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HANDBOOK ON EXISTING BEST PRACTICES AND INNOVATIVE WASTE WATER TREATMENT/WATER REUSE TECHNOLOGIES

USAID GOVERNING FOR GROWTH (G4G) IN GEORGIA

25 JANUARY 2017

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ACRONYMS

AA	Association Agreement
BAT	Best Available Techniques
BOD	Biological Oxygen Demand
BREF	Best Available Techniques Reference Document
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
CSTR	Continuous Stirred Tank Reactors
EDTA	Ethylenediaminetetraacetic acid
EU	European Union
EU	European Union
G4G	Governing for Growth in Georgia
IPPC	Integrated Pollution Prevention Control Directive
IWWS	Individual Waste Water System
IWWTP	Industrial Waste Water Treatment Plant
MBR	Membrane Biological Reactor
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
PE	Population Equivalent
PE	Population Equivalent
PHS	Priority Hazardous Substances
PS	Priority Substances
TSS	Total Suspended Solids
USAID	United States Agency for International Development
UWWTP	Urban Waste Water Treatment Plant
WFD	Water Framework Directive
WWSP	Waste Water Stabilization Ponds

DEFINITIONS

Public Sewage is sewage infrastructure designed for municipal public service of draining and treatment of urban waste water and drainage waste water. Building connections to public sewage, septic tanks and small treatment plants with treatment capacity smaller than 50 population equivalent (PE) are not categorized as public sewage.

Sewage consists of a network of feeders, channels, gutters and other equipment for draining waste water which are connected with the sewage network and from which drainage of waste water from buildings and drainage water from roofs and from hardened, paved or other covered area is assured.

Sewage System is a system for common collection and draining of urban and/or industrial waste water together with surface runoff waste water.

Waste Water is water which is after use or as atmospheric precipitation discharged into public sewage or waters. Waste water is a mixture of domestic, industrial/process or surface runoff water.

Cesspool is a single or double pit system with open joints or openings that allows collected waste water to flow to the surrounding soils.

Domestic Waste Water is waste water from residential settlements and services which originates predominantly from the human metabolism and from household activities.

Urban Waste Water is domestic waste water or the mixture of domestic waste water with industrial waste water and/or run-off rain water. Urban waste water originates from household activities for water use in sanitary places, cooking, washing and other housework. Urban waste water is also water which is generated in public buildings or by other activities and is by origin and by ingredients similar to domestic water.

Industrial (Process) Waste Water is water discharged after being used in, or produced by, industrial production processes and which is of no further immediate value to these processes. This waste water originates after industry, trade, economic or agriculture use and is not similar to urban waste water. Industrial waste water is also a mixture with technological and urban or/and rain water if mixed waters are discharged by common outflow into public sewage or directly into waters. Industrial waste waters are also cooling waters and liquids which are collected and run off from facilities for processing, storing or disposal of waste. Where process water recycling systems are installed, process waste water is the final discharge from these systems. To meet quality standards for eventual discharge into public sewers, this waste water should be processed.

Surface Runoff Water (Stormwater) is water which, as a result of atmospheric precipitation, runs off as polluted water from a hardened surface and drains into public sewage (or into soil).

Sewer Inflow (Infiltration) is groundwater entering sewage system through defective pipe joints and broken pipes. This water causes dilution of sewage waste water.

Untreated Waste Water is waste water discharged into ambient environment without treatment. Untreated waste water is released (directly or indirectly) into groundwater, watercourses, accumulations, lakes and sea without prior treatment in treatment plants.

Treated Waste Water is waste water discharged from a treatment plant. Waste water treatment includes physical (mechanical), chemical or biological methods of treatment or its combinations which is dependent on the exact standards of treatment.

Waste Water Treatment is a process to render waste water fit to meet applicable environmental standards or other quality norms for recycling or reuse. Three broad types of treatment are distinguished: primary, secondary and tertiary.

Leaching Field is a series of buried, perforated pipes set above porous material. The pipes distribute effluent to the soil close to the ground surface. A leaching field is part of a septic system (used instead of leaching pits).

Leaching Pit is a pit with openings that only receives liquid effluent (not solids). The pit distributes the effluent to the surrounding soils. A leaching pit is part of a septic system.

Primary Treatment is treatment of (urban) waste water by a physical and/or chemical process involving settlement of suspended solids, or other process in which the biological oxygen demand $(BOD)_5$ of the incoming waste water is reduced by at least 20% before discharge and the total suspended solids of the incoming waste water are reduced by at least 50%.

Secondary Treatment is treatment of (urban) waste water by a process generally involving biological treatment with a secondary settlement or other process, resulting in a BOD_5 removal of at least 70%, a chemical oxygen demand (COD) removal of at least 75% and the total suspended solids of the incoming waste water are reduced by at least 90%.

Tertiary Treatment is treatment (additional to secondary treatment) of nitrogen and phosphorous and/or any other pollutant affecting the quality or a specific use of water. In addition to requirements for secondary treatment, this treatment includes nitrogen removal of at least 70% and/or phosphorus removal of at least 80%. Tertiary treatment is additional treatment of substances that remain after secondary treatment. This improved treatment is necessary for sensitive areas of watercourses.

Treatment Plant is a facility for treatment of waste water which reduces or eliminates water pollution. Treatment plants are urban (UWWTP), industrial (IWWTP) or independent treatment plants.

Septic Tank is an enclosed tank that receives waste water. Solids settle to the bottom and are treated anaerobically. A septic tank is part of a septic system.

Urban Waste Water Treatment Plant (UWWTP) is a waste water treatment plant for urban waste water or for a mixture of urban and drainage waste water.

Industrial Waste Water Treatment Plant (IWWTP) is a waste water treatment plant for industrial (process) waste water, one or more devices of which are working the same or several different technological processes. If the industrial waste water drains off into the public sewage, then the IWWTP is designed for pre-treatment of industrial (process) waste water.

Population Equivalent is a unit for water loading with the organic biodegradable stuff which corresponds to pollution produced by one person during 24 hours. It is expressed as BOD_5 (a five-day biochemical oxygen demand). One PE is equal to 60g (BOD_5) of oxygen per day.

Sewage Connection Points are places of direct contact of the internal network within buildings with the sewage system.

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1. EXECUTIVE SUMMARY

This Handbook is prepared under the United States Agency for International Development (USAID) Governing for Growth (G4G) in Georgia grant project "Innovative Technologies for Water Re-use and Waste Water Treatment".

In order to create a more sustainable water future, the European Union-Georgia Association Agreement (EU-AA) encourages water conservation as a way to reduce demand. Technological innovations can help address existing water challenges. Recycling and wastewater treatment technologies can significantly reduce net water abstraction from the environment, thus contribute to sustainable water allocation practice.

Relatively simple wastewater treatment technologies can provide low cost sanitation and environmental protection and at the same time decrease pressure on scarce water resources. These technologies and sustainable approaches are widely spread throughout the world. In contrast, Georgia has not applied such innovations in order to improve water resources management. Not only does Georgia experience a lack of adequate technological solutions for wastewater treatment and re-use, but there is also a lack of relevant information, awareness and knowledge of innovative approaches and technologies for wastewater treatment and recycling.

By this particular research, G4G intends to explore the patterns of water use and treatment within the Aragvi River Basin area[1], measure existing awareness of innovative technologies among local business and help water agencies and businesses (private sector) in Georgia to raise their awareness in sustainable management of water resources and practice innovative and/or cost-effective approaches to sustainable water allocation.

Undisputedly, sanitation is a key element of sustainable development that significantly influences the human health and wellbeing worldwide. Both urban (domestic) waste water and industrial (process) waste water have to be treated and differences in their content and volumes are necessary to be taken into account. While domestic waste water does not exhibit great variability in regard to its content of organic and inorganic materials, its treatment is generally similar throughout different countries. In contrast, the content of industrial effluents varies from one industry to another, and therefore requires varying treatment, based on the specific industry producing such waste water. Furthermore, when various types of industrial effluents are released into the public sewer network or surface watercourses, it is necessary to specify them not only by the concentration of BOD, COD and suspended solids, but also by the content of organic and inorganic elements (specific pollutants), which vary from industry to industry.

This document attempts to provide the reader with a better understanding of the technology available and the factors that need to be considered in seeking a waste water system for any particular source of pollution. Based on the results of surveys using questionnaires, some examples of waste water treatment technologies were proposed in the Handbook.

[1] During preparation of above study, the specific focus were made on assessment of the industrial water and commercial water-use within the Aragvi River Basin area.

2. INTRODUCTION

Georgia regulates waste water treatment partly via an environmental permit issuing process. However, this process is only focused on large sources of pollution. In the case of small sources of pollution, there are no technical requirements applied to waste water treatment. Due to this fact, there are also an unknown number of different techniques used for waste water treatment from small companies (firms and manufactures). Furthermore, it is not known which disposal devices are employed downstream of effluents. In the last decade, residential, industrial and commercial developments have increased in Georgia after the breakdown caused by the collapse of the Soviet Union. New industrial sites and small manufacturing facilities were built which require reliable and effective waste water treatment systems to protect the environment and water resources. Therefore, there is a need to increase education (of waste water producers, decision makers, municipalities and general public as well) on the capabilities and limitations of existing waste water treatment systems to be used in Georgia.

PURPOSE OF THE HANDBOOK DOCUMENT

The goal of this document is to provide guidance to the various treatment and disposal systems that are currently available, and to describe their advantages and constraints so that those involved in the selection, design, construction, operation, maintenance, and permitting of these facilities can make informed decisions. Ultimately, the purpose of this document is to ensure the protection of valuable water resources and the environment through the effective use of industrial waste water treatment and disposal systems.

This document is intended to guide landowners, homeowners, developers, engineers and regulators (policy makers, water managers) on the selection and operation of appropriate waste water systems. The document also aims to provide this audience with information on a range of feasible, permanent, and reliable waste water treatment and disposal options that conform to current environmental regulations within the principles of EU water policy. On the other hand, the document does not provide solutions for specific site applications, but attempts to provide the user with a better understanding of the technology available and the factors that need to be considered in seeking a waste water system for any particular site.

This document was developed based on a review of applicable discussions with the regulatory body, questionnaires and communication with stakeholders (in Georgia) and engineering experience in the design and construction of waste water treatment systems in EU member states. The document provides general guidance based on past experience. Specific topics covered in the following chapters are as follows:

Chapter 2 of this document provides an introduction to legal framework and the regulatory aspects governing waste water treatment. This is intended to facilitate a basic understanding for decision-making perspective in approving waste water treatment installations.

Chapter 3 outlines and presents the list of types of industries.

Chapter 4 presents the various industrial waste water treatment (also urban waste water) and disposal methods.

Chapter 5 describes water reuse for different purposes.

Chapter 6 presents several examples of industrial waste water treatment based on the surveys conducted in the Aragvi River Basin.

Chapter 7 presents additional information in the form of a list of references and literature for further reading focused on waste water treatment and disposal methods.

Annex 1 presents fact sheets for the selected collection, transport, waste water treatment and disposal methods with descriptions of methods of operation, maintenance and suitability considering where to be applied, advantages, disadvantages and costs.

3. LEGAL ASPECTS

Approaches to waste water discharge come from legislative and conceptual requirements of each country where there are validated technical and technological approaches in relevant technical standards, manuals, and recommendations. The Government of Georgia signed an AA with the EU in 2014. One part of this AA is related to transposition and implementation of the EU water policy into the national legislation and practice. Minimization of the impact of industrial waste water (also urban waste water) on human health and aquatic environment are crucial requirements in this context.

THE EU WATER POLICY REQUIREMENTS

> *The Maastricht Treaty Art.174 establishing the European Community, demands that the Policy of the Community on the environment is "to contribute to pursuit of the objectives of preserving, protecting and improving the quality of the environment, in prudent and rational utilization of natural resources, and to be based on the precautionary principle and on the principle that preventive action should be taken, environmental damage should, as a priority, be rectified at source and that the polluter should pay.*

EU countries adopted a unified policy in the field of discharge and treatment of waste waters. This is applied by EU directives and regulations transposed into national legislation of member states. Under the AA, Georgia is obliged to transpose the specific EU legislation into national legislation so that uniform rules and requirements for waste waters discharge and treatment of the whole community are respected.

Water is one of the most comprehensively regulated areas of EU environmental legislation. Early European water policy began in the 1970s with the adoption of political programmes as well as legally binding legislation. A later period of water legislation followed a review of existing legislation and an identification of necessary improvements and gaps to be filled. This phase of water legislation included the Urban Waste Water Treatment Directive (91/271/EEC), the Integrated Pollution Prevention Control (IPPC) Directive 96/61/EC and Directive 76/464/EC on pollution caused by certain dangerous substances and its daughter directives.

The EU, which had been considering the need for a more global approach to water policy, based on consultations with all interested parties, agreed on the Directive of European Parliament and Council 2000/60/EC, which states the framework of the scope for Community measures in the field of water management (Water Framework Directive (WFD)).

In the recent years, the above mentioned directives were reviewed and/or amended to reflect the environmental objectives and create better understanding of the behaviour of chemical substances in the environment.

The document aligns with requirements and principles of EU legislation that are part of the AA, mainly:

- Directive 91/271/EC on urban waste water treatment in sounding of the Commission Directive 98/15/EC and statement of European Parliament and Council 1882/2003/EC (Directive UWWT);
- Directive 2000/60/EC, the WFD;
- Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (IPPC);
- Directive 2010/75/EU, the Industrial Emissions Directive;
- Directive 2013/39/EU amending Directives 2000/60/EC and 2008/105/EC regarding priority substances in the field of water policy.

The WFD is lays down technical specifications and minimum requirements for common environmental quality standards and emission limit values. The WFD also requires to identify other specific substances being discharged in significant quantities in the EU member states that pose a risk to the aquatic environment. For those pollutants, both environmental quality standards and emission limit values have to be defined. Such a list of the other specific substances will be also taken into account when developing the Programme of Measures (River Basin Management Plans).

The EU Directive 91/271/EEC is related to all discharges of urban waste water (Art. 12, Annex IB of the Directive) and of industrial waste water from the agro-food sector (Art. 13, Annex III of the Directive), as well as for all discharges of industrial waste water into urban collecting systems and treatment plants (Art. 11, Annex IC of the Directive) (see also the WFD for the requirement to provide for a wider base for reviewing such permits and authorisations and for amending their operation in the event of, for example, emergencies affecting the water status of receiving water bodies). The requirements of Directive 91/271/EEC on the agglomerations and sewage systems are summarized in Table 1.

Table 1: Requirements of Directive 91/271/EEC on the agglomerations and sewage system

	Sewage system	Waste water treatment
Agglomeration > 10,000 PE	Complete sewage system, Article 3, (1)	More strict treatment up to tertiary one (Article 5, (2))
Agglomeration > 2,000 PE	Complete sewage system, Article 3, (1)	Secondary or equivalent treatment in accordance of Annex I B, Article 4, (1.3)
Agglomeration < 2,000 PE	No specific requirements	No specific requirements, but "appropriate" treatment should be applied to reach the good status

The Dangerous Substances Directive defines the priority substances list. The Directive's aim is to contribute to the progressive reduction of emissions of dangerous and priority substances (PS) into water bodies and to achieve the elimination of priority hazardous substances (PHS) and hence achieve a concentration into the environment near to zero (for synthetic substances) or near to the background level (non-synthetic naturally occurring substances). Such requirements expect application of advance technologies to treat the industrial waste water.

