compartments that will not leak into the groundwater or the surrounding environment;
iii) Sufficient space (at least 60cm-100cm) should be left at the front and sides of the toilet structure to allow for user access to the front, and operator access to the front and sides. If possible, the same space should be allowed at the back of the toilet for any eventual maintenance;
iv) Handling and transport systems should involve minimal contact with the faeces;
v) Toilet paper and material such as tampons and sanitary pads should only be put into the toilet if they are bio-degradable. Otherwise, they should be treated as solid waste;
vi) Anal cleansing water should not be mixed with urine, but infiltrated into soil or added to the grey water and subsequently treated;
vii) Contents of potties and diapers and should be put into the faecal compartment;
viii) Further addition of absorbent materials, such as ash ,lime, a bulking agent, or sawdust, may be needed when diarrhoea is prevalent;
ix) Cleaning of squatting pan has to be done carefully with little water, to avoid introduction of water into the vault. A bulking agent has to be added regularly to the faeces; and
x) The collection chamber has to be checked and emptied in regular intervals
xi) Hand washing facilities should be provided

5.1.2.4 Operation and maintenance

i) Educate first-time users on the basic steps of using a urine-diversion toilet;
ii) Provide water and soap for hand washing;
iii) Ensure urine separation and keep the vault as dry as possible;
iv) Care should be taken to prevent chemicals from entering into the faecal drum/vault as this will ruin the composting process;
v) Ensure that sufficient cover material is being applied by users;
vi) Turn or push piles of compostable waste matter within the vault to maintain moisture;
vii) Cover faeces with ash after each use and especially after children use it.

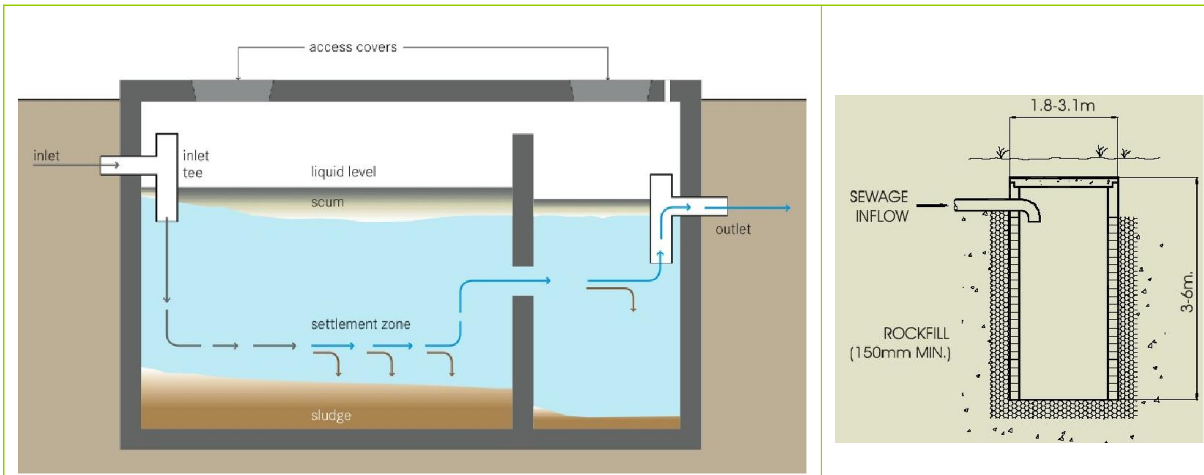
5.1.3 Septic Tank and Soak Away Pit

5.1.3.1 Brief System Description

A septic tank is a watertight tank, usually located just below ground, and receives both black water and grey water. A typical septic tank system normally operates by gravity, and consists of a tank and a soak-away pit. It is commonly used with pour flush toilets or cistern flush toilets. It functions as a storage tank for settled solids and floating materials (e.g. oils and grease). The overflow from a septic tank is directed to a soak away pit. The pit must be sized to allow percolation of the volume of liquid waste generated. A pit works well in soils with high permeability. In soils with lower permeability a trench can provide the larger surface area of percolation.

About 50% removal of BOD and Suspended Solids (SS) is usually achieved in a properly operated septic tank due to the settling of the solids during liquid waste storage.
A septic tank can be constructed of bricks and mortar and rendered, or of concrete. Its shape can be rectangular or cylindrical. A septic tank can be partitioned into two chambers to reduce flow short-circuiting and improve solids removal.

A soak away is a pit for collecting the liquid effluent from a septic tank, which is then allowed to infiltrate the ground. It should be noted that the effluent from a septic tank is by no means fit for discharge into a water body or on a land/ground where it could be directly or indirectly accessible to animals and humans.



a) Septic tank — *b) Soak away pit*

Figure 6: Longitudinal-section of a septic tank and soakaway pit

5.1.3.2 Sitting of a Septic Tank and Soak-away pit

i) Septic tanks should be located where they cannot cause contamination of any well, spring or other source of water supply. Underground contamination may travel in any direction and for considerable distances under saturated conditions. It is therefore necessary to rely on horizontal as well as vertical distances for protection.
ii) Septic tanks should not be installed in flood plains, drainage ways or depressions unless flood protection is provided.
iii) Septic tanks and soak-away pit should be located in firm soil, 2 to 5 m from buildings and boundaries, so as to facilitate sludge and scum removal by vacuum tankers.

5.1.3.3 General Design Considerations for Septic Tank

a) The guiding principles in designing a septic tank should be to;
- provide sufficient retention time for the black water in the tank to allow separation of solids and stabilization of liquid;
- provide stable quiescent hydraulic conditions for efficient settlement and flotation of solids;

- ensure that the tank is large enough to store accumulated sludge and scum; and
- ensure that no blockages are likely to occur and that there is adequate ventilation of gases.

b) The depth of liquid from the tank floor to the outlet pipe invert should be not less than 1.2 m; a depth of at least 1.5 m is preferable. In addition a clear space of between 0.30-0.45 m should be left between the water level and the under-surface of the cover slab;

c) The width should be at least 0.60m as this is the minimum space in which a person can work when building or cleaning the tank. It is recommended that the length should be 2 or 3 times the width;

d) For a tank of width W, the length of the first compartment should be 2 W and the length of the second compartment should be W. In general, the depth should be not greater than the total length;

e) The size of inspection chambers vary according to depth and number of branches. For shallow chambers: 600mm X 750mm. The length depends on the number of branches. A length of 750mm would possibly allow one branch connection; therefore for each additional branch increase the length by 230mm;

f) The black water must enter the septic tank with the minimum possible disturbance to the liquid and solids already in the tank. Surges and turbulence reduce the efficiency of settlement and can cause large amounts of solid matter to be carried out in the tank effluent. Surges are caused by flushing of the Water Closet (WC) and emptying of sinks and baths. Their effect can be minimized by using drain pipes of not less than 100 mm in diameter and ensuring that the gradient of the pipe approaching the septic tank is flatter than about 1 in 66; and

g) It is recommended that the floor of a septic tank should slope downwards towards the inlet. There are two reasons: firstly, more sludge accumulates near the inlet, so a greater depth is desirable; secondly, the slope assists movement of sludge towards the inlet during de-sludging.

5.1.3.4 General Design Considerations for Soak-away Pit

a) The size of the soak-away depends on the volume of the septic tank and percolation rate of the soil. However, the capacity of the pit should be at least equal to that of the septic tank. Soak away pits are commonly 2-5 m deep with a diameter of 1.0-2.5 m. Soak away pit should be sufficiently large to avoid flooding and overflow.

b) As a general rule, no soak away pit should be placed less than 3m from any building or boundary of the site on which it is situated.

5.1.3.5 Operation and Maintenance of a Septic Tank

Starting up the septic tank

The process of anaerobic digestion of the black water solids entering the tank can be slow in starting and it is a good idea to "seed" a new tank with sludge from a tank that has been operating for some time. This ensures that the necessary microorganisms are present in the tank to allow the digestion process to take place in a short time.

Maintenance
Some of the operation and maintenance required are the following:

a) Periodically removal of scum;
b) Check the vent screen, replace if torn;
c) Measure the depth of sludge accumulation so that removal will be effected in time and
d) Make sure that heavy and non-biodegradable waste matters are not channelled to the septic tank.

Sludge Removal

i) The most satisfactory method of sludge removal is by vacuum tanker. The sludge is pumped out of the tank through a flexible hose connected to a vacuum pump, which lifts the sludge into the tanker;
ii) Sludge removed from a septic tank includes fresh excrete and presents a risk of transmission of diseases of faecal origin. Careful disposal is therefore necessary, preferably in Waste Stabilization Ponds or Constructed Wetlands; and
iii) When a septic tank is de-sludged it should not be fully washed out or disinfected. A small amount of sludge should be left in the tank to ensure continuing rapid digestion.

5.2 Off-site Treatment Systems

5.2.2 Waste Stabilization Ponds (WSPs)

5.2.2.1 Brief Description

Waste Stabilization Ponds (WSPs) are large, shallow basins in which raw black water is treated entirely by natural processes involving both algae and bacteria. WSP systems comprise a single string of anaerobic, facultative and maturation ponds in series, or several such series in parallel. In essence, anaerobic and facultative ponds are designed for removal of Biochemical Oxygen Demand (BOD), and maturation ponds for pathogen removal, although some BOD removal also occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds.