The IPPC Directive covers mitigating pollution from various industrial sources throughout the EU. The Directive is based on several principles, namely (1) an integrated approach (all environmental components, including water), (2) best available techniques (both production and treatment technologies), (3) flexibility and (4) public participation.

The Directive 2010/75/EU on the Industrial Emissions Directive is the main EU instrument regulating pollutant emissions from industrial installations. The Directive is based on the **integrated approach,** meaning that the permits must take into account the whole environmental performance of the plant, covering e.g. emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure. Furthermore, emission limit values of the particular industrial facility must be based on the **Best Available Techniques (BAT).**

NATIONAL LEGISLATION

On the national level, the following documents were used during the development of the Handbook:

- The Constitution of Georgia;
- Law on Environmental Protection (IS 519, 10 December 1996);
- Law on Water (IS 936, 16 October 1997);
- Law on Public Health (RS 5069, 27 June 2007);
- Law on Environmental Permits (RS 5602, 14 December 2007);
- Draft Law on Water Resources (in progress);
- Resolution of the Government of Georgia on Approval of the Rules for Development of National Report on the State of the Environment (N 337, 06.05.2014);
- Resolution of the Government Georgia on Approval of the Rules for Protection of Surface Water Bodies from Pollution (N 425, 31.12. 2013);
- Resolution of the Government Georgia on Approval of the technical regulation on maximum permissible norms for pollutants discharged with wastewater into surface waters (#414 31.12. 2013);
- Resolution of the Government of Georgia on Approval of the Environmental Technical Regulations (#17 03.01. 2014).

4. CHARACTERISATION OF INDUSTRIAL PRODUCTION

Industrial production processes account for a significant level of pollutant inputs to the environment. As it was presented in the previous section, in the EU several directives are dedicated to issues related to addressing the impact of industrial activities on environmental quality. Due to the fact that there is only limited legislation related to this issue in Georgia, it was decided to use EU legislation requirements in this document.

TYPES OF INDUSTRIES

There is a large range of industries that produce a significant number of pollutants. Both volume of waste water and also its composition differ from industry to industry. However, it is not feasible to design waste water treatment methods for each individual pollutant. In fact, even for one product when different technologies are used, the content of pollutants in waste water can vary. This situation led to the decision that for the purpose of this document, the list of industries for which the BAT reference documents (BREF) were developed to support implementation of the IPPC Directive 2008/1/EC and Directive 2010/75/EU on Industrial Emissions in EU member states is used. The main reason for such a decision is that Georgia signed the EU-AA and transposition and implementation of the directives are obligatory. This list of industries for which the BREF exist along with expected industries in Georgia is presented in Table 2.

Table 2: The List of industries with the best available technologies and reference documents (based on IPPC Directive)

Available BAT reference documents (BREF) in EU	Expected industry in Georgia
Cement and Lime production	X
Ceramics	
Chlor-Alkali manufacture	
Cooling systems	X
Emissions from storage of bulk or dangerous materials	X
Ferrous metal processing	X
Food, drink and milk processes	X
Glass manufacture	
Intensive rearing of poultry and pigs	X
Iron and steel production	X
Large combustion plant	X
Large volume inorganic chemicals - Ammonia, acids & fertilisers	X
Large volume inorganic chemicals - Solid & others	X
Large volume organic chemicals	X
Management of tailings and waste rock in mining activities	X
Non-ferrous metal processes	X
Organic fine chemicals	
Polymers	
Pulp and paper manufacture	
Refineries	X
Slaughterhouses and animal by-products	X
Smitheries and foundries	
Speciality inorganic chemicals	
Surface treatment of metals and plastics	X
Surface treatments using solvents	X
Tanning of hides and skins	X
Textile processing	
Waste incineration	X
Waste treatments	X

5. INDUSTRIAL WASTE WATER TREATMENT SYSTEMS

There is a significant number of industrial waste water disposal and treatment systems (technologies) worldwide. This section will focus on proven, environmentally sound technologies in addition to those that are currently used or can be classified as "emerging sanitation technologies" in European nations and other developed countries.

WASTE WATER TYPES

Waste water, both industrial or urban (domestic), consists of many different constituents (solids, gases and liquids). The main constituent of waste water is water. However, it is very difficult to quantify the individual parts of the waste water and even it is hard to define them. If one wants to try to list all the chemicals that comprise waste water, dozens of chemical analyses would have to be performed. In order to simplify the process of characterizing waste water, the list of parameters needed has been reduced to several groups as for example: BOD, COD, total suspended solids (TSS), total nitrogen, total phosphorus, selected pollutants and total or faecal coliform bacteria.

In nature, the organic constituents of waste water are degraded (stabilized) by biochemical decomposition or by biological consumption. Both of these processes oxidize the constituents in waste water. The most abundant oxidizing agent is dissolved oxygen. Oxygen dissolved in waste water is consumed by the biological and chemical processes that degrade the constituents. COD is measured in mg/L, and the greater the COD, the higher the concentration of organic material in the waste water. On the other hand, BOD is also measured in mg/L, and characterizes the concentration of biodegradable organic material in the waste water.

Note:

COD in this document means test procedure that is based on the chemical decomposition of organic and inorganic contaminants, dissolved or suspended in waste water. The result of a chemical oxygen demand test indicates the amount of water dissolved oxygen (expressed as milligrams per liter of water) consumed by the contaminants, during two hours of decomposition from a solution of boiling potassium dichromate. The higher the chemical oxygen demand, the higher the amount of pollution in the test sample.

BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a robust surrogate of the degree of organic pollution of water.

In addition to the liquid portion of waste water, there is a solid portion as well typically quantified as TSS. TSS is dry filter residue measured in mg/L. Higher TSS equates to more solid materials in the waste water.

Other constituents in waste water include nutrients. The most common nutrients of concern are nitrogen and phosphorus. When either of these nutrients is introduced to nutrient limited waters, it can cause an algae bloom i.e. eutrophication. Algae blooms deplete the water of dissolved oxygen, and can result in the death of aquatic or marine life. In addition to adverse environmental effects, some nutrients have adverse health effects, notably "Blue Baby Syndrome" caused by nitrates in drinking water.

In addition to previous constituents, it has to be added that microorganisms thrive in waste water as well. Similarly, as for chemical constituents, the number of microorganisms is too large to quantify them individually. In practice, only a fraction of microorganisms are studied to determine the characteristics of waste water. Since a large number of pathogens exist in waste water, it is too difficult to determine the number of each individual species. For the purpose of the assessment of water quality regarding the microorganisms thriving in waste water, two categories of indicator organisms are quantified. The first is total coliforms and the second is faecal coliforms. Faecal coliforms are most commonly reported in colony forming units (CFU) per 100 mL of waste water, which is a direct count of the number of organisms in the sample.

Specific constituents mainly in industrial waste waters are heavy metals and synthetic organic compounds that originate from different industrial activities and residuals from households. Those constituents, in many cases, require the use of special techniques for waste water treatment. The use of treatment techniques depends on the presence of substance categories that should be ceased or eliminated to near "zero level" concentrations (priority hazardous substances) or background concentrations for natural substances.

In Table 3 selected industries with typical content of pollutants are presented for illustration.

Table 3: Industrial waste water with expected content of pollutants

Industry	Associated waste water pollutants
Textile	BOD, TSS, alkalinity
Leather goods	BOD, TSS, Chromium, alkalinity
Detergents	BOD, saponified soaps
Brewed beverages	BOD, TSS, alkalinity
Meats and poultry	BOD, TSS, alkalinity
Pulp and paper	High and low pH, TSS and inorganic compounds
Metal industries	Acidity, heavy metals
Plastics and resins	High and low pH, TSS and volatile organic compounds

TECHNOLOGY STEPS IN WASTE WATER TREATMENT

Generally, waste water must be treated in order for the waste water to be returned to the environment to minimize detrimental effects. This principle is even more pronounced for the industrial waste waters that in many cases contain hazardous and dangerous constituents for human health and aquatic environment.

The industrial waste water can be treated separately by the producer onsite at the industrial facility or can be discharged into the local (public) treatment facility. In this case, industrial effluent has to be pre-treated to the level that will be in compliance with regulations in the given country. Those regulations differ from country to country, but generally discharged industrial waste waters would be compatible with:

- The conveyance of the waste water to the local facility (taking into account e.g. highly odorous compounds);
- The processes at the local facility (taking into account e.g. chemicals that would inhibit biological treatment);
- The use or disposal of the treated waste water or resulting sludge (such as certain pesticides and or heavy metals).

Note: For the purpose of this Handbook, the term treatment will be used without distinguishing if industrial waste waters are treated at an onsite facility or discharged into the local sewerage system.

Technologies for providing treatment can be divided into the following categories*: physical, chemical and biological*.

In general, selecting a treatment method for industrial effluents depends primarily on the following factors:

- Identifying the various pollutants present in the effluent;
- Characterising the effluent (fluctuation of water discharges);
- Regulating the sewers (intensity and periods of pollution peaks) and separating the waste streams from industrial processes;
- Selecting the treatment technology based on the different available physical, chemical or biological treatment capabilities.

Note: Every industrial effluent (and pollutants) requires a specific treatment technology.

Furthermore, to design a suitable method for treating an industrial effluent, the following major parameters must be determined:

- Daily waste water volume;
- Maximum and minimum water discharges;

- Chemical characteristics of the water used in the industry;
- Continuous and intermittent manufacturing stages;
- Intensity and periods of pollution peaks;
- Possibility of separating waste streams;
- Possibility to carry out local or partial treatment, or recycling;
- Probability of secondary pollution incidents, even if slight or occasional that can worsen treatment plant operation (appearance of glues, fibers, oils, sand, etc.).

In general, when a treatment plant is designed, these parameters must be determined through analysis of the different manufacturing processes in the industrial facility, and comparison of the results with information from other similar industrial facilities.

When a treatment plant is constructed for a factory, the quantity of pollutants in the effluent must be precisely determined through continuous and routine analysis of the water and compared with chemicals used in the factory.

SITE CONDITIONS

When designing a waste water treatment and disposal system, the location's natural conditions have to be taken into account. Several site conditions are recognized to have significant influence over the selection of waste water treatment and disposal systems. These conditions should be investigated and analysed prior to construction of the waste water treatment and disposal system. They are as follows:

- <u>Depth to groundwater table (both potable and non-potable):</u> Treatment systems should generally be installed above the groundwater table to prevent inflow of groundwater into the system. Shallow groundwater can reduce the percolation zone and hence the degree of contaminant removal may result in groundwater contamination. Waste water can also back up into the treatment system if percolation is slower than the application rate.
- <u>Impermeable soil or rock formation:</u> Impermeable subsurface formations cause overlying material to saturate when effluent is applied and eventually stop percolating waste water, causing unacceptable ponding and surface runoff from the site (overflow or spill). If this occurs, the disposal system will have failed and public health will be at risk.
- <u>Steep terrain:</u> Steep terrains also impact the difficulty and therefore costs of excavation and installation of subsurface treatment tank systems.
- <u>Flood zones:</u> Ultimately, the construction of facilities in flood zones is generally disallowed due to personal safety and property loss considerations, and it is valid for the construction of waste water treatment and disposal systems as well.
- <u>Proximity to inland surface waters (both streams and other bodies of water):</u> A primary concern regarding the siting of waste water treatment and disposal facilities near inland surface waters is that the native water quality must be maintained so that beneficial uses are preserved. Thus, if the surface water serves as a potable drinking water source, irrigation water source, recreational venue, etc., these uses must be preserved with corresponding water quality standards. Therefore, any waste water treatment and disposal systems must not contaminate nearby surface waters.
- <u>Protection of groundwater resources</u>: Protection of this resource is one of the primary factors (drinking water source).
- <u>Hydrogeology</u>: Hydrogeology encompasses the distribution and movement of groundwater through the soil. Many of the items discussed above could be considered as falling under hydrogeology. The nature of groundwater is such that it is slow moving and difficult to predict without detailed studies. There are other conditions that can also impact treatment and disposal system performance, so care must be taken by the owner and the engineer to fully evaluate their site prior to selecting and installing any onsite waste water treatment system.

WASTE WATER COLLECTION AND TRANSPORT

Urban waste water is the combination of liquid or water carried wastes originating in the sanitary conveniences of dwellings, commercial or industrial facilities and institutions, in addition to any groundwater, surface water and storm water that may be present. Untreated waste water generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus poses environmental and health hazards, and consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of waste water management is the protection of the environment in a manner complying with public health and socio-economic concerns.

Waste water collection systems gather the used water from homes, businesses and industries and convey it to a waste water treatment plant. This type of system is also called a sanitary sewer or sewerage. A similar system known as a storm water collection system conveys water resulting from runoff of rain and snow from buildings and paved and unpaved areas to a natural watercourse or body of water, usually without treatment. This type of system is also known as a storm sewer. In the past, some sanitary sewers and storm sewers were combined into one system. Unfortunately, during heavy rains, the waste water treatment plants served by combined sewers often became hydraulically overloaded and washed out into the receiving stream causing a complete treatment system failure. For this reason, combined sewers are now uncommon.

The ancient Romans were one of the first civilizations to employ waste water collection through clay pipes and covered cannel sewers. They understood very well the importance of maintaining sanitary conditions. Modern waste water collection systems are a sophisticated combination of components that include; gravity sewer, lines, force mains, manholes, and lift (pump) stations. They represent one of the largest financial investments of public money for our municipalities.

Due to fact that these systems are underground where the public does not see them they are all too often “out of sight, out of mind.” The general public rarely understands that operation and maintenance of waste water collection systems is critical to maintaining modern sanitary conditions that are taken for granted. Only when a system fails (such as during a sewer back-up), does the public take notice of the waste water collection system.

In Annex 1, several methods of waste water collections and transports are described from centralized to individual collection. This description suggests that industrial effluents are supposed to be discharged into the public (local) sewerage systems.

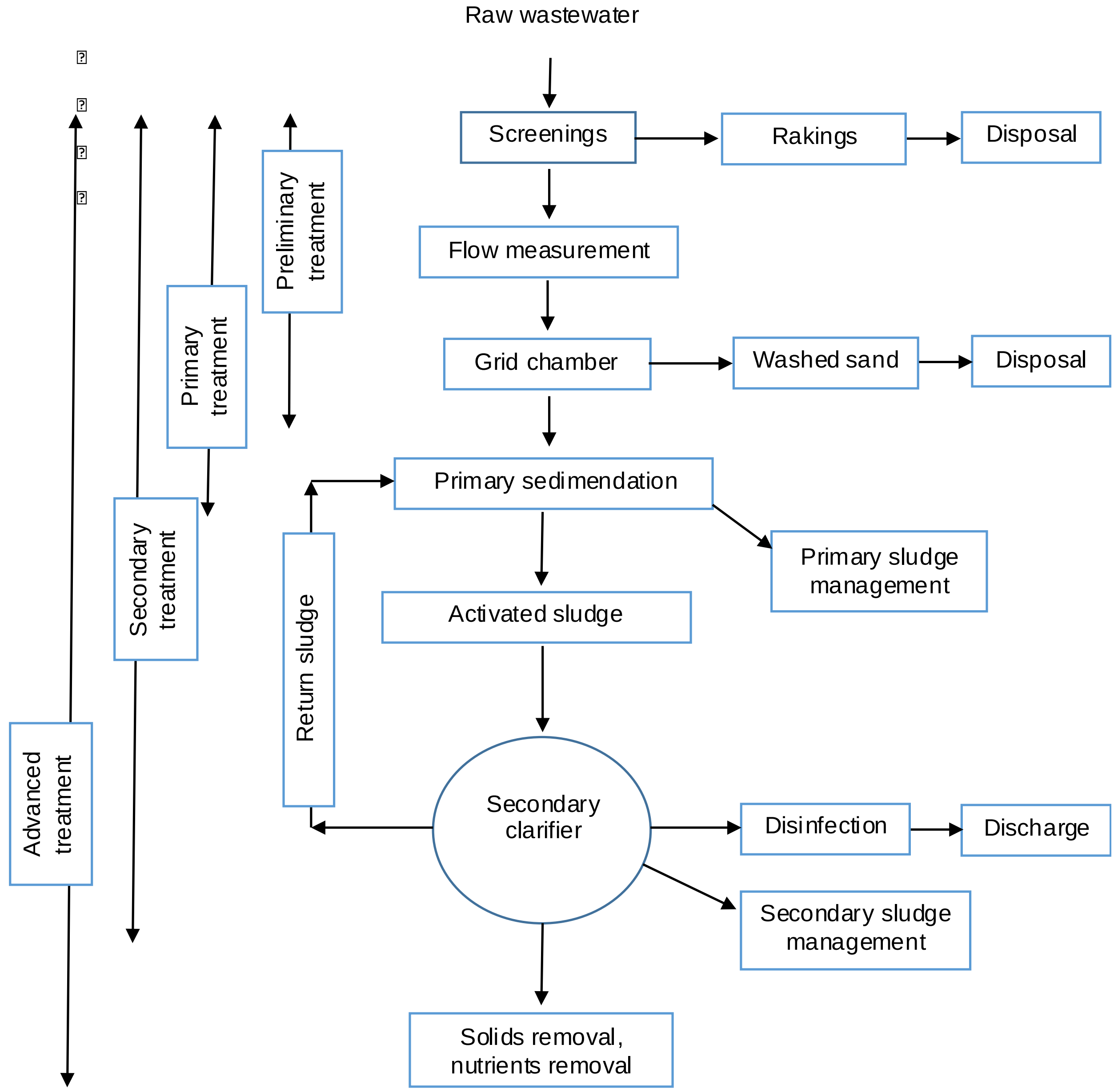
INDUSTRIAL WASTE WATER TREATMENT

Despite the fact that every pollutant requires a certain treatment technology, all of these different technologies include the following stages:

- Waste water flow equalisation.
- Physical treatment: This treatment can be an intermediate or final stage, based on the type of treatment.
- Chemical treatment: This treatment depends on the pollutants present in effluent and can be an intermediate or final stage.
- Biological treatment: The use of this treatment depends on the biodegradable contents of the waste water.
- Industrial sludge treatment: Although organic sludge exists in some cases, the sludge is primarily inorganic in nature. Industrial waste water contains large quantities of sludge, resulting particularly from chemical and physical treatment methods.

In Figure 1, a simplified scheme of basic technology steps that could be implemented in standard industrial waste water treatment plant is presented. This scheme provides clearly demonstrated borders between relevant treatment steps.

Figure 1: Scheme of the technological steps for waste water treatment



FLOW EQUALIZATION

The first step when designing the industrial waste water treatment is to analyse and recognize the fluctuations of industrial effluent. Based on this analysis, equalization will be determined. It can be done by two types: Flow equalisation and constituent (pollutants) equalisation.

Flow equalisation refers to changing the variations in rate of flow during the processing and clean-up cycles to a more steady flow rate that is nearly equal to the average flow rate for that period.

Constituent equalisation refers to the concentration of the target pollutants in the industrial waste waters. Generally, during a 24-hour period, the concentrations of individual pollutants in a given industrial waste water typically vary over wide ranges as start-up, operation, closure, and clean-up of processes takes place. Waste water treatment systems that are designed for given ranges of concentration of target pollutants often do not perform well when those pollutants are in concentrations significantly different from the design values. For this purpose, the simple dilution equation can be used to calculate concentrations of pollutants that result from mixture of different volumes of waste water with different concentrations.

In Annex 1, an example of the equalisation is described to illustrate the process.

PHYSICAL TREATMENT METHODS

The following physical treatment processes are described in this section:

- Screening (removal of coarse solids by use of a straining device);
- Sedimentation (gravity settling of pollutants out of the waste water);
- Flotation (the use of small gas bubbles injected into the waste water which causes pollutant particles in the waste water to rise to the surface for subsequent removal);
- Stripping (removal of volatile and semi-volatile organic compounds from waste water by use of air flow).

SCREENING METHODS

Screening is a physical treatment method that uses a physical barrier as the removal mechanism. Screening ranges from coarse bar racks, used to remove objects of several centimetres or more in size, to micro-screening, used to remove particles as small as macromolecules.

Bar racks are often the first treatment devices to be installed on route of waste waters to protect pumps and other equipment from damage. These devices remove objects such as pieces of products or raw materials, plastic materials, or other foreign objects that inadvertently gain access to the industry's system of drains and sewers. In practice, two types of bar racks are used. Racks with stationary bars equipped with a moving automatic mechanical cleaning system and filter screens, which have a slotted conveyor that passes all but the target objects.

The tangential screen operates in such a way that waste water enters the reservoir at the back of the screen, and after filling the reservoir, overflows over the top of the screen and flows down over the inclined face of the screen. Water and solids smaller than the mesh size of the screen proceed through the screen to the collection device, and are then conveyed to the next treatment step. All other solids slide down the incline to be collected at the bottom.

Rotating cylindrical screens are designed to continuously clean themselves, using the flushing action of the screened water itself.

Micro-screening is a physical treatment process that closely resembles the rotating screen, described previously. The major differences are in the size of the screen mesh openings and in the flow path taken by the waste water being screened.

PLATE AND FRAME FILTERS

Plate and frame filter presses, normally thought of in the context of waste water treatment as sludge dewatering devices, were also used with excellent results as separation processes for precipitated metals and other substances, immediately following flocculation.

MEMBRANE SEPARATION

Membrane separation processes include microfiltration, ultrafiltration, nanofiltration, reverse osmosis, dialysis, and electrodialysis. They use one or more membranes, which can be thought of as physical barriers between phases, through which only limited components of the phases can pass. These processes are used to separate molecular or ionic species from waste streams.

FILTRATION USING GRANULAR MEDIA

Deep bed granular filters operate in such a way that solid particles in the suspending medium are caused to follow a torturous path through the void spaces between the filter granules until one or more removal mechanisms result in the particle being retained somewhere within the depth of the filter. Deep bed granular filters use one, two, or more types of media, including sand, anthracite coal, and garnet.

Slow sand filters are characterized by a loading rate that is significantly lower than the more conventional filters that are sometimes referred to as "rapid sand filters." The mechanisms of removal in slow sand filtration include entrapment, adsorption, biological flocculation, and biological degradation.

PLAIN SEDIMENTATION

Plain sedimentation can be described as the separation of particulate materials from waste water as a result of the influence of gravity. A principal objective of plain sedimentation equipment is to produce "quiescent conditions." The process of plain sedimentation is often referred to as "clarification," and the devices used to accomplish plain sedimentation are called "clarifiers" or "settling tanks." There are three modes by which particles undergo the plain sedimentation process: Discrete settling, flocculent settling, and zone settling.

FLOTATION

Gravity flotation is used, sometimes in combination with sedimentation and sometimes alone, to remove oils, greases, and other floatables such as solids that have a low specific weight. Various types have been developed to harvest floated materials, and the collection device.

Dissolved air flotation is a solids separation process, similar to plain sedimentation. The force that drives is gravity, and the force that disturbs the process is hydrodynamic drag. Dissolved air flotation involves the use of pressure to dissolve more air into waste water than can be dissolved under normal atmospheric pressure, then releasing the pressure.

The floatation process is described in Annex 1.

ADSORPTION

Adsorption can be defined as the accumulation of one substance on the surface of another. The substance undergoing accumulation, and thus being adsorbed, is called the adsorbate, and the substance on which the accumulation is taking place is called the adsorbent. The adsorbate can be dissolved, in which case it is called the solute, or it can be of the nature of suspended solids as in a colloidal suspension. Colloidal suspensions of liquids or gases can also be adsorbed.

Activated carbon is the most common adsorbent in use for industrial waste water treatment. Other adsorbents include synthetic resins, activated alumina, silica gel, fly ash, shredded tires, molecular sieves and sphagnum peat.

ION EXCHANGE

Ion exchange is a physical treatment process in which ions dissolved in a liquid or gas interchange with ions on a solid medium. The ions on the solid medium are associated with functional groups that are attached to the solid medium, which is immersed in the liquid or gas.

In general, ion exchange is useful for removing inorganic substances, but not organic substances, and the reverse is normally the case for activated carbon. However, activated carbon can be very effective in removing metal ions from waste water, by simply chelating the metals with an organic chelant, such as EDTA, and certain organics can be removed by ion exchange type resins manufactured for that specific purpose.

STRIPPING

Stripping is a physical treatment technology, in the sense that no chemical reactions are involved. Stripping is a method of moving one or more chemical substances from one medium, either liquid or gas, to another, also either liquid or gas, but usually the opposite of the first medium. That is, if the first medium is liquid, the second is gas, and vice versa. An example of stripping as a treatment technology is the stripping of volatile and semi-volatile substances from waste water with air.

SCRUBBING

Scrubbing, like stripping, is a physical treatment technology because no chemical reactions are involved. An example of scrubbing as a treatment method is that of removing hydrogen sulfide from air using chlorine in a water solution of high pH.

CHEMICAL TREATMENT METHODS

Chemical methods of waste water treatment take advantage of two types of properties: (1) The chemical characteristics of the pollutants, regarding their tendency to react with, or interact with, treatment chemicals, and (2) the chemical characteristics of the products of reaction between pollutants and treatment chemicals, regarding their solubility, volatility, or other property that relates to the inability of the product to remain in water solution or suspension.

The following chemical processes can be used to remove substances from waste water:

pH control. A form of chemical treatment. However, it is necessary to be underlined that like flow equalisation, it is used with biological and physical treatment systems as well as with chemical treatment systems. The hydrogen ion concentration of industrial waste water has a major influence on its characteristics. What substances will dissolve in a given waste water, as well as how much of a given substance can be dissolved, is one important characteristic. Furthermore, the value of the pH of waste water must be within a certain range for bacteria and other microorganisms to live and thrive, and for fish and plants to live and thrive. On the other hand, such methods as chemical coagulation, activated carbon adsorption, ion exchange, chemical oxidation, and the release of gases such as hydrogen sulfide and ammonia into the water are absolutely dependent for success on the proper range of pH.

Reaction to produce an insoluble solid. The industry standard procedure for removing metals from waste waters is alkaline precipitation. Alternative methods include precipitation of the metal as the sulfide, precipitation as the phosphate, precipitation as the carbonate, or co-precipitation with another metal hydroxide, sulfide, phosphate, or carbonate.

Reduction of surface charge to produce coagulation of a colloidal suspension. A very high percentage of industrial waste waters consist of colloidal suspensions. In fact, it is often possible to destabilize industrial waste waters by chemical coagulation, allow separation of the destabilized colloidal material from the water, further treat the water to discharge quality by a polishing step, if necessary, and then recover the coagulant from the separated waste substances. The coagulant can be reused, and the waste substances can be further treated, if necessary. The advantage is that the polishing step can be significantly more economical than if it were used to treat the raw waste water, and, in some cases, the separated colloidal material can be recovered as a by-product.

Reaction to produce a biologically degradable substance from a nonbiodegradable substance. Some substances that are resistant to biodegradation can be chemically altered to yield material that is biodegradable. Hydrolysis, under either acidic or alkaline conditions, can be used to break up many large organic molecules into smaller segments that are amenable to biological treatment. Heat may be required for effective hydrolytic action and consideration of proper reaction time is very important.

Reaction to destroy or otherwise deactivate a chelating agent. Often, removal of metals from an industrial waste water by simple pH adjustment, with or without addition of sulfide, carbonate, phosphate, or a carbamate, is ineffective because of the presence of chelating agents. Chelating agents are of various make-up and include organic materials, such as ethylenediaminetetraacetic acid (EDTA), or inorganic materials, such as polyphosphates.

Oxidation or reduction to produce a non-objectionable substance. Some highly objectionable substances can be chemically oxidized and some can be reduced to produce non-objectionable substances such as carbon dioxide and water.

BIOLOGICAL TREATMENT METHODS

Biological treatment of industrial waste water is a process whereby organic substances are used as food by bacteria and other microorganisms. Almost any organic substance can be used as food by one or more species of bacteria, fungi, ciliates, rotifers, or other microorganism. In being so used, complex organic molecules are systematically broken down, or “disassembled” then reassembled as new cell protoplasm. Oxygen is required in either the dissolved molecular form or in the form of anions such as sulfate and nitrate. The end result is a decrease in the quantity of organic pollutants, and an increase in the quantity of microorganisms, carbon dioxide, water, and other by-products of microbial metabolism.

The following biological methods are commonly used to treat the industrial waste waters:

TREATMENT OF INDUSTRIAL WASTE WATERS USING AEROBIC METHODS

- Air activated sludge is an aerobic process in which bacteria consume organic matter, nitrogen and oxygen from the waste water and grow new bacteria. The bacteria are suspended in the aeration tank by the mixing action of the air blown into the waste water. There are many derivations of the activated sludge process, several of which are described in Annex 1.
- High purity oxygen activated sludge is an aerobic process very similar to air activated sludge except that pure oxygen rather than air is injected into the waste water.
- Aerated pond/lagoon is an aerobic process very similar to air activated sludge. Mechanical aerators are generally used to either inject air into the waste water or to cause violent agitation of the waste water and air in order to achieve oxygen transfer to the waste water. As in air activated sludge, the bacteria grow while suspended in the waste water (see Annex 1).
- Trickling filter is a fixed film aerobic process. A tank containing media with a high surface to volume ratio is constructed. Waste water is discharged at the top of the tank and percolates (trickles) down the media. Bacteria grow on the media utilizing organic matter and nitrogen from the waste water (see Annex 1).
- Rotating biological contactor is a fixed film aerobic process similar to the trickling filter process except that the media is supported horizontally across a tank of waste water. The media upon which the bacteria grow is continuously rotated so that it is alternately in the waste water and the air (see Annex 1).
- Oxidation ditch is an aerobic process similar to the activated sludge process. Physically, however, an oxidation ditch is ring-shaped and is equipped with mechanical aeration devices.

TREATMENT OF INDUSTRIAL WASTE WATERS USING ANAEROBIC TECHNOLOGIES

Anaerobic waste water treatment, accomplished through microbiological degradation of organic substances in the absence of dissolved molecular oxygen, has undergone a complete change of role since the mid-1980s. Used for decades as a slow-rate process requiring long retention times and elevated temperatures, it was considered economically viable for only wastes of high organic strength. Its principal role in waste water treatment was for stabilization of waste bio-solids from aerobic treatment processes, or as a treatment step preceding aerobic treatment in which large, complex molecules were broken down to more readily biodegradable substances. It is now used routinely, at ambient temperatures, on industrial waste waters having organic strengths as low as 2,000-5,000 mg/L COD.