They are used for black water treatment in temperate and tropical climates, and represent one of the most cost-effective, reliable and easily-operated methods for treating domestic and industrial liquid waste. Waste stabilization ponds are very effective in the removal of faecal coliform bacteria. Sunlight energy is the only requirement for its operation. Further, it requires minimum supervision for daily operation, by simply cleaning the outlets and inlet works. They are well-suited for low-income tropical countries where conventional liquid waste treatment cannot be achieved due to the lack of a reliable energy source. Further, the advantage of these systems, in terms of removal of pathogens, is one of the most important reasons for its use.

Anaerobic Ponds
They normally do not contain dissolved oxygen or algae. In anaerobic ponds, BOD removal is achieved by sedimentation of solids, and subsequent anaerobic digestion in the resulting sludge. The process of anaerobic digestion is more intense at temperatures above 15^{o}C. The anaerobic bacteria are usually sensitive to pH<6.2. Thus, acidic liquid waste must be neutralized prior to its treatment in anaerobic ponds. A properly-designed anaerobic pond will achieve about a 40% removal of BOD at 10^{o}C, and more than 60% at 20^{o}C. A shorter retention time of 1.0-1.5 days is commonly used.

Facultative Ponds
Facultative ponds (1-2 m deep) are of two types: Primary facultative ponds that receive raw liquid waste, and secondary facultative ponds that receive particle-free liquid waste (usually from anaerobic ponds, septic tanks, primary facultative ponds, and shallow sewerage systems). The process of oxidation of organic matter by aerobic bacteria is usually dominant in primary facultative ponds or secondary facultative ponds. The processes in anaerobic and secondary facultative ponds occur simultaneously. It is estimated that about 30% of the influent BOD leaves the primary facultative pond in the form of methane. A high proportion of the BOD that does not leave the pond as methane ends up in algae. This process requires more time, more land area, and possibly 2-3 weeks water retention time, rather than 2-3 days in the anaerobic pond. In the secondary facultative pond (and the upper layers of primary facultative ponds) black water BOD is converted into *"Algal BOD,"* and has implications for effluent quality requirements. About 70 – 90% of the BOD of the final effluent from a series of well-designed WSPs is related to the algae they contain.

In secondary facultative ponds that receive particle-free black water (anaerobic effluent), the remaining non-settleable BOD is oxidised by heterotrophic bacteria *(Pseudomonas, Flavobacterium, Archromobacter and Alcaligenes spp).* The oxygen required for oxidation of BOD is obtained from photosynthetic activity of the micro-algae that grow naturally and profusely in facultative ponds.

Facultative ponds are designed for BOD removal on the basis of a relatively low surface loading (100 – 400 kg BOD/ha.day), in order to allow for the development of a healthy algal population, since the oxygen for BOD removal by the pond bacteria is generated primarily via algal photosynthesis. The facultative pond relies on naturally-growing algae. The facultative ponds are usually dark-green in colour because of the algae they contain.

Maturation Ponds
The maturation ponds, usually 1-1.5 m deep, receive the effluent from the facultative ponds. Their primary function is to remove excreted pathogens. Although maturation ponds achieve only a small degree of BOD removal, their contribution to nutrient removal also can be significant. Maturation ponds usually show less vertical biological and physicochemical stratification, and are well-oxygenated throughout the day. The algal population in maturation ponds is much more diverse than that of the facultative

ponds, with non-motile genera tending to be more common. The algal diversity generally increases from pond to pond along the series. Although faecal bacteria are partially removed in the facultative ponds, the size and numbers of the maturation ponds especially determine the numbers of faecal bacteria in the final effluent. There is some removal of solids-associated bacteria in anaerobic ponds, principally by sedimentation.

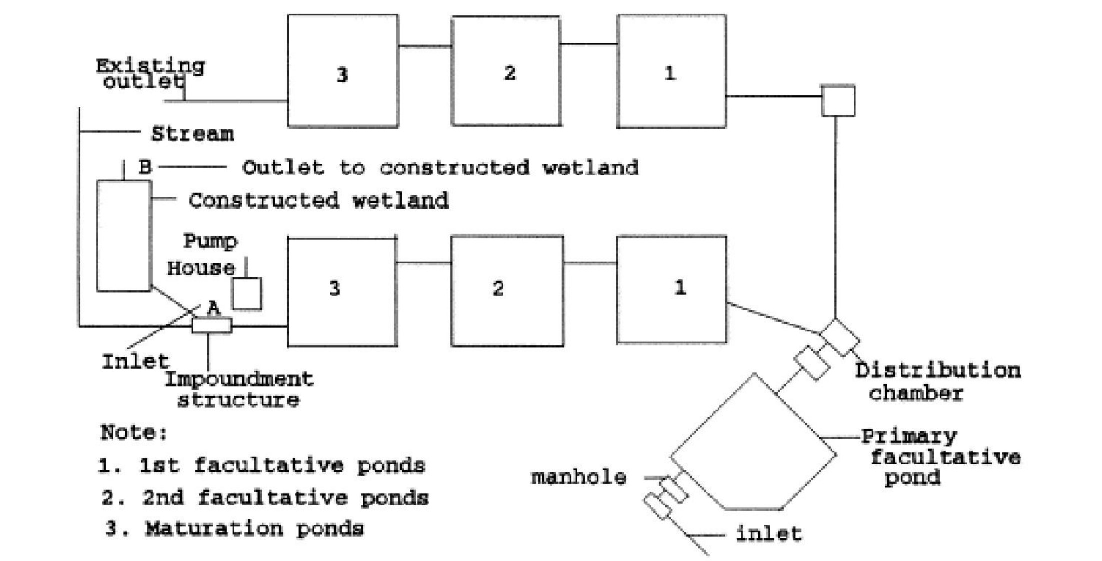


Figure 7: Typical layout of waste stabilization ponds

5.2.2.2 Sitting of Ponds

i) The WSPs should be located as far as practicable from habitation or any area which may be developed within a reasonable future period. The ponds should be located preferably about 500m downwind from the community they serve and away from any likely area of future expansion; this is to discourage people from visiting the ponds;

ii) Proximity of ponds to water supplies and other facilities subject to contamination and location in areas of porous soils and fissured rock formations should be critically evaluated to avoid creation of health hazards or other undesirable conditions. The WSPs should not be located within 300m of a well used to supply potable water;

iii) If practicable, WSPs should be located so that locally prevailing winds will be toward uninhabited areas. Preference should be given sites which will permit an unobstructed wind sweep across the ponds, especially in the direction of the locally prevailing winds;

iv) Location of ponds in catchment areas receiving significant amounts of runoff water is discouraged unless adequate provisions are made to divert storm water around the ponds and otherwise protect pond embankments

v) There should be vehicular access to and around the ponds and, in order to minimize earthworks, the site should be flat or gently sloping and

vi) Ponds should not be located within 2km of airports, as birds attracted to the ponds constitute a risk to air navigation.

5.2.2.3 General Design Considerations

i) Multiple ponds should be used to ensure flexibility if one or more ponds must be taken out of use for repair, enlargement or for some other reason. This flexibility allows maximum operational capability;
ii) The shape of the ponds should be such that there are no narrow, L-shaped or elongated portions. Round or square ponds may be used. Rectangular ponds should generally have a length not exceeding three times the width;
iii) The entire pond area shall be enclosed with a suitable fence to provide for public safety, to exclude livestock, and to discourage trespassing; and
iv) Appropriate signs should be provided along the fence around the pond to inform the public of the facility and advice against trespassing
v) Anaerobic ponds should be designed on the basis of volumetric BOD loading equation
vi) Facultative ponds should be designed on the basis of surface BOD loading equation
vii) Maturation ponds should be designed on the assumptions made that faecal coliform removal can be modelled by first order kinetics

5.2.2.4 Operation and Maintenance

a) Start-up Phase

i) Anaerobic ponds must be filled with raw black water and seeded with sludge from conventional black water treatment plants or septic tanks. After filling and seeding, the pond should gradually be loaded up to the design-loading rate. The pond contents should have a pH above 7, to allow the development of methanogenic bacteria. Lime or soda ash is added, if necessary, to rise the pH in the pond.
ii) If the sewerage system is new, and the flow rate, as well as the loading rate, to the anaerobic pond is low, the black water may be bypassed till the flow rate and the loading rate from the sewerage systems satisfies the condition to be discharged in the pond. It is important to have a bypass from the anaerobic pond that will be used during de-sludging.
iii) It is recommended that the ponds should be commissioned during the beginning of the hot season, in order to allow the quick establishment of microorganisms of importance for the waste stabilization ponds.

iv) The facultative pond should be commissioned before the anaerobic pond, in order to avoid odours during the release of anaerobic pond effluent to an empty facultative pond.
v) During the start-up phase of the facultative and maturation ponds, the ponds should be filled with freshwater (from tap, river or wells), thereby allowing the gradual development of algae and heterotrophic bacteria population. However, the primary facultative pond must be seeded as an anaerobic pond. If freshwater is not available, the secondary facultative and maturation ponds should be filled with raw

black water and left for 3-4 weeks, to allow the development of the microbial population.