There are two types of anaerobic waste water treatment systems suspended growth and attached growth. For an illustration, see Annex 1, where an example is described.

Suspended growth systems are those in which anaerobic microorganisms feed on the organic matter of waste water in a vessel or lagoon that contains no managed support medium to which the microorganisms attach.

Attached growth systems, also known as fixed film systems, have a support medium, often called “packing,” to which the anaerobic microorganisms attach as they grow. The media can be stationary or not. Stationary media include rocks, coal, plastic or metal discs, and plastic packing. Sand is an example of media that is not stationary.

INDUSTRIAL SLUDGE TREATMENT

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

The characteristics of sludge vary widely from relatively fresh faecal materials generated in latrines to sludge which has undergone bacterial decomposition in activated sludge systems. The treatment required is therefore dependent on the characteristics of the sludge. The former may contain large numbers of pathogens, whereas the latter will contain much less due to pathogen die-off. Sludge should, however, always be handled with care to avoid contact with pathogens. Sludge may be contaminated with heavy metals and other pollutants, especially when industrial wastes are disposed into the sewer. Pre-treatment of industrial wastes is therefore essential before discharge to the sewer. Treatment of sludge contaminated with high concentrations of heavy metals or toxic chemicals will be more difficult and the potential for re-use of the sludge will be limited.

Fecal sludge contains essential nutrients (nitrogen and phosphorus) and is potentially beneficial as fertilizer for plants. The organic carbon in the sludge, once stabilized, is also desirable as a soil conditioner, because it provides improved soil structure for plant roots.

Options for sludge treatment include stabilization, thickening, dewatering, drying and incineration. The latter is most costly, because fuel is needed and air pollution control requires extensive treatment of the combustion gases. It can be used when the sludge is heavily contaminated with heavy metals or other undesirable pollutants. Prevention of contamination of the sludge by industrial wastes is preferable to incineration. A conversion process to produce oil from sludge has been developed, which can be suitable for heavily contaminated sludge. The costs of sludge treatment are generally similar to the costs of removing the sludge from the waste water.

In the Annex 1, there are commented some most used sludge treatment technologies with basic description of technology.

OTHER INDUSTRIAL WASTE WATER TREATMENT AND DISPOSAL METHODS

There are several versions of land application as a waste water treatment method, including spray irrigation, wetlands treatment and overland flow. Land application systems also rely on the groundwater for final disposal of the water after treatment has taken place. Therefore, land application is appropriate for use with only those waste waters having all biodegradable organics. Bacteria and other microorganisms living in the soil use the organics as food for energy and reproduction.

It is important to note that a contaminated aquifer (e.g. by toxic chemicals) is impossible to recover. Therefore, heavily polluted waste water should be treated before surface groundwater recharge, even though the method provides some soil filtration treatment during percolation. For surface groundwater recharge the assimilation capacity of the receiving soil body and the hydrogeological conditions must be studied carefully. The following basic factors should be considered in particular:

- Location of geologic and hydraulic boundaries;
- Depth of the aquifer and transmissivity of the overlying material;
- Lithology;
- Storage capacity;
- Porosity;
- Hydraulic conductivity and natural in- and outflow of water to/from the aquifer;
- Availability of land, surrounding land use and topography;
- Economic and legal aspects concerning the recharge;
- Degree of public acceptance.

To avoid chemical reactions that would reduce aquifer porosity and recharge capacity, the recharge water must be chemically compatible with the naturally occurring groundwater and the aquifer material that it flows through. During operation, the quality (turbidity from sediments but also algae and bacteria, temperature, suspended solids, BOD, nitrogen and phosphorus, other chemicals, etc.) and quantity of the water to be recharged must be carefully controlled and monitored. Some of the methods are described in Annex 1.

Important note: *When designing, constructing and locating the soil infiltration system, climate condition in the area such as temperature extremes, rainfall, snow shall be taken into account. Such systems are allowed in the EU only for small waste water treatment systems up to 50 PE. Technical conditions are described in document CEN/TR 12566-2 and they have to be applied when constructing a waste water treatment system.*

6. WASTE WATER REUSE

After treatment, waste-water is either reused or discharged into the environment. Highly treated waste-water effluent from municipal waste-water treatment plants can be reused as a reliable source of water for agricultural irrigation, landscape irrigation, industrial recycling and reuse, groundwater recharge, recreational uses, non-potable urban reuse or even potable reuse. If not reused, treated waste-water is commonly discharged into a water body and diluted.

Effluent reclamation and reuse has received much attention lately, as a result of growing demand for water and unsustainable rates of consumption of natural water resources. A major concern in reuse applications is the quality of the reclaimed water, which is the main factor dictating the selection of the waste water treatment process sequence. This section describes the various effluent reuse applications with emphasis on effluent quality issues.

Agricultural use. Treated waste water effluent can be used for the irrigation of crops or landscaped areas. The main consideration associated with this effluent application method is the quality of the treated water and its suitability for plant growth. Some constituents in reclaimed water that are of particular significance in terms of agricultural irrigation include elevated concentrations of dissolved solids, toxic chemicals, residual chlorine and nutrients. Another highly important consideration is public health and safety hazards resulting from the potential presence of bacterial pathogens, intestinal parasites, protozoa and viruses. Concerns vary with the intended irrigation purpose and the degree of human contact. Potential constraints associated with the use of reclaimed waste water for irrigation include the marketability of crops and public acceptance, surface and groundwater pollution in the absence of adequate management, and high user costs, notably the cost of pumping effluent to irrigated land.

Industrial use. Reclaimed water is ideal for industries using processes that do not require water of potable quality. Industrial uses of reclaimed water include evaporative cooling water, boiler-feed water, process water, and irrigation and maintenance of the grounds and landscape around the plant. Each type of reuse is associated with a number of constraints on its applicability; the use of reclaimed water in cooling towers, for example, creates problems of scaling, corrosion, biological growth, fouling and foaming. These problems are also encountered when fresh water is used, but less frequently. Reclaimed water used as boiler feed water must be softened and demineralized, while process water quality is dependent on the requirements of the manufacturing process involved.

Recreational uses. Reclaimed water is widely used for recreational purposes, including landscape maintenance, aesthetic impoundments, recreational lakes for swimming, fishing, and boating, ornamental fountains, snow making and fish farming. The required treatment level for reclaimed water is dictated by the intended use; the greater the potential for human contact, the higher the treatment level required. For example, non-restricted recreational water use requires the treatment of secondary effluent by coagulation, filtration, and disinfection to achieve a total coliform count of fewer than three per 100 millilitres.

7. EXAMPLES FOR SELECTION OF TREATMENT AND DISPOSAL SYSTEMS

The overall system design consists of a treatment system and a disposal system. This may be approached by considering various combinations that will achieve defined treatment objectives in the range of economically accepted costs. In general, the treatment systems can be used with any of the disposal systems, but some combinations will provide greater pollutant reductions than others and the costs will vary. The selected methods will also depend on the site conditions and volume of the waste water and its character (domestic, urban, industrial or their combination).

In this context, it must be noted that there are multiple equipment suppliers for each of the different type of treatment systems described in this document. There are differences in materials of construction, size, mechanical design, component complexity and operating modes. The developer of the treatment and disposal system would be aware that not all systems are created equal in terms of expected performance, durability and ease operation. Selection of the “best” option (combination) could be based on a number of criteria including cost, degree of treatment, familiarity with technologies, skill of staff and experts recommendation, etc.

For additional understanding, some examples are presented to illustrate how to use the information that is presented in the previous chapters and illustrated by the fact sheets in Annex 1 to make a selection and combination of the treatment and disposal systems. These examples are based on the information received from the surveys conducted in the Aragvi River basin. Two different alternatives in each example will be considered if feasible, as follows:

(1) Minimum alternative; a minimally acceptable alternative, which meets objectives and requirements for the waste water to be treated and discharged into the recipient body;
(2) Enhanced alternative; treatment alternative that is more protective of public health and the environment.

EXAMPLE 1: SMALL HOTEL WITH 100 BEDS

Facility description

Ten permanent employees, restaurant service from 8:00 to 22:00, 70% occupation by guests during the year and laundry.

Site conditions

Locality can be characterized with a steep slope in the mountain area (slope less than 8 %) with a ground water level depth of more than five meters (m). There are no drinking water wells in the area, a surface water stream is far from the location and the hotel is not located in a flood zone. Furthermore, the place is without individual waste water treatment systems from other sources of pollution (households, hotels, guesthouses, manufactures) and with good draining soil (*Note: Due to slope and mountain area, it will be appropriate to consults permeability with experts and also the location the type of the soil (sand) filtration unit)*.

Characterisation of the waste water

Expected volume of waste water is 10 m^3/day, daily fluctuations with peaks of volume and pollution in morning and evening periods. Pollutants are expressed by BOD, TSS, nutrients (N and P), fecal coliforms, grease and detergents.

Some alternatives to treat waste water from the facility are as follows:

MINIMUM ALTERNATIVE

Septic tank (see Annex 1, 4.3 (2)) in volume of 50 m^3, with soil (sand) filtration bed for disposal of the effluent from septic tank (the area designated for disposal is excavated, and a layer of sand and gravels is installed with the distribution pipe system). This alternative relies on the soil (sand) filtration bed to provide substantial additional treatment in order to protect the environment and public health, due to fact that the septic tank provides only minimal treatment (*Note: If decided that waste water is* *reused, disinfection unit would be added*). The estimated results of the effluent quality are presented in Table 4.

Table 4: Estimated results of the effluent quality for the minimum alternative (example 1).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Septic tank	130	60	40	11	1 – 100 milion	Discharge only to the soil (sand) filtration bed
Soil (sand) filtration bed	20	4	25	5	10	Discharge to surrounding area or can be reused after disinfection

These are low cost alternatives. It is estimated that the investment costs would be around 5,000 EUR and operation and annual maintenance costs around 200 EUR. In this alternative there is no energy consumption.

ENHANCED ALTERNATIVE

Activated sludge system – SBR reactor (Annex 1, 4.3 (10)) unit with soil (sand) filtration bed for disposal of the effluent from. The activated sludge unit will provide the secondary treatment (with high removal of organic matter and nitrogen) and the soil (sand) filtration bed provides additional treatment, making this alternative highly protective of the environment and public health (*Note: If decided that waste water is reused, disinfection unit would be added*). The estimated results of the effluent quality are presented in Table 5.

Table 5: Estimated results of the effluent quality for the enhanced alternative (example 1).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Activated sludge system – SBR reactor	20	20	15	6	1 – 100 million	Discharge only to the soil (sand) filtration bed
Soil (sand) filtration bed	5	4	10	4	10	Discharge to surrounding area or can be reused after disinfection

This alternative is higher in costs compared to the previous one. It is estimated that the investment costs would be around 15,000 EUR and annual operation and maintenance costs (including energy consumption) around 600 EUR.

EXAMPLE 2: SEVERAL HOTELS, GUESTHOUSES AND/OR HOUSEHOLDS IN ONE PLACE

Facility description

Buildings are scattered in several groups (distance between the groups is large than 500 m) in different small catchments. On the other hand, distance between buildings within given group of buildings is not greater than 100 m.

Site conditions

Location is in mountainous terrain with a steep slope (less than 8 %), depth of the ground water level is more than 5 m, no drinking water wells are around, surface water stream is far from the location and buildings are not located in a flood zone. The area is without individual waste water treatment systems from other sources of pollution (if present will be connected to the proposed system).

Characterisation of the waste water

Designed volume of waste water is expected as from 500 PE that means approximately 50 m^3/day, daily fluctuations with peaks of volume and pollution in morning and evening periods, pollutants expressed by BOD, TSS, nutrients (N and P), fecal coliforms, grease, detergents and oil substances from the parking places for hotel and restaurants.

Some alternatives to treat waste water from the facility are as follows:

MINIMUM ALTERNATIVE

Decentralized sewerage (collection) system without pumping stations (slope sufficient to transport waste water into the treatment system) for each group of buildings. This collection system requires high investment costs (approximately 150 EUR per meter of canalisation). For small groups of buildings, cesspools will be constructed to collect waste water and transported by a special vehicle to the sewerage system.

This alternative will require on site pre-treatment grease and oil separator for each restaurant in the area. Pre-treatment screens should be located at the waste water treatment plant, followed by storage in a big septic tank with a retention time of at least three days (see Annex 1, 4.3 (2)), followed by flow to a constructed wetland system (see Annex 1, 4.3 (6)) to provide the secondary treatment. Treated waste water is discharged into the surface water stream with concentrations of pollutants as it is presented in Table 6.

Table 6: Estimated results of the effluent quality for the minimum alternative (example 2).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Constructed wetland system	25	20	35	8	1 – 100 milion	Discharge to the surface water body

This alternative requires high investment costs for canalization. If one meter costs 150 EUR per meter for an estimated 1 km canalization, it could be around 150,000 EUR. Cost for the waste water treatment plants are estimated to be on the on the level of 80,000 EUR. Annual operation and maintenance costs can be in the range of 200 – 500 EUR.

ENHANCED ALTERNATIVE

Activated sludge system (see Annex 1, 4.3 (11) with nitrification and denitrification process for nitrogen removal and soil (sand) filtration bed is added to protect the environment and public health (*Note: If decided that waste water is reused, disinfection unit would be added*). Treated waste water is discharged into the surface water stream with concentrations of pollutants as it is presented in Table 7.

Table 7: Estimated results of the effluent quality for the enhanced alternative (example 2).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Activated sludge system	15	15	15	5	1 – 100 million	Discharge only to the soil (sand) filtration bed
Soil (sand) filtration bed	5	4	10	3	10	Discharge to surface water body or can be reused after disinfection

This alternative is more expensive, 120,000 € due to higher investment costs for soil (sand) filtration bed) compared to minimum alternative. However, annual operation and maintenance costs would be similar to the minimum alternative.

EXAMPLE 3: MUNICIPALITY (AGGLOMERATION) WITH AROUND 5000 PE INCLUDING FOOD FACTORY (SMALL BREWERY AND DRINKS)

Facility description

Municipality (agglomeration) with around 5,000 PE including food factory (small brewery and drinks), located on the river bank.

Site conditions

Locality with low slope and no flooded zone, with depth of groundwater approximately three meters. Several individual cesspools and/or septics are used in the municipality. Bigger restaurants and cantinas should have on effluent grease and oils separator to avoid problems with pipe clogging on sewerage and waste water treatment plant.

Characterisation of the waste water

Expected volume of waste water is about 1,000 m^3/day and organic pollution load is expected as from 5,000 PE, with daily fluctuations with peaks of volume and pollution in morning and evening periods. Wastewater from a small brewery and drinks production is stored in an equalisation basin near the factory and then continuously pumped into sewage. Pollutants expressed by BOD, TSS, nutrients (N and P), fecal coliforms and grease.