b) Maintenance

i) Maintenance of the ponds should be carried out regularly to avoid odors, flies and mosquito nuisances. The routine maintenance includes:
   - Removing screenings and grit from the inlet and outlet works;
   - Cutting grasses on the embankment, and removing it so that it does not fall in the ponds;
   - Removing floating scum and floating macrophytes from the surface of the maturation and facultative ponds;
   - Spraying scum on the surface of the anaerobic ponds and not removing it, since this will help the treatment processes;
   - Removing any accumulated solids in the inlet and outlet works;
   - Repairing any damaged embankment as soon as possible; and
   - Repairing any damage of the fences or gates.

ii) A clear form should be prepared, clearly showing the tasks to be performed by the operator, and which should be counter-checked weekly by the foreman/supervisor.

iii) Anaerobic ponds require de-sludging when they are one third full of the sludge by volume. However, it is recommended that an annual de-sludging be carried out.

iv) The sludge from the pond may be disposed of in sludge lagoons or tankers that transport it to a landfill site, agricultural land or other suitable disposal area.

c) Monitoring and Evaluation of Performance

Frequent monitoring of the final effluent quality of a pond system is required to address the following needs:

- Regular assessment regarding whether or not the effluent complies with the local discharge or reuse standards; and
- Detection of any sudden failure, or determining if the pond effluent has started to deteriorate; it also may help identify the causes of the problem(s) and the remedial actions to be taken.

Two levels of monitoring are recommended. Level 1 involves taking samples of the final effluent at least monthly or weekly, for analysis of the parameters for which effluent discharge or reuse requirements exist. Level 2 is implemented when the Level 1 monitoring indicates that the effluent is failing to meet necessary standards, thereby requiring a more detailed study. Twenty-four hour flow-weighted composite samples are preferable for most of the parameters to be analyzed, although grab samples are necessary for some of them (pH, temperature, faecal coliform). The methods for collecting composite samples are as follows:

- Automatic sampler -- which takes samples every 1-2 hours, with subsequent manual flow weighting if this is not done automatically;
- Grab samples -- every 1-3 hours, with subsequent manual flow weighting; and
- Column samples – near the final pond outlet.

Some of the common parameters for monitoring, depending on the liquid waste treatment objective, may include pH; Biological Oxygen Demand (BOD); Dissolved Oxygen; Chemicals Oxygen Demand (COD); suspended solids (SS); chlorophyll-a; helminth eggs; nutrients (nitrogen; and phosphorus); heavy metals; and faecal coliform.

5.2.3 Constructed Wetlands

5.2.3.1 Brief System Description

Constructed wetlands (CWs) are designed and constructed to employ wetland vegetation to assist in treating liquid waste in a more controlled environment than occurs in natural wetlands. The system is particularly useful for treating septic tank effluent or grey water, landfill leachate and other wastes that require removal of high concentrations organic matter, suspended solids, pathogenic organisms, and nutrients such as ammonia and other forms of nitrogen and phosphorus. CWs should not be used to treat raw black water and, in industrial situations, the wastes may need to be pre-treated so that the biological elements of the wetlands can function effectively with the effluent.

Constructed wetlands for liquid waste treatment can be categorized as either Free Water Surface (FWS) or Subsurface Flow (SSF) systems. In FWS systems, the flow of water is above the ground, and plants are rooted in the sediment layer at the base of water column (Figure 7). In SSF systems, water flows though a porous media such as gravels or aggregates, in which the plants are rooted (Figure 8).

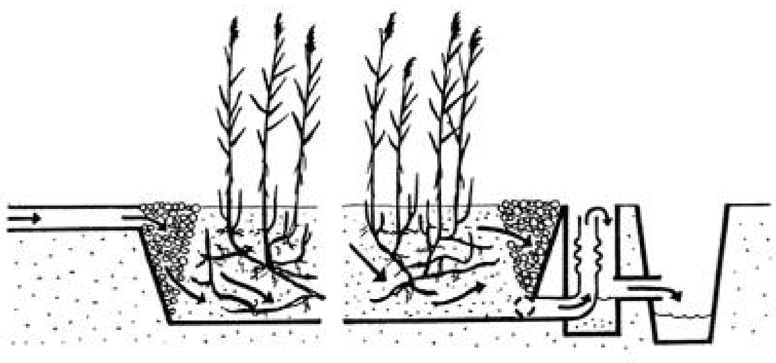


Figure 8: Horizontal sub-surface flow wetland

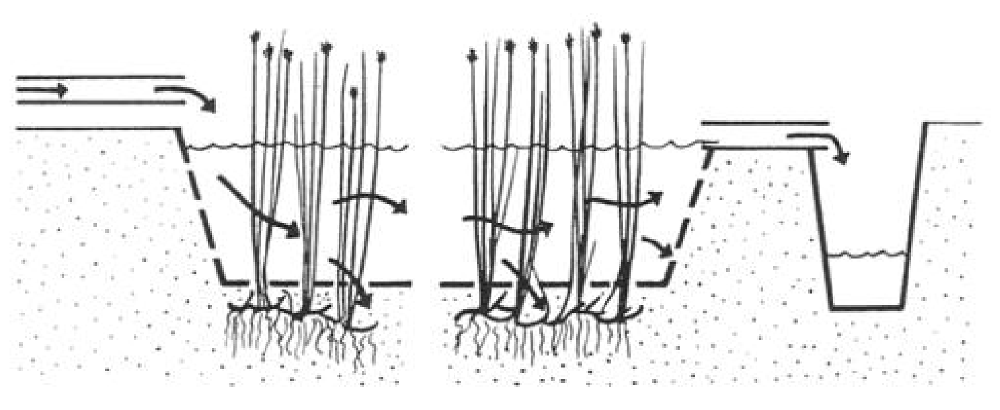


Figure 9: Horizontal surface flow wetland

SSF systems are most appropriate for treating primary liquid waste, because there is no direct contact between the water column and the atmosphere. There is no opportunity for vermin to breed, and the system is safer from a public health perspective. The environment within the SSF bed is mostly either anoxic or anaerobic. Oxygen is supplied by the roots of the emergent plants and is used up in the Biofilm growing directly on the roots and rhizomes, being unlikely to penetrate very far into the water column itself. SSF systems are good for nitrate removal *(denitrification)*, but not for ammonia oxidation (nitrification), since oxygen availability is the limiting step in nitrification.

FWS systems are very appropriate for polishing secondary and tertiary effluents, and for providing habitat. The environment in the FWS systems is generally aerobic at, and near, the surface, tending toward anoxic conditions near the bottom sediment. The microbial film grows on all available plant surfaces, and is the main mechanism of pollutant removal. FWS usually exhibits more biodiversity than does SSF systems.

Constructed wetlands are relatively inexpensive to construct, operate and maintain; provide effective liquid waste treatment; and provide indirect benefits such as green space, wildlife habitats and recreational and educational areas.

The disadvantages include the land requirements (cost and availability of suitable land); biological and hydrological complexity and our lack of understanding of important process dynamics; and possible problems with mosquitoes and pests.

5.2.3.2 Sitting of the CWs

i) The site should be protected from surface inflow waters;
ii) The system may be used for small communities and, therefore, may be located close to the users;
iii) If groundwater contamination is a potential problem, the bottom of the wetland may be sealed with a suitable material. However, generally no liner will be necessary in the constructed wetland.

5.2.3.3 General Design for Constructed Wetlands

i) CWs should be preceded with screens or comminution as preliminary treatment facilities. Imhoff tanks, septic tanks and stabilization pond(s) should be used as primary treatment facilities. Small communities with water flow rates less than 380 m^3/day may use septic tanks as primary treatment facility to reduce organic solids.

ii) There are three possible configurations for wetland cells used for liquid waste treatment: In parallel, in series, or a combination of the two. The main advantage for cells in parallel is the flexibility and redundancy in operation, so that individual cells can easily be taken off-line for maintenance and repair. The water flow can be re-directed to other cells, allowing for ongoing operation of the liquid waste treatment plant and the wetland. When the wetland cells operate in series, the water moves sequentially from one cell to next, forming a chain of wetland cells. The main operational advantage of cells in series is minimization of short-circuiting, leading to better overall treatment in the system. The selected configuration must be based on a clear understanding of the objectives, influent water quality, desired effluent water quality, hydraulic regime and site specific constraints and opportunities.

iii) An L/W value as low as 1 is recommended for SSF while an L/W ratio of at least 10 is required for the SF.

iv) The bed slope for SSF should be 2% or less, while that for SF should be 0.5% or less. The substrate depth should be 0.6 m.

v) The BOD loading for SSFCW should not exceed 133 kg/ha.day.

vi) Hydraulic Loading Rate should not exceed 5cm/day. However, Tanzanian experience reveals that hydraulic loading of up to 20 cm/day provide sufficient liquid waste treatment.

5.2.3.4 Operation and Maintenance

a) Commissioning

Sometimes commissioning of the wetland is referred as the time from planting to the date where the wetland is considered operational. Operation during this period should ensure an adequate cover of the wetland vegetation.