Centralized sewage (collection) system with pumping stations will transport waste water from different locations of the agglomeration to the centralized wastewater treatment plant. This collection system needs high investment costs that can be around even 80% of the overall waste water treatment system (based on the experience from the EU member states when implementing UWWT Directive 96/271/EEC). It is expected that after centralized collection system will be constructed, all old systems will be connected to the sewage system and water will be treated in the waste water treatment plant. The waste water treatment plant will be situated below the municipality on the river bank.

Some alternatives to treat waste water from the facility are as follows:

MINIMUM ALTERNATIVE

Pre-treatment facility (fine screens – 6 mm, sand traps), activated sludge system (obviously two parallel reactors of continuous stirred reactors) to provide the secondary treatment and settler to separate sludge and sludge management unit (or composting).

This alternative will also require on site pre-treatment grease and oil separator for each restaurant. Brewery and drinks factories should be equipped with equalization and neutralization tanks to avoid a fluctuation of water quality and flow.

Inflow to the wastewater treatment plant should be processed through pre-treatment screens, grit chambers (see Annex 1, 4.3 (1)), as the main treatment step is activated sludge systems – continuous stirred tank reactors (CSTR) (see Annex 1, 4.3 (11)) to provide the secondary treatment without enhanced nutrient removal. Treated waste water is then discharged into the surface water stream with concentrations of pollutants as it is presented in Table 8.

Table 8: Estimated results of the effluent quality for the minimum alternative (example 3).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Activated sludge system	20	20	25	6	1 – 100 million	Discharge to the surface water body

This alternative requires high investment costs to canalization. If one meter costs 150 EUR per meter for an estimated one km canalization it could be around 150,000 EUR. Costs for the waste water treatment plants are estimated to be on the on the level of 500,000 EUR. Annual operation and maintenance costs can be in the range of 2,500 – 5,000 EUR.

ENHANCED ALTERNATIVE

Same as in the minimum alternative, but a wastewater treatment plant equipped with nutrient removal and also sludge management thickening unit is introduced. This will increase the investment and operating costs of the treatment system.

Table 9: Estimated results of the effluent quality for the enhanced alternative (example 3).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Suspended growth activation	10	15	15	2	1 – 100 million	Discharge only to the soil (sand) filtration bed
Disinfection and (sand) filtration bed	5	4	10	1	0	Discharge to surface water body or can be reused after disinfection

This alternative is more expensive 750,000 € due to higher investment costs for nutrient removal by soil (sand) filtration bed compared to the minimum alternative. However, annual operation and maintenance costs would be similar to the minimum alternative.

EXAMPLE 4: ECOLOGY FREE-TIME SPORT PARK WITH GUESTHOUSES (IDEA FOR FUTURE INVESTMENT)

Facility description

Twenty-five permanent employees, guesthouse with capacity of 150 beds, restaurant service from 8:00 to 22:00, 70% occupation by guests during the year and laundry, summer/winter free time sport park with daily load approximately 250 people. All water sanitary systems in ecology park are equipped with dual sanitary pipes for grey water (showers, washing machines, kitchen sinks) and for black water (WC toilets with low-flush system or waterless urinals) to spare water use.

Site conditions

In the lowland area (slope less than 3%), depth of the ground water level is more than five meters, rare drinking water wells surrounding, surface water stream far from the place and free time zone is not located in flood zone, without individual waste water treatment systems from other sources of pollution (households, hotels, guesthouses, manufactures) and good draining soil.

Characterisation of the waste water

Expected volume of waste water 25 m^3/day, daily fluctuations with peaks of volume and pollution in morning and evening periods, pollutants expressed by BOD, TSS, nutrients (N and P), fecal coliforms, grease and detergents. Average daily organic pollution load on 200 PE.

Some alternatives to treat waste water from the facility are as follows:

ECOLOGICAL ALTERNATIVE

Wastewater (5 m^3/day) from all toilets in park flows to small wastewater treatment plant (Activated sludge system - see Annex 1, 4.3 (11). Effluent from this waste water treatment plant together with the rest of waste water from park activities (20 m^3/ day) is flowing into small constructed wetland treatment plant (20x20 m) as the second step of treatment. The effluent from constructed wetland can be used for irrigation of green plants or after disinfection can be re-used flushing water in WC toilets or as technical water some park activities.

The estimated results of the effluent quality are presented in Table 10.

Table 10: Estimated results of the effluent quality for the minimum alternative (example 4).

Treatment system	BOD mg/l	TSS mg/l	Total nitrogen mg/l	Total phosphorus mg/l	Fecal coliforms per 100 ml	Remark
Small activated sludge system	25	25	20	5	1 – 100 million	Discharge only to the CW system
Constructed wetland system	5	5	5	2	5	Using as water for irrigation or reuse as technical water

It is estimated that the investment costs would be around 15,000 EUR (small activated sludge system) + 10,000 EUR (constructed wetland system) + 5,000 EUR (dual pipe system, low water WC, irrigation and reuse devices) and annual operation and maintenance costs around 1,000 EUR.

Several industries, their associated waste water pollutants and common treatment processes used to treat those pollutants are shown in Table 11. The treatment methods vary in depends on type of production, requirements on effluent (effluent from factory into sewerage or enhanced treatment with effluent into river), etc.

Table 11: Selected industries and treatment processes for waste waters

Industry	Associated waste water pollutants	Treatment methods
Textile	BOD, TSS, alkalinity	Neutralization, chemical precipitation, coagulation, biological treatment
Leather goods	BOD, TSS, Chromium, alkalinity	Sedimentation, biological treatment
Detergents	BOD, saponified soaps	Screening, chemical precipitation, adsorption
Breweries	BOD, TSS, alkalinity	Centrifugation, anaerobic and aerobic biological treatment
Meats and poultry	BOD, TSS, alkalinity	Screening, sedimentation, coagulation, flotation,

		biological treatment
Pulp and paper	High and low pH, TSS and inorganic compounds	Sedimentation, neutralization, biological treatment
Metal industries	Acidity, heavy metals	Neutralization, flotation, sedimentation, chemical precipitation, biological treatment
Plastics and resins	High and low pH, TSS and volatile organic compounds	Neutralization, biological treatment

FURTHER READINGS AND REFERENCES

EU Directive 2000/60/EC establishing a framework for Community action in the field of water policy (Water Framework Directive).

Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment).

Guidance on "Terms and Definitions of the Urban Waste Water Treatment Directive 91/271/EEC" (2007).

Hallahan, Dennis F. "The Standard Septic System: Still an Effective Choice for Onsite Waste water Treatment," Water Engineering and Management. Des Plaines: Volume 149, Issue 10; pp. 33-36. October 2002.

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Gray N. F. (2005). Water Technology: An Introduction for Environmental Scientists and Engineers (2nd Edition), Elsevier Science & Technology Books, ISBN 0750666331, Amsterdam, The Netherlands.

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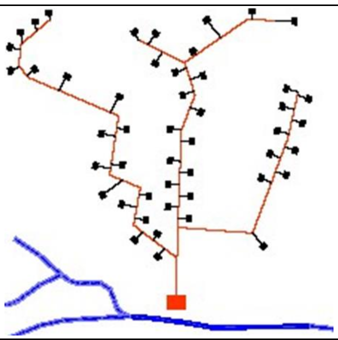
Metcalf & Eddy. „Wasteater Engineering – Treatment and Reuse". 4th Edition, McGraw Hill 2004, ISBN 007-124140-X, Singapore.

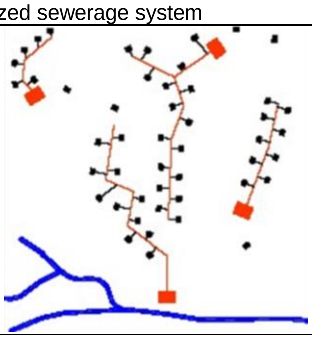
Esplugas, S., Bila, D. „Ozonation and advanced oxidation technologies to remove endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) in water effluents" J. of Hazardous Materials 149 (2007) pp.631-642.

Tilley, E.; Ulrich, L.; Luethi. „Compendium of Sanitation Systems and Technologies". 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2014.

LIST OF FIGURES AND TABLES

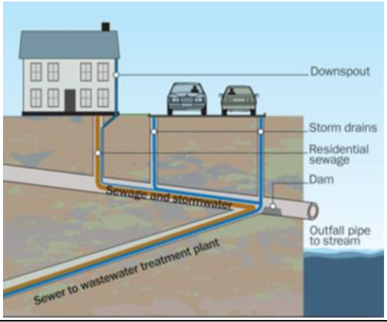
ANNEX 1

<table>
<tr><th colspan="2">4.2. Waste water collection and transport</th></tr>
<tr><td colspan="2">4.2.1. Centralized sewerage system</td></tr>
<tr><td></td><td>Technology description:
Sewage is collected by an underground pipe system transported to the <u>single</u> centralized treatment facilities.
Centralized sewerage system consists of individual connections (households, commercial enterprises et.) to a piped reticulation system. The reticulation systems normally include a series of pump stations to convey the sewage through the system, especially on lowland communities due to flat topography and high groundwater levels. Manholes and other access chambers are required to maintain and clean reticulation systems.</td></tr>
<tr><td colspan="2">Operation and Maintenance:
• High degree of operation and maintenance if pumping is required
• Skilled personnel required</td></tr>
<tr><td>Advantages:
• Minimal intervention by users
• Promotes good hygiene practices</td><td>Disadvantages:
• High capital costs
• Ample and reliable piped water supply required
• Adequate treatment disposal required</td></tr>
<tr><td>Relative costs:
• Low to moderate Operation and Maintenance (O&M) costs
• High capital costs</td><td>Suitability:
• High population density
• Continuous build-up areas
• Areas without high level of underground water</td></tr>
<tr><td>Energy use:
• Low to moderate</td><td>Pollution reduction:
• None</td></tr>
</table>

<table>
<tr><th colspan="2">4.2. Waste water collection and transport</th></tr>
<tr><td colspan="2">4.2.2. Decentralized sewerage system</td></tr>
<tr><td></td><td>Technology description:
Produced sewage is collected by an underground pipe system transported to the two or more decentralized treatment facilities.
Each separate decentralized sewerage system consists of individual connections (households, commercial enterprises et.) to a piped reticulation system. The reticulation systems normally include a series of pump stations to convey the sewage through the system, especially on highland communities due to hilly topography and lower population density.</td></tr>
<tr><td colspan="2">Operation and Maintenance:
• High degree of operation and maintenance if pumping is required
• Skilled personnel required</td></tr>
<tr><td>Advantages:
• Minimal intervention by users
• Promotes good hygiene practices</td><td>Disadvantages:
• Higher operational costs
• Two or more separate WWTPs</td></tr>
<tr><td>Relative costs:
• Moderate O&M costs
• Moderate capital costs</td><td>Suitability:
• Moderate population density
• Discontinuous build-up areas
• Without high level of underground water</td></tr>
<tr><td>Energy use:
• Low to moderate</td><td>Pollution reduction:
• None</td></tr>
</table>

4.2. Waste water collection and transport

4.2.3. Combined sewerage system



Technology description:

Combined sewerage systems are large networks of underground pipes that convey domestic sewage, industrial waste water and storm water runoff in the same pipe to a centralized treatment facility.

During dry weather, the combined sewer system and waste water treatment plants have the capacity to transport and treat all the sanitary sewage entering the system. However, when flow in the sewer increases as a result of rainfall or snowmelt, the sewer pipes or treatment plants may reach their capacity. When this happens, to discharge excess waste water into nearby waterbodies to prevent health and human safety issues that may result from localized flooding in neighborhoods and in treatment plants.

Operation and Maintenance:
- It must be designed to maintain “self-cleansing” velocity that no particles accumulate
- Maintenance should be done by professionals.
- It must be systematically planned and carefully implemented.
- Overflows are required to avoid hydraulic surcharge of treatment plants during heavy rain events.

Advantages:
- Minimal intervention by users, low health risk
- No nuisance from smells, mosquitos or flies
- Stormwater and greywater can be managed at the same time
- No problems related to discharging industrial waste water

Disadvantages:
- Extension of the system can be difficult and costly
- Difficult to construct in high-density areas, difficult and costly to maintain
- Recycling of nutrients and energy becomes difficult
- Unsuitability for self-help, requires skilled engineers and operators
- Problems associated with blockages and breakdown of pumping equipment

Relative costs:
- Very high capital costs
- Moderate O&M costs

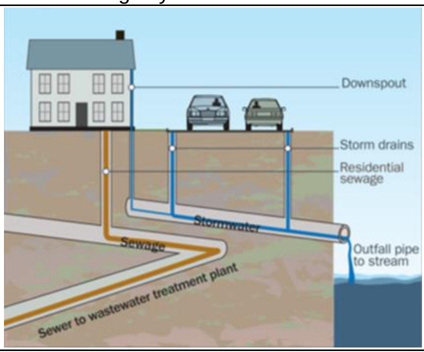
Suitability:
- High population density
- Old cities with high water consumption
- Sufficient water as a transport medium needs to be available.
- A professional management system must be in place.
- They provide a high level of hygiene and comfort for the user.

Energy use:
- Low to moderate

Pollution reduction:
- None

4.2. Waste water collection and transport

4.2.4. Separate sewerage system



Technology description:

In contrast to combined (conventional) sewer system, produced sewage and storm water are transported separately. During heavy rains, overflow contains no harmful sewage (black water) and WWTPs operates under steady flows without hydraulic peaks.

Storm water in general is less contaminated and doesn’t cause pollution in water bodies.

Operation and Maintenance:
- High degree of operation and maintenance if pumping is required
- Skilled personnel required

Advantages:
- Surface run-off, greywater and blackwater can be managed separately
- Limited of sewage overflow, low health risk
- No problems related to discharging industrial waste water
- Surface run-off and rainwater can be reused

Disadvantages:
- Difficult to construct in high-density areas, difficult and costly to maintain
- Requires skilled engineers and operators
- Problems associated with blockages and breakdown of pumping equipment
- Adequate treatment and/or disposal required
- Higher risk of water pollution by accidents

Relative costs:
- Higher O&M costs
- High capital costs

Suitability:
- Moderate population density
- Areas with often storms
- Enough water for transportation must be available

Energy use:
- Low to moderate

Pollution reduction:
- None

4.2. Waste water collection and transport

4.2.5. Sewerage system in industry

Technology description:

Industrial sewers, such as refinery sewer systems do not tie into municipal systems because refinery waste products are not compatible with prevalent sanitary sewage treatment. To prevent waste products from entering rivers and lakes, almost all large industrial plants have facilities to separate and collect wastewater. The wastewater streams in largest industrial plants can be classified under the following four basic sewer systems:

- The oily water sewer
- The acid (chemical) sewer
- The storm water sewer
- The sanitary sewer

Operation and Maintenance:

- High degree of operation and maintenance if pumping is required
- Skilled personnel required

Advantages:

- Separate maintenance of all types of wastewater
- Non-mix system for better treatment
- Surface run-off and rainwater can be reused
- Obviously better effluent quality

Disadvantages:

- Problems associated with blockages and breakdown of pumping equipment
- Requires also separate treatment steps
- Requires skilled engineers and operators
- Higher risk of water pollution by accidents

Relative costs:

- Higher O&M costs
- High capital costs

Suitability:

- For large industrial areas
- Where different types of wastewater are produced

Energy use:

- Low to moderate

Pollution reduction:

- None

4.2. Waste water collection and transport

4.2.6. Individual collection system – cesspool

Technology description:

Cesspool is a very general description for different on-site collection systems for excreta, feces und urine. They are one of the common on/site waste water collection system in the absence of a sewer collection network. They typically serve one household or are shared by families. The size of the tank depends on the availability of land and on the construction costs. Their capacity might range from 5 to 50 m3. If a cesspool is water-tight it needs to be emptied frequently. When the cesspool is not tight, liquids leached out and polluted soil and underground water. Sewage from cesspools should be transported by special cars to nearest sewerage system or direct to nearest WWTPs.