The water level within the wetland during this time needs to be controlled carefully, to prevent seedling from being desiccated or drowned. Once the plants are established, the water level may be raised to operational level. Plant loss may occur during the commissioning, therefore requiring transplanting.

b) Operation

The management of the constructed wetlands consists of four tasks and these are as follows:

i) Operational control (e.g. varying water level);
ii) Monitoring (e.g. water quality, habitat, flora and fauna);
iii) Inspection (e.g. structures and embankments);
iv) Maintenance (e.g. repair damage to the structures and control weeds)

The operation of a constructed wetland after commissioning must include:

i) Maintaining the embankments;
ii) Removing litter and debris;
iii) Checking the water flow rate to a constructed wetland to determine if it is in accordance with the design;
iv) Removing any blockages in the inlet and outlet works;
v) Replacing plants as required;
vi) Removing any unwanted weed species from the constructed wetland;
vii) Checking the plants for any sign of diseases;
viii) Protecting the deep open water;
ix) Correcting erosion and slumping; and
x) Checking for any signs of over-flooding (for sub-surface flow constructed wetlands).

c) Monitoring

i) Useful parameters for monitoring wetland performance include dissolved oxygen (DO), BOD, COD, total phosphorus, *orthophosphorus*, total nitrogen, total *Kjeldha*l nitrogen, ammonia nitrogen, oxidized nitrogen, faecal coliform, pH, suspended solids, electrical conductivity, and heavy metal concentrations.
ii) Water flow rates to and from the constructed wetland also must be measured.
iii) The sampling may be done using either an automatic or manual sampler. Samples within the wetland must sometimes be taken for the purpose of comparison.

5.2.4 Trickling Filters

5.2.4.1 Brief Description

Trickling filters are one of the oldest technologies used for liquid waste treatment. A trickling filter is a fixed film attached growth aerobic process for treatment of organic matter from the liquid waste. The surface of the bed is covered with the bio-film and as the liquid waste trickles over this media surface, organic matter from the liquid waste comes in contact with the aerobic bacteria and oxidation of organic matter occurs.

The solid media can be stones, gravel or specially manufactured plastic media. The media provides a large surface area for bacteria to attach to, while at the same time allowing free movement of air. The media is randomly packed and the liquid waste is applied on the top through rotary arm which trickles down over the filter media surface (Figure 10), hence, the name trickling filter.

Since, the liquid waste is applied through the rotary arm from the top of the reactor the bio-film grown on the media surface receives liquid waste intermittently. Rotary arm rotates as a result of jet action as the liquid waste is sprayed horizontally on the filter bed; hence, external power is not required for rotation of the arm. However, for trickling filter of small diameter (less than 6 m) power driven rotary arm may be needed.

As the liquid waste trickles down leaving the wet bio-film, the bio-film is exposed to the air voids present in the media, and thus oxygen from the air, after solubilizing in the water adhering on bio-film, is made available to aerobic bacteria grown in the bio-film by diffusion of oxygen through the bio-film. The end product CO_2 diffuses out of the bio-film into the flowing liquid. Treated liquid waste is collected from the bottom of the bed through an under drainage system and is settled in the final settling tank.

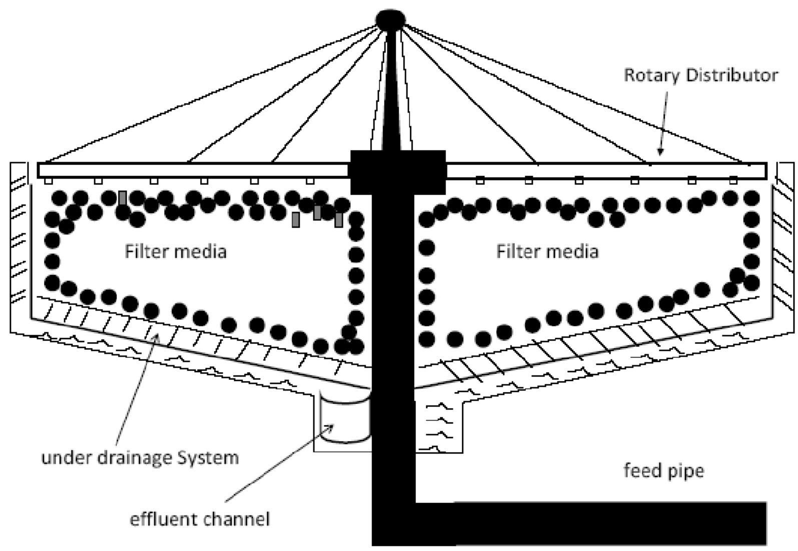


Figure 10: Schematic diagram of a trickling filter

Liquid waste has to undergo primary treatment before trickling filtration, otherwise solids will block the filter. Treated liquid waste can, however, be returned to the trickling filter, if this will assist with either treating the liquid waste further (second pass) or more generally for a more uniform distribution of water over the trickling filter bed.

5.2.4.2 General Design Considerations of a Trickling Filters

a) In order to avoid filter plugging, a maximum specific surface of100 m^2/m^3 is recommended for organic liquid waste treatment and up to 300 m^2/m^3 for nitrification, because of slow growth rate of nitrifies.

b) The clearance between the rotary distributor arm and filter should be between 150-225 mm above the filter bed. Typical head loss in the distributor is 0.6 to 1.5. The velocity of liquid waste moving through arm should be more than 0.3 m/s to prevent deposition of solids. The arm length could be as low as 3m to as high as 35m depending on the diameter of the filter.

c) Free draining out of filtered liquid waste should be ensured through provision of 1:5 slope towards the outlet; and design average flow velocity for under-drains to be not less than 0.6 m/s

d) For better air flow, open area over the top of the under-drains should be more than 15%. Each 23m^2 filter area should have 1m^2 area of ventilation manholes or vent stacks.

e) Recommended air flow required is 0.3 $m^3/m^2/min$

5.2.4.3 Operation and Maintenance

Start up of a trickling filter

i) Check all mechanical equipment (pumps, valves, end gates and nozzles) prior to introducing any liquid waste;

ii) Open the end gates to flush the arms of any debris, adjust the arms to level and close the end gates;
iii) Check for even flow distribution and speed of rotation;
iv) Check the nozzles to ensure even spray patterns; and
v) Adjust the recirculation ratio to obtain optimum wetting of the filter/media.

Maintenance

i) Check the functioning of all operational mechanical equipment and electric motor (daily);
ii) Check the distributor arms to ensure they are level and adjust the distributor arms for levelness (Quarterly);
iii) Flush the distributor arms and nozzles and clean/repair as required (weekly)
iv) Check for odours (daily);
v) Perform scheduled maintenance;
vi) Check the distributor arms as well as bearings and lubricate them (monthly);
vii) Lubricate equipment accordingly (annually); and
viii) Perform filter cover maintenance (annually).

5.3 Storm Water Management

It is widely recognized that developments impact negatively on drainage systems. By taking into consideration natural hydrological patterns and processes it is possible to develop storm water management systems in manner that reduces these potentially negative impacts and mimic nature. In this context, storm water management objectives should aim at the following:

- Minimize threat of flooding;
- Protect receiving water bodies;
- Promote multi-functional use of storm water management systems; and
- Develop sustainable storm water systems.

5.3.2 General Principles

Storm water management should consider the hydrological, geomorphological, ecological, soil, land use and cultural characteristics of a catchment and its drainage network. If the interactions noted above are not recognised, there is the potential for well-intended management techniques to have a greater environmental impact than unmitigated storm water runoff.

A set of broad and holistic principles that can be followed for effective storm water environment management are:

i) *Minimize hydrological impacts:* minimizing the impacts of urbanization on the hydrological characteristics of a catchment. If land use results in an inappropriate stream flow regime (e.g. runoff from an agricultural catchment causing erosion), this should be mitigated where practical;

ii) *Maintain water quality:* minimizing the amount of pollution entering the storm water system and removing an appropriate amount of any residual pollution by implementing storm water management practices;

iii) *Maximize vegetation landscape:* maximizing the value of indigenous vegetation; and

iv) *Maximize aquatic habitat:* maximizing the value of physical habitats to aquatic fauna within the storm water system.

In general, the aim should be to provide a storm water management system which mimics nature, utilizes natural features in the storm water cycle, will be an asset to the community and will function efficiently with relatively little maintenance.

5.3.3 Good Storm water Management System Practices

i) A storm water management hierarchy defining preferred storm water management practices is as follows:
   a) *Retain and restore (or rehabilitate) valuable ecosystems:* Retaining or restoring (if degraded) existing valuable elements of the storm water system, such as natural channels, wetlands and riparian vegetation;
   b) *Source control - non-structural measures:* These involve non-structural techniques for limiting changes to the quantity and quality of storm water at the source.
   c) *Source control - structural measures:* Constructed management techniques installed at or near the source to manage storm water quantity and quality ; and
   d) *In-system management measures:* Constructed management techniques installed within storm water systems to manage storm water quantity and quality prior to discharge into receiving waters. This may include constructed wetlands, sand filters and oil and grit separators.

ii) Land use planning should be done in relation to the natural context and characteristics of the site. The appropriate placement of land uses will enhance the multi-functionality of the storm water systems and their use as an amenity by residents in the area.

iii) Severely polluted storm water may constitute a health hazard to downstream residents and an ecological hazard to downstream aquatic ecosystems. Consideration should therefore be given to diverting such water off-site for treatment, at least during low-flow periods when water quality is likely to be most impacted.

iv) As a general principle litter, silt and other pollutants emanating from a catchment should be trapped as close to source as possible. This is of particular importance when the storm water discharges into a sensitive environment, and where damage may result if the pollutant is not trapped and removed.

v) It is strongly recommended that any planting programmes carried out in storm water management systems should make use of locally indigenous plant species.