Operation and Maintenance:

- Has to be emptied regularly by a vacuum truck. The sludge needs secondary treatment.
- No skilled personnel required
- Special technical equipment is required (gully sucker)

Advantages:

- Collects faecal sludge in a closed tank (avoids spreading of pathogens)
- Can be emptied with a vacuum truck which guarantees more safety for the operators health
- Easy but definitely not the best solution

Disadvantages:

- Costs to empty may be significant compared to capital costs
- High-risk of groundwater pollution
- Development of gases and bad smell
- No specific reuse of nutrients and energy contained in faeces and urine
- Sludge requires secondary treatment and/or appropriate discharge

Relative costs:

- Low O&M costs (only for accumulation)
- Moderate capital costs

Suitability:

- Communities without connection to sewerage
- Located in long distance to nearest sewerage system

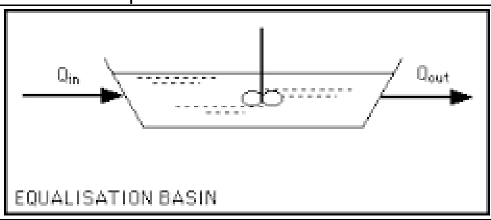
Energy use:

- Low to moderate

Pollution reduction:

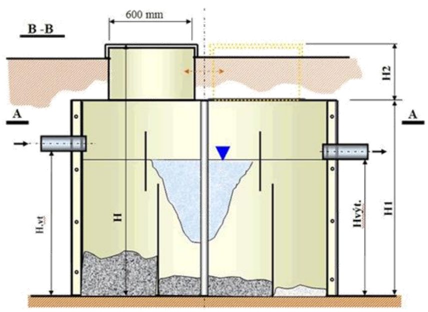
- Very low or none

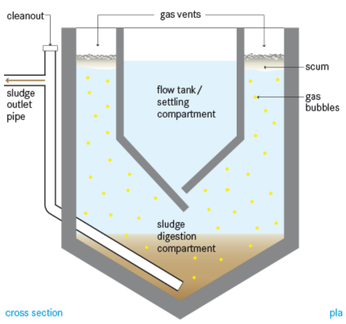
4.2. Waste water collection and transport	
4.2.7. Individual transport system	
	Technology description: Produced sewage from cesspools or septic tanks is transported by special cars to nearest sewerage system or direct to nearest WWTPs. Transfer stations act as intermediate dumping points for fecal sludge/blackwater when it cannot be easily transported to a treatment facility. It is emptied by a vacuum truck.
Operation and Maintenance: • No skilled personnel required • Special technical equipment is required (gully sucker) • Sludge from transfer or sewer discharge stations is treated in an appropriate secondary treatment facility and not be illegally dumped	
Advantages: • May reduce illegal dumping of faecal sludge • Potential for local job creation and income generation • Reduces transport distance and may encourage more community-level emptying solutions	Disadvantages: • May cause blockages and disrupt sewer flow (sewer discharge station) • Sludge requires secondary treatment and/or appropriate discharge • Requires an institutional framework taking care of access fees, connection to sewers or regular emptying and maintenance
Relative costs: • High O&M costs • Moderate capital costs	Suitability: • Communities without connection to sewerage • For individual houses without connection to sewerage system, located in long distance to nearest sewerage system • The site for the transfer station should be easily accessible, conveniently located, and easy to use. • A proper legal and institutional framework is required as well.
Energy use: • Low to moderate	Pollution reduction: • None

4.2. Waste water collection and transport	
4.2.8. Wastewater equalization	
	Technology description: Flow equalization is used to minimize the variability of water and wastewater flow rates and composition. Each unit operation in a treatment train is designed for specific wastewater characteristics. Improved efficiency and control are possible when all unit operations are carried out at uniform flow conditions. If there exists a wide variation in flow composition over time, the treatment efficiency of the overall process performance may degrade severely
Operation and Maintenance: • No skilled personnel required • Special technical equipment is required (floating switch)	
Advantages: • May reduce mass and hydraulic overloading of reactors • May improve treatment efficiency of reactors • May reduce volume of treatment reactors	Disadvantages: • Higher requirements on equipment control • More treatment step reactors
Relative costs: • Low O&M costs • Moderate capital costs	Suitability: • Industrial branches with higher fluctuation of wastewater production • Industrial branches with higher fluctuation wastewater quality
Energy use: • Low	Pollution reduction: • None

4.3. Waste water treatment	
1. Screens, Grease Trap, Grid chamber	
	Technology description: Pre-treatment is the preliminary removal of waste water or sludge constituents, such as oil, grease, and various solids (e.g., sand, fibres and trash). Pre-treatment units can retard the accumulation of solids and minimize subsequent blockages. They can also help reduce abrasion of mechanical parts and extend the life of the sanitation infrastructure. Oil, grease, sand and suspended solids can impair transport and/or treatment efficiency through clogging and wear. Therefore, prevention and early removal of these substances is crucial for the durability of a treatment system. Pre-treatment technologies use physical removal mechanisms, such as screening, flotation, settling and filtration.
Operation and Maintenance: All pre-treatment facilities must be regularly monitored and cleaned to ensure proper functioning. If the maintenance frequency is too low, strong	

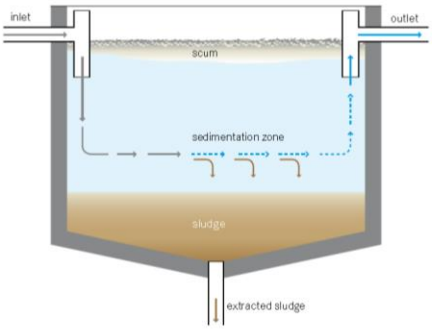
odours can result from the degradation of the accumulated material. Insufficiently maintained pre-treatment units can eventually lead to the failure of downstream elements of a sanitation system. The pre-treatment products should be disposed of as solid waste in an environmentally sound way.	
Advantages: • Simple and robust technology • Efficient solids removal • No electrical energy is required (small units) • Little space and small area required • Long service life	Disadvantages: • Regular cleaning must be ensured • Removed waste require further treatment • Removal of solids and grease is not pleasant • Lower reduction of organic pollution
Relative costs: • Moderate O&M costs • Moderate capital costs	Suitability: • Grease traps should be applied where considerable amounts of oil and grease are discharged. • Screening is essential where solid waste may enter a sewer system, or at the entrance of treatment plants. • A grit chamber helps prevent sand deposits and abrasion in waste water treatment plants.
Energy use: • None or low energy use	Typical pollution reduction: BOD: 0 – 5 % TSS: 5 – 35 % Ntot: 0 – 10 %

4.3. Waste water treatment	
2. Septic tank	
	Technology description: A septic tank is a watertight chamber made of brick work, concrete or plastic. Septic tanks are used for pre-treatment of waste water with a high content of settleable solids, typically for effluent from domestic sources. Liquid flows through the tank and heavy particles sink to the bottom, while scum (mostly oil and grease) floats to the top. Over time, the solids that settle to the bottom are degraded anaerobically. However, the rate of accumulation is faster than the rate of decomposition, and the accumulated sludge and scum must be periodically removed. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate. Effluent is infiltrated into the ground or transported via a sewer to a (semi-) centralised treatment plant. Accumulating faecal sludge needs to be dug out the chamber regularly and correctly disposed of.
Operation and Maintenance: • Should be checked for water tightness. Scum and sludge levels regularly • Sludge needs to be dug out every 1 – 5 years a discharged properly. • No skilled personnel required	
Advantages: • Simple and robust technology, long service life • No electrical energy is required • Little space and small area required (underground)	Disadvantages: • Low reduction in pathogens, solids and organics • Regular desludging must be ensured • Effluent and sludge require further treatment • Two or more separate WWTPs
Relative costs: • Moderate O&M costs • Moderate capital costs	Suitability: • No for area with high level of groundwater of flooding areas • This technology is most commonly applied at the household level. • Larger, multi-chamber septic tanks can be designed for groups of houses, public buildings
Energy use: • None	Typical effluent reduction: BOD: 30 – 60 % TSS: 50 – 75 % Ntot: 0 – 10 %

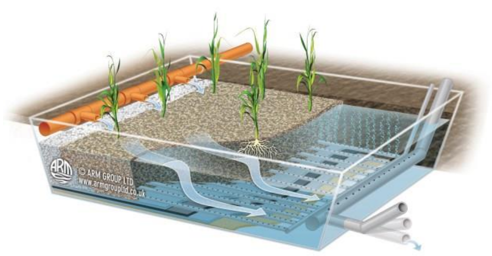
4.3. Waste water treatment	
3. Imhoff tanks	
	Technology description: Imhoff tanks are used for domestic or mixed waste water. The Imhoff tank consists of a two-story tank in with sedimentation is accomplished in the upper compartment and digestion of the settled solids is accomplished in the lower compartment. Sludge then falls through an opening at the bottom into the lower tank where it is digested anaerobically. Methane gas is produced in the process and is prevented from disturbing the settling process by being deflected by baffles into the gas vent channels. Effluent is odorless because the suspended a dissolved solid in the effluent do not come into contact with the active sludge. When sludge is removed it needs to be further treated in drying beds or other such device for pathogen control.

Operation and Maintenance: • Requires removal of scum and sludge at a regular interval	
Advantages: • Improved effluent quality compared to septic tank • Low land space required • Resistant against organic shock loading • No energy required	Disadvantages: • Effluent requires further treatment step • Relatively deep tanks are required, possible problems with underground water • Complicated design then septic tank
Relative costs: • Low capital costs but higher the septic tank • Low O&M costs	Suitability: • Relatively small scale on site industrial waste and sewage • This technology is most commonly applied for groups of houses and/or public buildings (e.g., schools)
Energy use: • Energy generated (biogas) but not captured	Typical effluent reduction: BOD: 30 – 50 % TSS: 50 – 70 % Ntot: 0 – 10 %

4.3. Waste water treatment	
4. Waste water stabilisation ponds	
	Technology description: Waste or Waste Water Stabilization Ponds (WWSPs) are large, man-made water bodies in which blackwater, greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. WWSPs are low-cost for O&M and BOD and pathogen removal is high. However, large surface areas and expert design are required. The effluent still contains nutrients (e.g. N and P) and is therefore appropriate for the reuse in agriculture , but not for direct recharge in surface waters.
Operation and Maintenance: Very simple. Removing vegetation (to prevent BOD increase and mosquito breath) scum and floating vegetation from pond surfaces, keeping inlets and outlets clear, and repairing any embankment damage.	
Advantages: • Resistant to organic and hydraulic shock loads • High reduction of solids, BOD and pathogens • Low operating cost • No electrical energy required • No real problems with flies or odours if designed and maintained correctly • Can be built and repaired with locally available materials • Effluent can be reused in aquaculture or for irrigation in agriculture	Disadvantages: • Requires large land area • High capital cost depending on the price of land • Requires expert design and construction • Sludge requires proper removal and treatment • De-sludging (normally every few years) • Mosquito control required • If the effluent is reused, salinity needs to be monitored • Not always appropriate for colder climates
Relative costs: • Low capital costs where land prices are low • Low O&M costs	Suitability: • For countries with no very cold climate • For low requirement effluent quality • For all types of waste water (industrial, sewage)
Energy use: • Very low or no energy use	Typical effluent reduction: BOD: 70 - 90 % TSS: 70 – 80 % Ntot: 30 – 60 %

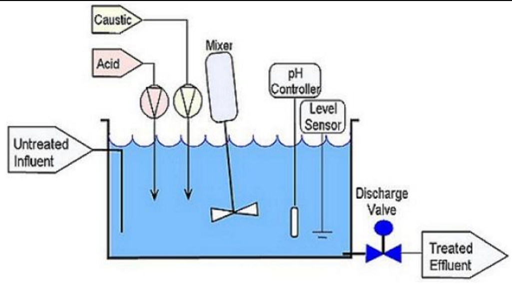
4.3. Waste water treatment	
5. Sedimentation tanks	
	Technology description: The main purpose of a sedimentation tank (settler) is to facilitate sedimentation by reducing the velocity and turbulence of the waste water stream. Settlers are circular or rectangular tanks that are typically designed for a hydraulic retention time of 1.5-2.5 h. The tank should be designed to ensure satisfactory performance at peak flow. In order to prevent eddy currents and short-circuiting, as well as to retain scum inside the basin, a good inlet and outlet construction with an efficient distribution and collection system (baffles, weirs or T-shaped pipes) is important. Large primary clarifiers are often equipped with mechanical collectors that continually scrape the settled solids towards a sludge hopper in the base of the tank, from where it is pumped to sludge treatment facilities. A sufficiently sloped tank bottom facilitates sludge removal. Scum removal can also be done either manually or by a collection mechanism.
Operation and Maintenance: In settler regular sludge removal is necessary to prevent septic conditions and the build-up and release of gas which can hamper the sedimentation	

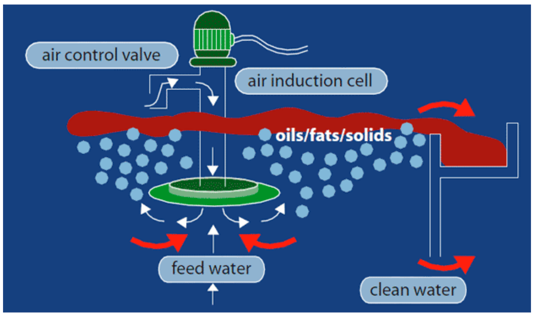
process by re-suspending part of the settled solids. Sludge transported to the surface by gas bubbles is difficult to remove and may pass to the next treatment stage. Frequent scum removal and adequate treatment/disposal is also important. Skills and technological knowledge are required	
Advantages: • Simple and robust technology • Efficient removal of suspended solids	Disadvantages: • Frequent sludge removal • Effluent, sludge and scum require further treatment • Short-circuiting can be a problem • Little organic and nutrient removal
Relative costs: • High capital and O&M costs in large-scale units • Low capital and O&M cost in small-scale units	Suitability: • For all types of waste water (industrial, sewage) with high content of suspended solids • If further technology step requires low load of solid waste water (trickling filter, MBR, etc)
Energy use: • Depends on unit size and installed technology	Typical pollution reduction: BOD: 20 - 40 % TSS: 30 – 60 % Ntot: 5 – 20 %