5.3.4 General Design Considerations

Design for storm water should consider the following;

- Identifying the factors affecting the quantity of storm water flow
- Estimation of Quantity of Storm Water from design methods
- Hydraulic analysis

5.4 Selection Criteria for Liquid Waste Management Technology

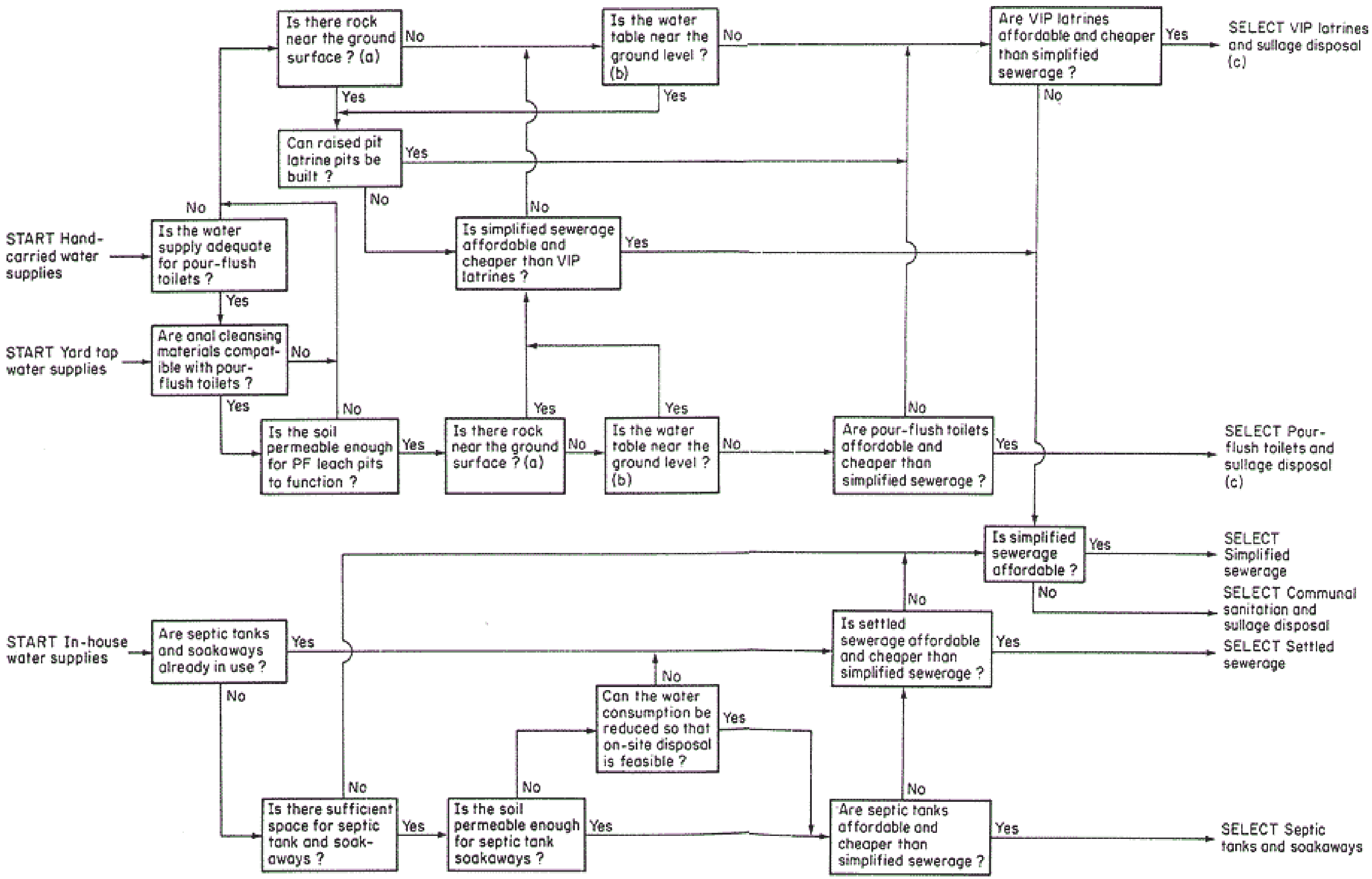
The choice of liquid waste technology in any particular situation has to take into account appropriateness, affordability and sustainability as the main criteria. However, in order to simplify the selection of appropriate technology an algorithm presented in Figure 11 is recommended for this purpose.

The algorithm has considered several main criteria in the selection process that includes:

- Availability of water (hand-carried water supplies, tap water supplies and in-house water supplies);
- Topography and geological characteristics of the area (rocks, soil permeability, water table);
- Space availability (population density);
- Capital and operational costs.

What is clear from the algorithm is that there are many technologies that are environmentally sound which can be selected based on the local conditions and preference. In water shortage area, the amount of tap water required to transport pollutants to the treatment facility is hardly affordable, therefore disposal of domestic liquid waste could opt for VIP latrines or composting latrines. In urban areas, access to sewerage system is very limited (<15%), therefore most communities rely on on-site sanitation in its various forms, which happens to be a relevant and viable option.

On the other hand, where there is adequate water supply, simplified sewerage system, conventional sewerage system or settled sewerage system (wetlands/lagoons) may be applicable. However, currently, the use of constructed wetlands for liquid waste treatment in urban areas is gaining increasing attention and these have been identified as a much more cost-effective option for both black water and storm water treatment. Better still, they can be integrated into agricultural and fish production systems.



Sanitation technology selection algorithm. Notes: (a) to < 1 m; (b) to within 0.5 m either permanently or seasonally; (c) decide between single pits and alternating twin pits

Figure 11: Sanitation technology selection algorithm (Source: UNEP, 2005)

CHAPTER SIX

REUSE OF TREATED LIQUID WASTE

6.1 Liquid Waste Reuse and Sustainability

Rapidly growing demand for food and energy on the one hand and continuing urbanisation on the other hand, stress on water resources is steadily increasing. Therefore, reuse and recycling of water will inevitable play a leading part when it comes to sustainable development.

The reuse of treated liquid waste for irrigation and industrial purposes can be used as strategy to reduce demand for freshwater and reduce liquid waste discharges into water bodies thereby reducing and preventing pollution.

The population growth is expected to put more pressure on the already scarce and increasingly degraded water resources. Liquid waste reuse can offer significant approach for conserving and extending available water supplies. Water reuse may also present with an alternate liquid waste disposal method as well as providing pollution abatement by diverting effluent discharge away from sensitive water bodies. Therefore, liquid waste reuse presents an array of potential economic, environmental and social benefits.

6.1.1 Potential Options for Liquid Waste Reuse

Water quality is the most important in water reuse systems for ensuring sustainable and successful liquid waste reuse applications. While the nutrient content of treated liquid waste may have some economic value, the presence of pollutants should be recognised. Less obvious characteristics, such as elevated levels of dissolved solids and changes in water chemistry can be significant in both industrial and agricultural systems. In the latter, serious consequences relating to salinity, soil structure and soil permeability can occur.

The positive and negative aspects of each reuse practice must be assessed. The effects on public health and on the environment should be evaluated. The options for reuse may include irrigation, aquaculture, tree growing, recreational and industrial purposes.

Most common types of liquid waste reuse options are summarized in Table 1. Table 2 presents the most important water quality parameters and their significance in the case of municipal liquid waste reuse.

Standards for liquid waste reuse have been adopted from the WHO Guidelines (1989) (Table 2). The Guidelines are set to minimize exposure to workers, crop handlers, field workers and consumers, and recommend treatment options to meet the guideline values.

Table 1: Options and water quality related requirements for reuse of liquid waste

Reuse option	Required treatment	Reclaimed water quality	Reclaimed water Monitoring	Setback distances
Urban Reuse Landscape irrigation, vehicle washing, toilet flushing, fire protection, commercial air conditioners, and other uses with similar access or exposure to the water	• Secondary treatment • Filtration • Disinfection	• pH = 6–9 • <10 mg/L biochemical oxygen demand (BOD) • < 2 turbidity units (NTU) • No detectable fecal coliform/100 mL4 • 1 mg/L chlorine (Cl_2) residual (min.)	• pH – weekly • BOD – weekly • Turbidity – continuous • Coliform – daily • Cl_2 residual –continuous	15 m to potable water supply wells
Agricultural Reuse for non-Food Crops Pasture for milking animals; fodder, fiber and seed crops	• Secondary treatment • Disinfection	• pH = 6–9 • < 30 mg/L BOD • < 30 mg/L total suspended solids (TSS) • < 200 fecal coliform/100 mL • 1 mg/L Cl_2 residual (min.)	• pH – weekly • BOD – weekly • TSS – daily • Coliform – daily • Cl_2 residual –continuous	90 m to potable water supply wells
Indirect Potable Reuse Groundwater recharge by spreading into potable aquifers	• Site specific • Secondary treatment and disinfection (min.). May also need filtration and/or advanced liquid waste treatment	Site specific meet drinking water standards after percolation through vadose zone.	• pH – daily • Turbidity – continuous • Coliform – daily • Cl_2 residual –continuous • Drinking water standards–quarterly • Other – depends on pollutant	30 m to areas accessible to the public (if spray irrigation) site specific

NOTES

Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contactors, and many stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and TSS do no exceed 30 mg/L.

Table 2: Water quality parameters for reuse of treated liquid waste and their significance

Parameter	Significance	Approximate range in treated Liquid waste
Total Suspended Solids (TSS)	TSS can lead to sludge deposits and anaerobic conditions. Excessive amounts caused clogging of irrigation systems. Measures of particles in liquid waste can be related to microbial contamination, turbidity. Can interfere with disinfection effectiveness	• < 1 to 30 mg/l
Organic indicators TOC Degradable Organics (COD, BOD)	Measure of organic carbon. Their biological decomposition can lead to depletion of oxygen. For irrigation only excessive amounts cause problems. Low to moderate concentrations are beneficial.	• 1 – 20 mg/l • 10 – 30 mg/l
Nutrients (N,P,K)	When discharged into the aquatic environment they lead to eutrophication. In irrigation, they are beneficial, nutrient source. Nitrate in excessive amounts, however, may lead to groundwater contamination.	• N: 10 to 30 mg/l • P: 0.1 to 30 mg/l
Stable organics (e.g. phenols, pesticides, chlorinated hydrocarbons)	Some are toxic in the environment, accumulation processes in the soil.	
pH	Affects metal solubility and alkalinity and structure of soil, and plant growth.	
Heavy metals (Cd, Zn, Ni,etc.)	Accumulation processes in the soil, toxicity for plants	
Pathogenic organisms	Measure of microbial health risks due to enteric viruses, pathogenic bacteria and protozoa	• Coliform organisms: < 1 to 10^4 /100 ml • other pathogens: Controlled by treatment technology
Dissolved Inorganics (TDS, EC, SAR)	Excessive salinity may damage crops. Chloride, Sodium and Boron are toxic to some crops, extensive sodium may cause permeability problems	

CHAPTER SEVEN

DISPOSAL OF TREATED LIQUID WASTE INTO THE ENVIRONMENT

7.1 Disposal to Coastal Waters

Dilution and dispersion are valuable processes for reducing the impacts of many non-toxic and non-accumulative pollutants. The effects of most ocean discharges are statistically insignificant when compared to total loads in the ocean. However, there may be locally significant effects, particularly for large quantities of discharge. These effects include:

- Bacterial - may be unfit for swimming or shellfish harvesting
- Aesthetics - It may be unsightly due to oil, grease, plastics, litter or odour
- Nutrients - near shore productivity may be increased nuisance algal growths, which are a particular problem in estuaries
- Toxicants – may impact on biota and have the potential for making produce unacceptable for use.

Bioaccumulation is a critical factor in assessing long-term impacts of effluent discharge. The potential for bioaccumulation of heavy metals, pesticides and other organics and pesticides should be controlled to minimise chronic effects on human health and the environment.

Table 3 provides guidelines for the various categories of discharge to coastal waters and indicates the related environmental values, issues and guideline treatment levels that apply. These categories are dependent upon the mixing processes that dominate the discharge.

Table 3: Coastal water discharge options and treatment levels

Discharge option	Limiting environmental values applying to each discharge option	Effluent parameters of major concern	Minimum level of treatment
coastal waters via extended outfall	Maintenance of aquatic ecosystems	toxicants, pathogens, floatables, oil and grease, suspended solids	**A**
coastal waters high tidal range	maintenance of aquatic ecosystems and recreation	pathogens, toxicants, floatables, oil and grease, suspended solids.	**B**
coastal waters near shore (other than bays and estuaries)	maintenance of aquatic ecosystems, recreation and aesthetic enjoyment	pathogens, toxicants, floatables, oil and grease, suspended solids nutrient impact, surfactants	**C**
bays and estuaries	maintenance of aquatic ecosystems, recreation and aesthetic enjoyment	Oil and grease, nutrients, pathogens, toxicants, floatables colour, suspended solids, BOD, surfactants	**C**

NOTES		
Treatment Process Category	**Parameters of interest**	**Examples of Treatment Processes**
A Pre-treatment	Gross solids (for fine screens, some readily settleable solids)	Screening
B Primary Treatment	Gross solids plus readily settleable solids	Primary sedimentation
C Secondary Treatment	Most solids and BOD	Biological treatment, chemically assisted treatment, lagoons
D Nutrient removal	Nutrients after removal of solids	Biological, chemical precipitation
E Disinfection	Bacteria and viruses	Lagooning, ultraviolet radiation, chlorination

7.2 Disposal to Inland Water Bodies

The ability of inland water to maintain environmental values has been threatened by population growth, , urbanisation and unsustainable use of catchments.

Issues to be considered in discharging effluent to inland water bodies include:

- avoiding or minimizing the amount of contaminants in the effluent through awareness campaigns;
- reusing or recycling treated effluent where practical ;
- returning effluent to a stream to provide environmental flows only where effluent quality is at least commensurate with ambient water quality objectives;
- adopting accepted modern treatment technology with the aim of improvement over time;
- applying national environmental quality standards for effluent where the discharge is a major determinant of the receiving stream quality; and
- avoiding discharges entering potable water supply and streams having high environmental value by optimal location of the sewerage pipes.

Table 4 sets out the effluent parameters of concern and the guideline treatment levels for discharge to inland waters. The minimum treatment level defines the lower end of the spectrum for each discharge to inland waters.

Table 4: Inland water discharge options and treatment levels

Discharge option	Limiting environmental values applying to each discharge option	effluent parameters of major concern	minimum level of treatment
Rivers, lakes, dams and streams	ecosystem protection	dissolved solids, toxicants, floatables, colour, turbidity, TSS, nutrients, BOD, pH.	**C and D**
	recreation and aesthetics	toxicants, floatables, colour, turbidity, TSS, nutrients, BOD, pathogens, odour, oil and grease.	**C and E**

	raw water for drinking water supply	dissolved solids, toxicants, floatables, colour, turbidity, TSS including algae, nutrients, BOD, pH, pathogens, taste and odour producing compounds.	**C, D and E**
	agricultural water	dissolved solids, toxicants, floatables, TSS,pH, pathogens.	**C**
	industrial water	dissolved solids, toxicants, floatables, colour, turbidity, TSS, nutrients, BOD, pH.	**C, D and E**

NOTES

Treatment Process Category	**Parameters of interest**	**Examples of Treatment Processes**
A Pre Treatment	Gross solids (for fine screens, some readily settleable solids)	Screening
B Primary Treatment	Gross solids plus readily settleable solids	Primary sedimentation
C Secondary Treatment	Most solids and BOD	Biological treatment, chemically assisted treatment, lagoons
D Nutrient removal	Nutrients after removal of solids	Biological, chemical precipitation
E Disinfection	Bacteria and viruses	Lagoons, ultraviolet radiation, chlorination

7.3 Land Application

Land application is the discharge of effluent from the liquid waste treatment process on an area of land with the primary aim of irrigation or disposal.

Generally, water quality limits are set for effluent before application. They are set to minimise potential health risks and effects on the receiving environment, and are monitored to determine compliance. The basic principles for land application are:

- the build up of any substance in the soil should not preclude sustainable use of the land in the long term;
- the effluent is not detrimental to the vegetative cover;
- any change to the soil structure should not preclude the use of the land in the long term;
- any runoff to surface waters or percolation to groundwater should not compromise the agreed environmental values; and
- no gaseous emissions to cause nuisance odour.

There should be storage capacity for times when climatic conditions halt operations or require reduced loading rates. Where spray irrigation is used, the potential health risk from aerosol spray drift should be evaluated. The proximity of the operation to communities and access by the public during and after irrigation are factors that may place limitations on spray irrigation.

Table 5 lists discharge options, guideline treatment levels, the limiting factors for each land application option, and associated parameters likely to be of concern. These factors should be considered in detail before adopting a particular option. The type of land application and local conditions will determine the level of treatment required.