4.3. Waste water treatment	
6. Constructed wetland (Reed Bed Systems)	
	Technology description: Constructed wetlands are engineered wetland systems which can treat a variety of waste effluents: domestic waste water, agricultural runoff, stromwater and even industrial effluents. Treatment takes place through a variety of complex natural chemical, physical and biological processes, including sedimentation, precipitation, adsorption, assimilation from the plants and microbiological activity. The system utilizes aquatic plants, such as Phragmites reeds, bulrushes and cattails. A cost-effective system is designed to work under gravity, thus minimizing any need for pumps or other electrical devices. The flow may be either horizontal or vertical and, in the case of horizontal flow wetlands, may be either above or below the surface.
Operation and Maintenance: Relatively simple for constructing and operation, but some technical skills and technological knowledge are required	
Advantages: • Utilisation of natural processes • High reduction of BOD, suspended solids and pathogens • Ability to nitrify due to good oxygen transfer • Less clogging than in a Horizontal Subsurface Flow Constructed Wetland • Requires less space than a Free-Water Surface or Horizontal Flow Wetland	Disadvantages: • Requires a large land area • Little nutrient removal • Risk of clogging, depending on pre- and primary treatment • Long start-up time to work at full capacity • Requires expert design and construction supervision • Not very tolerant to cold climates • Effective pre-treatment required
Relative costs: • Low capital costs where sand and land prices are low • Low O&M costs then activated sludge systems	Suitability: • For small plant size • For all types of waste water (industrial, sewage) • Obviously applied for pretreated sewage in lower size (10 – 2000 p.e) or as a post-treatment plant
Energy use: • Very low or no energy use	Typical effluent reduction: BOD: 70 - 90 % TSS: 75 – 85 % Ntot: 40 – 80 %

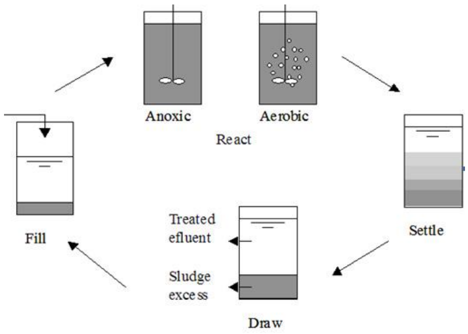
4.3. Waste water treatment	
7. Coagulation and floculation	
	Technology description: Coagulation-flocculation is a chemical water treatment technique typically applied prior to sedimentation and filtration (e.g. rapid sand filtration) to enhance the ability of a treatment process to remove particles. Coagulation is a process used to neutralise charges and form a gelatinous mass to trap (or bridge) particles thus forming a mass large enough to settle or be trapped in the filter. Flocculation is gentle stirring or agitation to encourage the particles thus formed to agglomerate into masses large enough to settle or be filtered from solution.
Operation and Maintenance: • Requires trained operators for effective maintenance	
Advantages: • Simplicity and cost-effectiveness • Separates many kind of particles from water	Disadvantages: • Input of chemicals required • Qualified personnel required for design (e.g. construction of chambers

• Enhances filtration process • Uses abundant and low cost chemicals	and dosage of chemicals) and system maintenance • Transfer of toxic compounds into solid phase and formation of sludge that has to be treated subsequently • Relatively time consuming process
Relative costs: • High capital costs • Moderate - high O&M costs	Suitability: • For wastewater with high content of dissolved and suspended particles
Energy use: • Low to moderate energy use	Typical effluent reduction: BOD: 30 – 80 % TSS: 65 – 90 % Ntot: 10 – 20 %

4.3. Waste water treatment	
8. Neutralisation	
 	Technology description: Neutralization is the process of adjusting the pH of water through the addition of an acid or a base, depending on the target pH and process requirements. Some processes such as boiler operations and drinking water standards need neutral water at a pH of 7. Water or wastewater is generally considered adequately neutralized if: – its damage to metals, concrete, or other materials is minimal; – it has little effect on fish and aquatic life; – it has no effect on biological matter (i.e., biological treatment systems).
Operation and Maintenance: • Requires trained operators for effective maintenance	
Advantages: • Separates many kind of metals from water • Enhances biological processes	Disadvantages: • Qualified personnel required for dosage of chemicals and system maintenance • Input of chemicals (acid or alkaline) required • Transfer of dissolved metals into solid phase and formation of sludge that has to be treated subsequently • Relatively time consuming process
Relative costs: • Moderate capital costs • Moderate - high O&M costs (depends on chemical costs)	Suitability: • For wastewater with high content of metals or with extremely pH values (low then 5,5 or higher then 9,0)
Energy use: • Low energy use	Typical effluent reduction: BOD: 10 – 30 % TSS: 0 – 30 % Ntot: 0 %

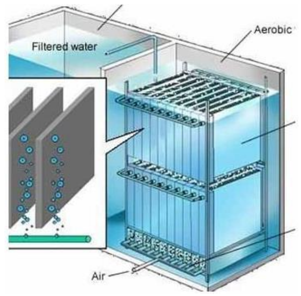
4.3. Waste water treatment	
9. Flotation	
 	Technology description: Flotation is a treatment process that clarifies wastewaters (or other waters) by the removal of suspended matter such as oil or solids. The removal is achieved by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. Flotation is very widely used in treating the industrial wastewater effluents from oil refineries, petrochemical and chemical plants, natural gas processing plants, paper mills, general water treatment and similar industrial facilities.
Operation and Maintenance: • Requires trained operators for effective maintenance	
Advantages: • Separates many kind of suspended solids • More effective treatment than sedimentation process • Low surface requirements than sedimentation process • Obviously higher concentration of floated sludge than after sedimentation	Disadvantages: • Qualified personnel required for system maintenance • Higher energy demand
Relative costs: • Moderate capital costs • Moderate O&M costs	Suitability: • For wastewater with high content of suspended solids with bad sedimentation characteristics
Energy use:	Typical effluent reduction:

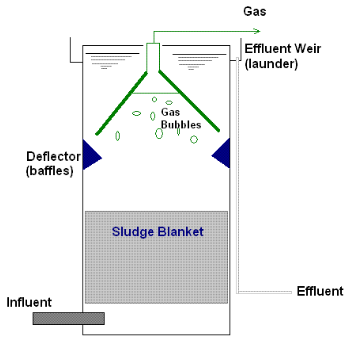
• Higher energy use	BOD: 10 – 30 % TSS: 50 – 90 % Ntot: 0 %

4.3. Waste water treatment	
10. Activated sludge systems – Sequential Batch reactors (SBR)	
	Technology description: The process can be operated in batches, where the different conditions are all achieved in the same reactor but at different times. The treatment consists of a cycle of five stages: fill, react, settle, draw and idle. During the reaction type, oxygen is added by an aeration system. During this phase, bacteria oxidize the organic matter just as in activated sludge systems. Thereafter, aeration is stopped to allow the sludge to settle. In the next step, the water and the sludge are separated by decantation and the clear layer (supernatant) is discharged from the reaction chamber. At least two tanks are needed for the batch mode of operation as continuous influent needs to be stored during the operation phase. Very small systems (e.g. serving small settlements) may apply only one tank. In this case, the influent must either be retained in a pond or continuously discharged to the bottom of the tank in order to not disturb the settling, draw and idle phases.
Operation and Maintenance: High (complicated) operation and maintenance required High technology required skilled installation	
Advantages: • Low land space required • High effluent quality • Efficient nitrification and denitrification possible • High effluent quality in terms of BOD and suspended solids removal, also in terms of pathogens	Disadvantages: • Requires expert design and construction, • High technology requiring skilled operation and maintenance inputs • Obviously two parallel reactors required
Relative costs: • High capital costs (two or more reactors) • Moderate O&M costs	Suitability: • Relatively small scale on site industrial waste and sewage, optimally for discontinued flows • Where skilled technical backup is available
Energy use: • Moderate energy use	Typical effluent reduction: BOD: 80 – 95 % TSS: 75 – 90 % Ntot: 70 – 95 %

4.3. Waste water treatment	
11. Activated sludge systems – continuous stirred tank reactors (CSTR)	
	Technology description: Activated sludge refers to a mass of microorganisms cultivated in the treatment process to break down organic matter into carbon dioxide, water, and other inorganic compounds. The activated sludge process has three basic components: 1) a reactor in which the microorganisms are kept in suspension, aerated, and in contact with the waste they are treating; 2) liquid-solid separation; and 3) a sludge recycling system for returning activated sludge back to the beginning of the process. There are many variants of activated sludge processes, including variations in the aeration method and the way the sludge is returned to the process. order to not disturb the settling, draw and idle phases.
Operation and Maintenance: High (complicated) operation and maintenance required High technology required skilled installation	
Advantages: • Resistant to organic and hydraulic shock loads • Can be operated at a range of organic and hydraulic loading rates • High reduction of BOD and pathogens (up to 99%) at after secondary treatment • High nutrient removal possible • High effluent quality • Little land required compared to extensive natural system (e.g. waste stabilization ponds) • Can be modified to meet specific discharge limits	Disadvantages: • High energy consumption, a constant source of electricity is required • High capital and operating costs • Requires operation and maintenance by skilled personnel • Prone to complicated chemical and microbiological problems • Requires expert design and construction • Sludge and possibly effluent require further treatment and/or appropriate discharge
Relative costs: • High capital costs • High O&M costs	Suitability: • Where skilled technical backup is available • For all ranges of plant sizes (5 – 100 000 p.e)

	• For all types of waste water (industrial, sewage)
Energy use: • High energy use (0,3 – 0,6 kWh/m3)	Typical effluent reduction: BOD: 80 – 95 % TSS: 80 – 90 % Ntot: 70 – 85 %

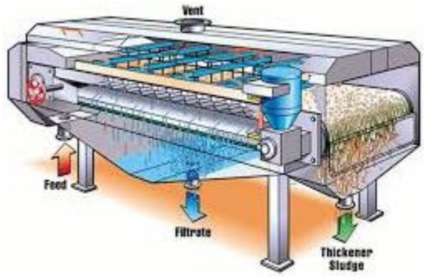
4.3. Waste water treatment	
12. Activated sludge systems – Membrane bioreactor (MBR)	
	Technology description: Membrane bioreactors combine conventional biological treatment (e.g. activated sludge) processes with membrane filtration to provide an advanced level of organic and suspended solids removal. In an MBR system, the membranes are submerged in an aerated biological reactor. The membranes have porosities ranging from 0.035 microns to 0.4 microns. This level of filtration allows for high quality effluent to be drawn through the membranes and eliminates the sedimentation and filtration processes typically used for waste water treatment. Because the need for sedimentation is eliminated, the biological process can operate at a much higher mixed liquor concentration, typically in the 1.0-1.2% solids range, which is 4 times that of a conventional plant.
Operation and Maintenance: High (complicated) operation and maintenance required as well as technology required skilled installation	
Advantages: • Secondary clarifiers and tertiary filtration processes are eliminated, small plant footprint • Footprint can be further reduced because other process units such as UV disinfection can also be eliminated • Can be designed to prolong sludge age, hence lower sludge production • Very high effluent quality • High loading rate capability	Disadvantages: • Requires expert design and construction • Membrane complexity and fouling • Complicated membrane treatment • Higher oxygen demand • Very skilled operators needed
Relative costs: • High capital costs • High O&M costs	Suitability: • This technology is most successfully applied if very high effluent requirements are defined. • Where skilled technical backup is available • For all types of waste water (industrial, sewage)
Energy use: Higher energy use (0,6 – 1,5 kWh/m3)	Typical effluent reduction: BOD: 85 – 95 % TSS: > 98 % Ntot: 70 – 9 %

4.3. Waste water treatment	
13. Upflow Anaerobic Sludge Blanket - UASB	
	Technology description: The UASB reactor is a single tank process in an industrial waste water or blackwater treatment system achieving high removal of organic pollutants. Waste water enters the reactor from the bottom, and flows upward. A suspended sludge blanket filters and treats the waste water as the waste water flows through it. Bacteria living in the sludge break down organic matter by anaerobic digestion, transforming it into biogas. Solids are also retained by a filtration effect of the blanket. The upflow regime and the motion of the gas bubbles allow mixing without mechanical assistance. Baffles at the top of the reactor allow gases to escape and prevent an outflow of the sludge blanket. As all aerobic treatments, UASB require a post-treatment to remove pathogens, but due to a low removal of nutrients, the effluent water as well as the stabilised sludge can be used in agriculture.
Operation and Maintenance: Medium to high degree of operation and maintenance level required, highly skilled personnel required	
Advantages: • High reduction of BOD, low sludge production • High organic and hydraulic loading rates • Biogas can be used for energy • No aeration system required, low energy consumption • Effluent is rich in nutrients and can be used for agricultural irrigation • Low land demand	Disadvantages: • Requires operation and maintenance by skilled personnel; • difficult to maintain proper hydraulic conditions (upflow and settling rates must be balanced) • Long start-up time to work at full capacity • Requires expert design and construction • Effluent and sludge require further treatment and/or appropriate discharge
Relative costs: • Low capital cost (specific to load) • Low operation costs	Suitability: • High strength organic industrial waste water • Where skilled technical backup is available

	• Low content of suspended solids.
Energy use: • Higher energy use (0,6 – 1,5 kWh/m3)	Pollution reduction: BOD: 75 – 90 % TSS: 60 - 80 % Ntot: 10 – 15 %

4.4. Sludge management

1 Sludge thickening



Technology description:	The thickening is the first step, often unavoidable, reduced volume of sludge removed from the waste water system. It optimizes the steps of conditioning, stabilization and dehydration by reducing the sizes of structures and operating costs. Processes used are the gravitational settling thickening (thickening static) and dynamic thickening (concentration implementing dynamic energies). Many types of technological devices: thickening ponds, sedimentation tanks, belt thickeners, decanters, etc.
Operation and Maintenance: Medium to high degree of operation and maintenance level required and highly skilled personnel required	
Advantages: • Reducing of water content in sludge • More effective handling in next technological steps (stabilization, dewatering) • Wide range of capacities for devices • Possibility to control of effluent sludge content • No electrical energy required (ponds)	Disadvantages: • Electrical energy required (centrifuges, belt presses) • Skilled personnel required • High capital costs required (centrifuges, belt presses) • Low output sludge concentration (ponds, tanks)
Relative costs: • Low - high capital cost (ponds – centrifuges) • Low - high operation costs (ponds – centrifuges)	Suitability: • With high daily sludge production (centrifuges, belt presses) • With low daily sludge production (ponds, tanks)
Energy use: • Depends on used type Low energy use (ponds, tanks) High energy use (centrifuges)	Pollution reduction: • Reduction of sludge amount 2 – 3 % ponds, tanks 3 – 8 % belt press, centrifuge

4.4. Sludge management

2. Anaerobic digestion

Technology description:	Anaerobic digestion of sludge is used for the conversion of the organic fraction of large volumes of slurries and sludge into biogas. Biogas is recovered and used either directly for heating the reactors or transformed into combined power and heat and fed into the grid. It can also be upgraded to natural gas quality. Typical substrates are excess sludge from waste water treatment plants or waste slurries from agriculture (manure) or (diary) industry. Energy crops may also be added in order to increase the gas yield. Due to increasing fuel prices and climate change, biogas generation from wastes and energy corps at large-scale is gaining interest also in developing countries.
Operation and Maintenance: High-tech expert design is required. Operation and maintenance requires a strict organisation and the continuous involvement of experts. Very high degree of operation and maintenance level required Very skilled personnel required	
Advantages: • Combined treatment of different organic waste and waste waters possible • High reduction of the volume of waste • Generation of a renewable energy (biogas) • Potential for greenhouse gas emission reduction (collection of methane; green energy production) • Remaining sludge could be used as fertiliser • Low space requirements	Disadvantages: • Experts are required for the design, construction, operation and maintenance • Reuse of produced energy (e.g. transformation into, fire/light, heat and power) needs to be established • High sensitivity of methanogenic bacteria to a large number of chemical compounds • Requires seeding (start-up can be long due to the low growth yield of anaerobic bacteria)
Relative costs: • High capital cost • High operation costs	Suitability: • Only for very high daily sewage sludge production (> 10 000 p.e.)
Energy use: • High energy use (also biogas energy production)	Pollution reduction: • Reduction of sludge amount