Table 5: Inland water discharge options and treatment levels

Land application option	Limiting factors for different environmental media	Effluent parameters of major concern	minimum level of treatment
Evaporation ponds	• Air – aesthetic enjoyment (odours) • Water – seepage, run-off	Odour emission, toxicants, BOD, pathogens	**Nil**
Irrigation • agricultural	• Air – odours • Land – potential for long term soil contamination and adverse impacts on vegetation and soil properties	Odours, dissolved solids, toxicants, pH, pathogens, nutrients	**C and E**
• landscape			**C and E**
Disposal (infiltration)	• groundwater – existing and potential environmental values • Land – potential for long term degradation of land and/or crop and vegetation	Solids, BOD, nutrients, pathogens, toxicants, dissolved solids, pH	**C and D**

NOTES

Treatment Process Category	Parameters of interest	Examples of Treatment Processes
A Pre Treatment	Gross solids (for fine screens, some readily settleable solids)	Screening
B Primary Treatment	Gross solids plus readily settleable solids	Primary sedimentation
C Secondary Treatment	Most solids and BOD	Biological treatment, chemically assisted treatment, lagoons
D Nutrient removal	Nutrients after removal of solids	Biological, chemical precipitation
E Disinfection	Bacteria and viruses	Lagoons, ultraviolet radiation, chlorination

CHAPTER EIGHT

SLUDGE MANAGEMENT

8.1 Major Sources of Sludge

Sludge is produced from the treatment of liquid waste in on-site (e.g. septic tank) and off-site (e.g. activated sludge) systems. This is inherently so because a primary aim of liquid waste treatment is removing solids from the liquid waste. In addition, soluble organic substances are converted to bacterial cells, and the latter is removed from the liquid waste.

Management options are chosen based the sustainability concept implying those which do not harm the environment, either by using non-renewable resources or by resulting in a build-up of constituents, which can safely be assimilated in the environment. The three options available for sustainable management of sludge include:

i) Utilising the calorific energy value of the sludge (e.g. heat generation)
ii) Using the useful components of the sludge (e.g. as a soil conditioner, compost)
iii) Extracting useful constituents from the sludge (e.g. nutrients – N, P and K)

8.2 Sludge Characterization

Black water exhibit wide variations in their properties depending on origin and previous treatment. Many parameters have therefore been introduced and tests developed to measure specific properties of sludge in relation to particular methods of treatment. Parameters can be grouped in physical, chemical and biological parameters:

i) physical parameters give general information on sludge proc ess ability and handle ability;
ii) chemical parameters are relevant to the presence of nutrients and toxic/dangerous compounds, so they become necessary in the case of utilisation in agriculture;
iii) biological parameters give information on microbial activity and organic matter/pathogens presence, thus allowing the safety of use to be evaluated.

A list of parameters which can be used, and their relevance to treatment and disposal steps, is presented in Table 6. The sludge characteristics which are important to know strictly depend on the handling and disposal methods adopted. The important parameters in relation to the disposal/use options listed in Table 6 are briefly discussed.

Table 6: Disposal and use operations parameters

Parameter	Stabilization										
	Anaerobic	Chemical	Thermal	Thickening	Dewatering	Drying	Transportation	Landfilling	Composting	Agriculture	Incineration
Temperature	x				x	x			x		x
Density				x		x	x				
Rheological properties					x	x	x	x		x	x
Settleability				x	x						
Solids concentration	x	x	x	x	x	x	x	x	x	x	x
Volatile solids	x	x	x				x	x	x	x	x
Digestability	x										
pH	x	x							x	x	
Volatile acids	x										
Fats and oils	x									x	
Heavy metals	x							x	x	x	x
Nutrients	x								x	x	
Particle size				x	x						
Specific resistance				x	x						
compressibility					x						
Calorific value											x
Leachability							x				
Microbiological properties	x								x	x	

8.3 Sludge Handling and Management Options

8.3.1 Storage

For liquid sludge, the most suitable ways of storing should include:

- tanks/vessels having a square, rectangular or circular cross section with vertical walls;
- excavated lagoons/ponds, normally lined at the bottom, with inclined walls.

The most widely used systems of storage for dewatered sludge should be dumps, basins and containers. The storage of dewatered sludge generally requires a drainage control for water and gases and, in areas with heavy rainfall, covering and sealing systems.

8.3.2 Transportation

Transport by truck is the most convenient method that can be used. The most significant advantages are relatively low investment costs and a high degree of flexibility. Rerouting and alteration of collection points are also easily arranged. Drawbacks are possible leakage and odour/dust emission. Sludge can also be transported by pipeline or railway.

8.3.3 Reuse of Sludge for Agricultural Purposes

In principle, all types of sludge can be spread on farmland if they fulfil the quality requirements (heavy metals, pathogens, pre-treatment) in accordance with the Soil Quality Standards Regulations of 2007. Pathogens and heavy metals can, however, limit the reuse of sludge. Heavy metals and toxic chemicals are difficult to remove from sludge. Preventing these chemicals from entering the liquid waste or sludge should be the aim of liquid waste management for sludge intended for reuse in agriculture or horticulture. Reuse may still be possible for purposes such as mine site rehabilitation, highway landscaping or for landfill cover.

8.3.4 Composting

As a general reference, the water content of a compostable mixture of organic wastes should be around 55% while the organic matter content should be greater than 70%, facilitating effective bio-degradation. High moisture content above 60%, reduces the temperature, porosity and thus the oxygen concentration while a low moisture content, below 50%, could limit the rate of composting. At values of 10-15% the bacterial metabolism generally ceases to function. Bacterial activity is also influenced by pH, with the optimal values being between 5.5 and 8.

Because liquid waste sludge is rich in nutrients, its carbon to nitrogen ratio is low (5 to 10). A balance of the nitrogen and carbon content is necessary for the proper growth of micro-organisms. The carbon to nitrogen ratio (C/N) of the mixture is therefore commonly used to define the optimum functional conditions. Although values ranging between 25 and 30 are recommended, the types of substrates concerned must be evaluated when establishing the ideal ratio. Waste materials that can be used for this purpose include saw dust, mulched garden wastes, forest wastes and shredded newspaper.

8.3.5 Anaerobic Digestion

Anaerobic digestion is usually carried out in a specially built digester, where the content is thoroughly mixed. After digestion, the sludge is passed to a sedimentation tank where the sludge is thickened. Biogas is collected from the digester. The thickened sludge requires further treatment prior to reuse or disposal.

8.3.6 Thickening

Thickening is carried out in a sedimentation tank or in a sedimentation pond. The latter is advantageous if land area is available, because the sludge can be allowed to settle over a much longer period and a higher solids content of the thickened sludge is achieved. The water removed from thickening needs treatment. It can be returned to the inlet of an off-site liquid waste treatment plant, or in the case of sludge from on-site units by an aerobic treatment process such as lagooning.

8.3.7 Dewatering and drying

Dewatering aims to reduce the water content further so that the solids content of the sludge is about 20 % (equivalent to 1 kg dry sludge with 4 L of water). The sludge can then be handled like a solid. Dewatering can be done mechanically using a filter press (employing pressure or vacuum), or a centrifuge. It can also be done using drying beds. A drying bed consists of a 30 cm bed of sand with an under-drainage (Figure 12). Sludge is applied on the sand bed and is allowed to dry by evaporation and drainage of excess water over a period of several weeks depending on climatic conditions. Bacterial decomposition of the sludge takes place during the drying process while moisture content is sufficiently high. During the rainy season the process may take a longer time to complete and sizing the area of the drying beds should take this into account.

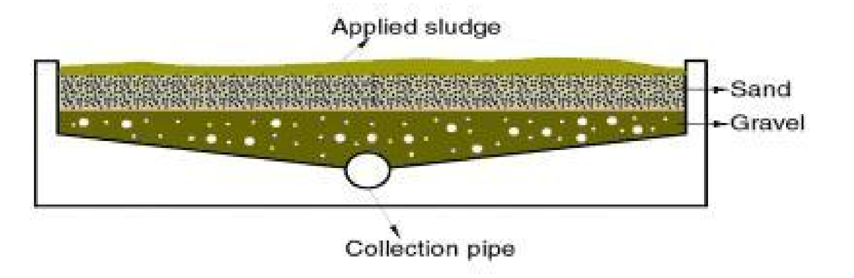


Figure 12: sludge drying bed

8.3.8 Incineration

Incineration of sludge that contains hazardous substance such as heavy metals can be performed in cement kilns after pre-drying, because they have a high calorific value. Pollutants should be stabilized in the clinker which is an interesting way of treating polluted sludges. Incineration results in a large volume reduction of the sludge.

8.3.9 Land filling

Final or ultimate disposal of sludge, which cannot be reused, is by landfilling. Since sludge for landfilling usually contains heavy metals or toxic chemicals, lining of the landfill with clay or plastic liner may be required to prevent contamination of groundwater. Guidelines for landfill should be;

- Trench method is usually chosen where the level terrain is available, soil are deep and ground water table is deep;
- The trench may be completely excavated prior to beginning the operation or it may be excavated progressively as work proceeds;
- The trench should be self draining
- The fill begins at one end of the trench and develops progressively along its length; and
- Trenches are usually 1.8 to 3m deep and, depending on local conditions, 3.5 to 10m in width

Sludge can only be deposited after dumping an at least 3 meters thick solid waste ground layer. Continuously spread sludge layers have to be avoided. Sludge piles have to be covered with solid waste.

CHAPTER NINE

SAMPLING ANDMONITORING OF LIQUID WASTE

Sampling and Monitoring of the environment and treated liquid waste are needed to determine whether;

- predicted effluent quality is achieved;
- level of impact or change caused by the management system is as predicted;
- setting of environmental standards are met

9.1 Monitoring of Liquid Waste

Monitoring of effluent quality may be undertaken to:

- assess treatment plant performance
- meet a regulatory requirement
- detect changes in effluent quality that could have an impact on the environment
- provide data for long term planning and to confirm design criteria
- meet research needs.