4.4. Sludge management	
3. Sludge dewatering	
	Technology description: Mechanical dewatering is normally associated with large waste water treatment plants and is used to separate sludge (residual sludge from waste water treatment plants or faecal sludge from on-site sanitation) into a liquid and a solid part. The principal methods are belt filter presses, centrifuges and chamber filter presses. These techniques are usually sophisticated and rarely cost-efficient for smaller systems to be implemented on community level. The process does not treat the sludge, it only separates solid from liquid parts. Both solid and liquid parts still contain pathogens and pollutants.
Operation and Maintenance: Medium to high degree of operation and maintenance level required Highly skilled personnel required	
Advantages: • Little operator skill or attention is required during the (automated) process • High operational capacity • These processes can be completely automated • Reduces volume of sludge and saves storage and transport costs • Possibility to control of effluent sludge content	Disadvantages: • This is an expensive high-tech solution for dewatering sludge and only used in large scale treatment plants • Skilled personnel required • Dosing of flocculants for effective dewatering • Needs expert design • Constant power supply needed • Both dewatered sludge and effluents are still infectious, and further treatment is necessary
Relative costs: • Very high capital cost (centrifuges) • High operation costs (energy, flocculants)	Suitability: • For high daily sludge production (centrifuges, belt presses)
Energy use: • Very high energy use	Pollution reduction: • Reduction of sludge amount (25 – 35 % TSS)

4.4. Sludge management	
4. Co-Composting (sludge + organic waste)	
	Technology description: Co-composting is the controlled aerobic degradation of organics, using more than one feedstock (faecal sludge and organic solid waste). As organic waste is normally used the organic solid waste collected from households and institutions and composted either at decentralised (community-based) or centralised composting plants. Faecal sludge has a high moisture and nitrogen content, while biodegradable solid waste is high in organic carbon and has good bulking properties (i.e., it allows air to flow and circulate). By combining the two, the benefits of each can be used to optimize the process and the product. There are two fundamental types of composting techniques: open or windrow composting, a slower process conducted outdoors with simple equipment, and the enclosed system composting, where composting is performed in a building, tank, box, container or vessel.
Operation and Maintenance: Very low degree of operation and maintenance level required No very skilled personnel required	
Advantages: • Large-scale composting reduces the amount of waste that needs to be transported to final disposal • Provides a valuable resource that can improve local agriculture and food production • Will encourage the use of organic farming and gardening, reduce the need for chemical fertilizers • A high removal of helminth eggs is possible • Low capital and operating costs • No electrical energy required	Disadvantages: • Requires a large land area (that is well located) • Long storage times • Requires professional collection and marketing of the compost • Labour intensive • Compost is too bulky to be economically transported over long distances • Lack of effective marketing of compost can result in financial losses and closure of the plant
Relative costs: • Low capital cost • Low operation costs	Suitability: • Where source of well-sorted biodegradable solid waste is available • Where agricultural production is active
Energy use: • Very low energy use	Pollution reduction: • Reduction of sludge amount

4.4. Sludge management

5. Incineration

Technology description:

Incineration of dewatered sludge from WWTPs helps to reduce the volume and the health risks of sludge. Incineration reduces the volume of the dry sludge and produces a sterile non-harmful residue that is free from toxic organic chemicals and pathogens. It provides a safe alternative solution when faced with land scarcity for waste disposal and if anaerobic digestion or composting is not an option. Moreover, it also helps to recover some of the energy used in the combustion process especially in large treatment plants whereby there is a huge quantity of sludge generation. The disposal of sewage sludge along with the incineration of household rubbish can be integrated both in newly planned plants as well as retrofitted in older plants

Operation and Maintenance:
High-tech expert design is required.
Operation and maintenance requires a strict organisation and the continuous involvement of experts.
Very high degree of operation and maintenance level required and very skilled personnel required

Advantages:

- Combined treatment of different organic waste and waste waters possible
- High reduction of the volume of waste
- Generation of a renewable energy (biogas)
- Potential for greenhouse gas emission reduction (collection of methane; green energy production)

Disadvantages:

- Experts are required for the design, construction, operation and maintenance
- Reuse of produced energy (e.g. transformation into, fire/light, heat and power) needs to be established

Relative costs:

- High capital cost
- High operation costs

Suitability:

- Only for very high daily sewage sludge production (> 100 000 p.e.)
- Sludge is contaminated with toxic compounds and can´t be used in composting systems

Energy use:

- High energy use (but also energy production)

Pollution reduction:

- Reduction of sludge amount to 10-20 %

4.5. Waste water disposal (discharge)

1. Surface water discharge

Technology description:

If there is no other more productive reuse intention the final effluents from sanitation systems that underwent a proper treatment can be discharged directly into receiving water bodies such as creeks, rivers, lakes etc. This is particularly useful in areas where water resources are heavily utilised or water scarcity in general exists. This allows recharging these surface water bodies, linked groundwater resources and thus contributes to the overall integrated management of the water resources. The use of the surface water body, whether it is for industry, recreation, spawning habitat, etc., will influence the quality and quantity of treated waste water that can be introduced without deleterious effects.

Operation and Maintenance:
Regular monitoring and sampling is important to ensure compliance with regulations and to ensure public health requirements. Depending on the recharge method, some mechanical maintenance may be required. In order to guarantee smooth operation and prevent any risk of pollution of clean aquifer, a thorough and detailed hydro geological study should be conducted before selecting the site and the method of recharge.

Advantages:

- May provide a ‘drought-proof’ water supply (from groundwater)
- May increase productivity of water bodies by maintaining constant levels
- Improves the quality of saline aquifers, facilitating the use of the water for agriculture and livestock

Disadvantages:

- Discharge of nutrients and micro-pollutants may affect natural water bodies and/or drinking
- Introduction of pollutants may have long-term impacts
- May negatively affect soil and groundwater properties

Relative costs:

- Low capital cost (depends on distance from WWTP effluent to surface water)
- Very low operation costs

Suitability:

- This is particularly useful in areas where water and groundwater resources are heavily utilized
- Where acute problems with dropping watersheds, soil salinisation, or water scarcity in general exist.

Energy use:

- Very low operation costs

Pollution reduction:

- None

4.5. Waste water disposal (discharge)

2. Groundwater discharge

Technology description:

Artificial groundwater discharge (recharge) is the planned, man-made increase of groundwater levels. By improving its natural replenishment capacities and percolation from surface waters into aquifers, the amount of groundwater available for abstraction is increased. Treated effluent and/or stormwater is discharged into aquifers either directly or after pre-treatment. This is particularly useful in areas where water and groundwater resources are heavily utilised and acute problems with dropping watersheds.

Operation and Maintenance:
Regular monitoring and sampling is important to ensure compliance with regulations and to ensure public health requirements. Depending on the recharge method, some mechanical maintenance may be required. In order to guarantee smooth operation and prevent any risk of pollution of clean aquifer, a thorough and detailed hydro geological study should be conducted before selecting the site and the method of recharge.

Advantages:
- May provide a 'drought-proof' water supply (from groundwater)
- Technology is easy to understand and operate
- Groundwater recharge collects water during wet season for use in dry season, when demand is highest
- Recharge with treated effluents improve the quality of saline aquifers, facilitating the use of the water for agriculture and livestock

Disadvantages:
- Discharge of nutrients and micro-pollutants may negatively affect the receiving soil and aquifer
- Pollutants may have long-term impacts
- Potential of groundwater contamination from injected surface water runoff, especially from agricultural fields and road surfaces
- Recharge can degrade the aquifer unless quality control of the injected water is adequate

Relative costs:
- Low capital cost (depends on distance from WWTP effluent to surface water)
- Very low operation costs

Suitability:
- This is particularly useful in areas where water and groundwater resources are heavily utilised
- Where acute problems with dropping watersheds, soil salinisation, saltwater intrusion in coastal areas or water scarcity in general exist

Energy use:
- Low energy use

Pollution reduction:
- None

4.5. Waste water disposal (discharge)

3. Land disposal

Technology description:

To reduce dependence on freshwater and maintain a constant source of water for irrigation throughout the year, waste water of varying quality can be used in agriculture. Some waste water moreover contain valuable nutrients. The concept of agricultural irrigation combined with nutrient fertilization, either by adding fertilizer to the irrigation water or by applying (partly) treated waste waters of varying quality is called fertigation. Urine, which is rich in nutrients (mainly N and P) can also be added to the irrigation water. However, only water that has had secondary treatment should be used to limit the risk of crop contamination and health risks to workers.

Operation and Maintenance:
There are two kinds of irrigation technologies appropriate for treated waste water:
1) Drip irrigation above or below ground, where the water is slowly dripped on or near the root area; and
2) Surface water irrigation where water is routed overland in a series of dug channels or furrows.
To minimize evaporation and contact with pathogens, spray irrigation should be avoided.

Advantages:
- Reduces depletion of groundwater and improves the availability of drinking water
- Reduced need for fertilizer
- Even distribution of nutrients throughout the root zone by drip irrigation
- Low risk of pathogen transmission if water is properly treated

Disadvantages:
- May require expert design and installation
- Drip irrigation is very sensitive to clogging, i.e., the water must be free from suspended solids
- Nutrient content in the used waste water might vary and difficult to predict
- Risk of soil salinization if the soil is prone to the accumulation of salts
- Social acceptance may be low in some areas

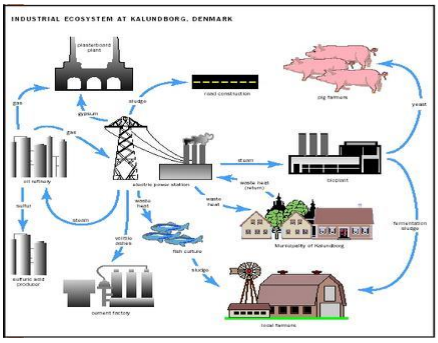
Relative costs:
- Low to moderate capital and operating costs

Suitability:
- Crops such as corn, trees, tobacco, and foods requiring processing (e.g., sugar beets) can be grown safely with treated effluent, energy crops like poplar, willow can be grown in short-rotation and harvested for biofuel production.

Energy use:
- Low energy use

Pollution reduction:
- Depends on soil quality, type of plant, etc.

5. Waste water reuse	
1. Agricultural use - Aquaculture	
	Technology description: The term aquaculture refers to the controlled cultivation of aquatic plants and animals by making use of various types of waste water as a source for nutrients and/or warm temperatures for plants and fishes to grow. In aquacultural plant production the plants are grown mainly with two different methods: ‘Hydroponics’ is where the cultivated plants are grown with plant roots directly exposed to water; and ‘Floating Plant Ponds. A floating plant pond is a modified maturation pond with floating (macrophyte) plants. Plants such as water hyacinths or duckweed float on the surface while the roots hang down into the water to uptake nutrients and filter the water that flows by.
Operation and Maintenance: Floating plants require constant harvesting. The harvested biomass can be used for small artisanal businesses, or it can be composted. Mosquito problems can develop when the plants are not regularly harvested. Depending on the amount of solids that enter the pond, it must be periodically desludged.	
Advantages: • Water hyacinth grows rapidly and is attractive • Continuous (and off-season) cultivation possible • No soil borne diseases or nematode damage, the output products of one biological system serve as input for another biological system • Hydroponics allows vertical production which minimises the production area	Disadvantages: • Requires large land (pond) area • Some plants can become invasive species if released into natural environments • For hydroponics, high management skills are required • Trained staff is required for the constant operation and maintenance of the pond.
Relative costs: • Relatively low capital costs; • Operating costs can be offset by revenue • For hydroponics, moderate to high investments are needed, which limits the production to high value crops	Suitability: • A floating plant pond is only appropriate when there is a sufficient amount of land. • Harvested hyacinths can be used as a source of fibre for rope, textiles, baskets, etc. • Hydroponics are an option in areas with poor soil quality or where agricultural land is not sufficiently available.
Energy use: • Low energy use	Pollution reduction: • High reduction of BOD and solids

5.Waste water reuse	
2. Industrial use	
	Technology description: Reusing water in industry has the potential to reduce the costs of water supply and waste water treatment by industries and reduces pressure on water resources. Waste water can be reused within a business itself, or between several businesses through industrial symbiosis. Depending on the type and quality of the waste water, it may either be reused directly, or treated before reuse (i.e. recycled).
Operation and Maintenance: Very different methods of operation and maintenance depend on type of industry, requirements on reused water, etc.	
Advantages: • Reduces the amount of water used. • Reduces water bills. • Reduces the volume of generated waste water (no waste). • Reduces costs through industrial symbiosis (by-product reuse, sharing management of utilities, sharing ancillary services).	Disadvantages: • Requires high knowledge about quality of water for reuse. • Requires financial investments. • Requires a high level of trust between industries. • Requires modification of current operations both for direct reuse and treat-and-reuse.
Relative costs: • Implementing reuse or treat-and-reuse measures requires initial investment which may be costly (depending on modifications required and technology).	Suitability: • Almost any business can incorporate measures for reuse of waste water. • While direct reuse measures may be relatively easy to implement, the cost of implementing waste water treatment systems may prohibit waste water recycling within a business.
Energy use: • Depends on applied technology	Pollution reduction: • Obviously no reduction of pollution

<table>
<tr><th colspan="2">5. Waste water reuse</th></tr>
<tr><td colspan="2">3. Environmental and recreational use</td></tr>
<tr><td></td><td>Technology description:

Environmental and Recreational Reuse refers to a variety of activities that in general enhance the overall quality of the environment where they are implemented. This can include activities such as creation or restoration of wetlands, creation of water bodies for recreational or aesthetic purposes and stream augmentation. In particular, reclaimed water's use in wetlands can be particularly important since healthy wetlands can serve many purposes including water purification, water preservation and wildlife habitats.</td></tr>
<tr><td colspan="2">Operation and Maintenance:
Very different methods of operation and maintenance depend on type of use, requirements on reused water, etc.</td></tr>
<tr><td>Advantages:
Creates pleasant atmosphere in town, in nature,
Conduces to balanced temperature in local environment
Substitutes using of potable water (fountains, small lakes)
Supports small businesses in near surround</td><td>Disadvantages:
Requires high knowledge about quality of water for reuse.
Requires financial investments.
Mosquito problem can arise
Children could drink reused water</td></tr>
<tr><td>Relative costs:
Implementing reuse or treat-and-reuse measures requires initial investment which may be costly (depending on modifications required and technology).</td><td>Suitability:
Where no water areas are available
Where low humidity is in environment</td></tr>
<tr><td>Energy use:
Depends on applied technology</td><td>Pollution reduction:
Obviously no reduction of pollution.</td></tr>
</table>

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