9.2 Sampling of Liquid Waste

The nature and frequency of sampling required will depend on a large number of factors. These include the:

- sensitivity of the environment
- nature of the treatment process
- risks to the environment
- quantity of the discharge
- variability of the inflow
- composition and variability of the inflow's industrial waste component
- reliability of the treatment process
- competence of the operating staff
- effectiveness of the plant's maintenance and supervision
- remoteness of the plant

It is recommended that sampling can be done in two levels:

- a small number of critical parameters such as indicators of general plant performance and those most likely to vary and have the greatest potential for short term impact on the environment; and
- a broad suite of parameters covering all those with identified potential for impact on the environment including suspended solids, BOD, temperature, pH, oil and grease, nutrients, dissolved solids, pathogens and toxicants.

The sampling frequency is largely dependent on treatment system size and the robustness of the treatment process. In cases where there may be a significant impact on the environment, more frequent sampling may be required. Table 7 presents the recommended sampling frequencies for different liquid waste treatment system types. Two sampling frequencies are recommended for each plant size.

Table 7: Recommended sampling frequencies for different effluent treatment systems

Liquid waste treatment system type	Principal Process Parameters	System Retention time	Treatment system size			
			Very small (<0.5MLD)	Small (0.5-3 MLD)	Medium (3-20 MLD)	Large (> 20 MLD)
A,B	TSS, BOD	All	Q	Q	W	2 x W
C	TSS, BOD	Long retention time	Q	Q	M	W
		Short retention time	M	W	2 x W	2 x W
D	TSS, N, P, BOD	Long retention time	Q	Q	M	W
		Short retention time	M	W	2 x W	2 x W
E	*E. Coli*	Long retention time	Q	Q	M	W
		Short retention time	M	M	2 x W	2 x W
F	Any site specific needs	All	W	W	2 x W	2 x W

NOTES:

	Liquid waste treatment system	Examples of treatment processes
A	Pre-treatment	screening
B	Primary treatment	Primary sedimentation
C	Secondary treatment	Biological treatment, chemically assisted treatment, lagoons
D	Nutrient removal	Biological and chemical precipitation
E	Disinfection	Lagoons, ozonation, chlorination
F	Advanced liquid waste treatment	Sand filtration, microfiltration

ABBREVIATIONS

BOD = Biological Oxygen Demand **TSS** = Total Suspended Soils	**P** = Phosphorus **N** = Nitrogen	**MLD** = Million Litres per Day **W** = Weekly	**2 x W** = Twice weekly **Q** = Quarterly **M**= Monthly

9.1 Standards for Monitoring of Liquid Waste Discharges

National Environmental Standards Committee has set standards for liquid waste discharges in accordance to the requirements of the Environmental Management Act (2004) (Section 140-150). In addition, the East African Community (EAC) has developed Regional Standards for Industrial and Municipal Effluent Discharges into Sewerage and River Systems for adoption by Partner States.

Industrial effluents are discharged into either public sewers or water bodies. The maximum permissible limits and test methods for industrial effluents discharged into public sewers are given in Table 8. In addition, maximum permissible limits and test methods for municipal effluent from treatment systems and sometimes industrial effluents into water are given in Table 9.

Table 8: EAC Regional Standards for Industrial effluents discharged into public sewers — Maximum permissible limits

S/N	Parameter	Maximum permissible limits	Test Method or Equivalent
1.	Total Suspended Solids	250 mg/L	ISO 11923
2.	Total Dissolved Solids	2000 mg/L	-
3.	Turbidity	300 NTU	ISO 7027 APHA Standard Methods: 2130B
4.	pH	6.0-9.0	ISO 10523
5.	Temperature	20-35^{o}C	
6.	Biochemical Oxygen Demand (BOD) for 5 days at 20^{o}C	500 mg/L	ISO 5815
7.	Chemical Oxygen Demand (COD)	1000 mg/L	ISO 15705/6060
8.	Total Phosphorus	10 mg/L	ISO 6878/15681: Part 1 & 2
9.	Sulphides	1 mg/L	APHA Standard Methods: 4110B ISO 10530
10.	Sulphates	400 mg/L	APHA Standard Methods: 4110 B. ISO 10304: Part 2
11.	Nitrates	20 mg/L	ISO 7890: Part 3; APHA Standard Methods: 4110 B.
12.	Nitrites	2 mg/L	ISO 6777
13.	Ammonium nitrogen	5 mg/L	ISO 11905: Part 1/5664
14.	Total nitrogen	30 mg/L	ISO 5663
15.	Colour	300 TCU	ISO 7887
16.	Odour	No offensive odour	
17.	Cyanides	0.2 mg/L	ISO 6703
18.	Chloride	600 mg/L	ISO 10304-1 APHA Standard Methods: 4110B
19.	Total residue chlorine	1 mg/L	ISO 7393-2
20.	Fluorides	8 mg/L	APHA Standard Methods: 4110 B. ISO 10304: Part 1
21.	Iron	3.5 mg/L	ISO 6232
22.	Arsenic	0.2 mg/L	ISO 11885/11969/6595

S/N	Parameter	Maximum permissible limits	Test Method or Equivalent
23.	Cadmium	0.1 mg/L	ISO 5961/8288
24.	Total Chromium	2 mg/L	ISO 9174/11083
25.	Copper	1 mg/L	ISO 8288/11885
26.	Aluminum	2.0 mg/L	ISO 10566/12020
27.	Lead	0.05 mg/L	ISO 8288/11885
28.	Barium	1.5 mg/L	ISO 14911
29.	Total mercury	0.002 mg/L	ISO 5666
30.	Nickel	1 mg/L	ISO 8288/11885
31.	Selenium	0.1 mg/L	ISO 9965/11885
32.	Zinc	5 mg/L	IS0 8288/11885
33.	Silver	0.1 mg/L	ISO 15586: 2003 ISO 11885
34.	Organochlorine pesticides	0 mg/L	ISO 6468: 1996
35.	Oils and grease	5 mg/L	APHA Standard methods 5520 ISO 9377: Part 1 - 3
36.	Phenols	2 mg/L	ISO 6468/ISO 14402 / 6439
37.	Benzene	0 mg/L	ISO 6468: 1996
38.	Dichloromethane	0.2 mg/L	ISO 10301: 1997

Source: EAC, 2012

Table 9: EAC Regional Standards for Industrial and municipal effluents discharged into water bodies — Maximum permissible limits

S/N	Parameter	Maximum permissible limits	Test Method or Equivalent
1.	Total Suspended Solids	100 mg/L	ISO 11923
2.	Turbidity	30 NTU	ISO 7027 APHA Standard Methods: 2130 B.
3.	pH	6.0 – 9.0	ISO 10523
4.	Temperature change	± 3 ^{0}C	
5.	Biochemical Oxygen Demand (BOD) for 5 days at 20^{o}C	30 mg/L	ISO 5815
6.	Chemical Oxygen Demand (COD)	60 mg/L	ISO 15705/6060
7.	Total Phosphorus	5 mg/L	ISO 15681: Parts 1 & 2
8.	Sulphides	1 mg/L	ISO 10530
9.	Sulphates	50 mg/L	ISO 10304: Part 2 APHA Standard Methods: 4110 B.
10.	Nitrates	5 mg/L	ISO 7890 PART 3 APHA Standard Methods: 4110 B.
11.	Nitrites	1 mg/L	ISO 6777
12.	Total nitrogen	10 mg/L	ISO 5663
13.	Ammonium nitrogen	5 mg/L	ISO 11905 part 1 / 5664
14.	Colour	50 TCU	ISO 7887
15.	Odour	No offensive odour	

16.	Cyanides	0.05 mg/L	ISO 6703
17.	Total residue chlorine	0.2 mg/L	ISO 7393-2
18.	Fluoride	2 mg/L	ISO 10304
19.	Arsenic	0.01 mg/L	ISO 11885/11969/6595
20.	Cadmium	0.01 mg/L	ISO 5961/8288
21.	Hexavalent chromium	0.05 mg/L	ISO 9174
22.	Total Chromium	1 mg/L	ISO 9174/11083
23.	Copper	0.5 mg/L	ISO 8288/11885
24.	Lead	0.01 mg/L	ISO 8288/11885
25.	Total mercury	0.001 mg/L	ISO 5993/5666
26.	Nickel	0.5 mg/L	ISO 8288/11885
27.	Selenium	0.02 mg/L	ISO 9965
28.	Zinc	5 mg/L	ISO 8288/11885
29.	Silver	0.1 mg/L	ISO 11885
30.	Aluminium	2 mg/L	ISO 10566/12020
31.	Organo-chlorine pesticides	0 mg/L	ISO 6468
32.	Oils and grease	5 mg/L	ISO 9377 Parts 1-3
33.	Phenols	0.002 mg/L	ISO 14402/6439
34.	PCBs	0.003 mg/L	ISO 6468
35.	Benzene	0 mg/L	ISO 7875: Parts 1 & 2
36.	Faecal coliform	400 in 100 ml of water	ISO 9308 Part 3/ ISO 6222
37.	Total Dissolved Solids	1200 mg/L	-

Source: EAC, 2012