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Decentralised Wastewater Treatment

Centralisation or decentralisation

The need for sustainable management of water resources is growing due to increasing pollution and emerging water supply shortages. Our environment suffers from repetitive and high pollutant load due to inadequate wastewater treatment. Adequate solutions can reduce the proportion of the population that cannot access clean water and increase the efficiency of wastewater treatment. The goal of environmental sustainability is to maximise the reuse of treated wastewater and the recovery of by-products. Treatment technologies must be efficient and reliable with low investment and maintenance costs in geographies, where the centralised wastewater collection and treatment is not feasible.

Features of centralised treatment

- Wastewater collection is responsible for the 80–90% of investment costs (sewerage network cost).
- In addition to regular maintenance, the entire system needs to be reconstructed every 50–60 years, disrupting traffic and other utilities.
- Large amounts of treated wastewater as point source can cause eutrophication in the receiving water body.
- Heavy rainfall or uneven industrial discharges may result in hydraulic overload of the treatment plant.
- Diluted wastewater requires more expensive treatment.
- Accidents may disrupt the system, causing severe contamination of the receiving water body.
- In case of a full-scale treatment plant, an economically sound solution can be achieved where large agglomeration with large population density needs to be covered.
- It is highly dependent on the electricity price, which represents economic and political exposure.

Features of decentralisation

- It can be applied from the individual level up to community level.
- Suitable for suburban, rural, industrial, commercial and residential areas.
- Helps in planning the development of isolated communities.
- Local wastewater treatment solutions are suitable for isolated or dispersed settlements or where the space is limited.
- Reduces or eliminates the difficulties of treated wastewater disposal and much shorter pipelines are used compared to centralised systems.
- Small wastewater treatment plants prove to be a viable option if properly constructed and operated.
- Small wastewater treatment plants should be remotely controlled.
- The cost of decentralisation technologies increasingly competes with centralised solutions.
- Small wastewater treatment plants can provide environmental sustainability by promoting the potential reuse of treated wastewater and nutrient recovery.

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– Separation of domestic wastewater and rainwater can be solved, thus it avoids dilution.
– Separation of contaminants can be solved at the source, thus it facilitates the treatment process, the potential reuse and improves treatment efficiency and energy use.
– It is possible to eliminate the mixing of domestic wastewater with industrial wastewater.

It can be seen that both systems have advantages and disadvantages. The choice between the two systems always requires individual consideration. Legal, environmental, economic and technical aspects must all be taken into consideration.

List of these aspects:

– local conditions
– the recipient type and capacity against pollutant load
– the amount, composition and flow variation of the wastewater
– environmental and health conditions
– the efficiency achieved by the treatment system
– the amount and composition of the sludge produced and its disposal
– the technical feasibility of the investment
– investment and operating costs, available tender sources

Decentralisation of wastewater management has various levels: from an individual local system to larger clusters or semi-centralised sites.

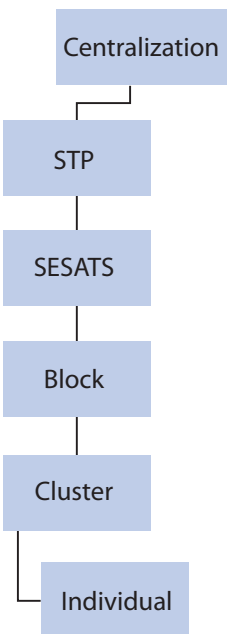

Figure 1

Transition systems between centralised and individual systems [1]

Note: STP – "Satellite treatment plant". Such a treatment plant operates independently of conventional large scale plants. Wastewater from the sewerage network is treated and the sludge, backwash and treated wastewater are returned to the network. SESATS – Semi-centralised management systems. Block – Handles wastewater from individual buildings (such as schools). Cluster – Usually 4–12 or more houses form a cluster. Individual – One home with a different treatment system.

In addition to centralised and decentralised systems, there are also hybrid solutions. In such cases, there is one central wastewater treatment plant in a given area, but decentralised solutions are also used. This can typically occur in agglomerations where wastewater discharges appear or demographic growth would result higher load in the existing centralised treatment plant. There are several reasons to consider connecting new discharges to existing systems. On the one hand, it may be necessary to re-design an existing plant, and as a result, it may need to expand it. Moreover, new pipelines to the existing sewerage network must be built. This entails significant costs and additional workload for the existing sewer system, which was also originally designed for lower capacity. In such a case, it is advisable not to fulfil the increased capacity requirement by the central plant and the sewer system, but by other solutions.

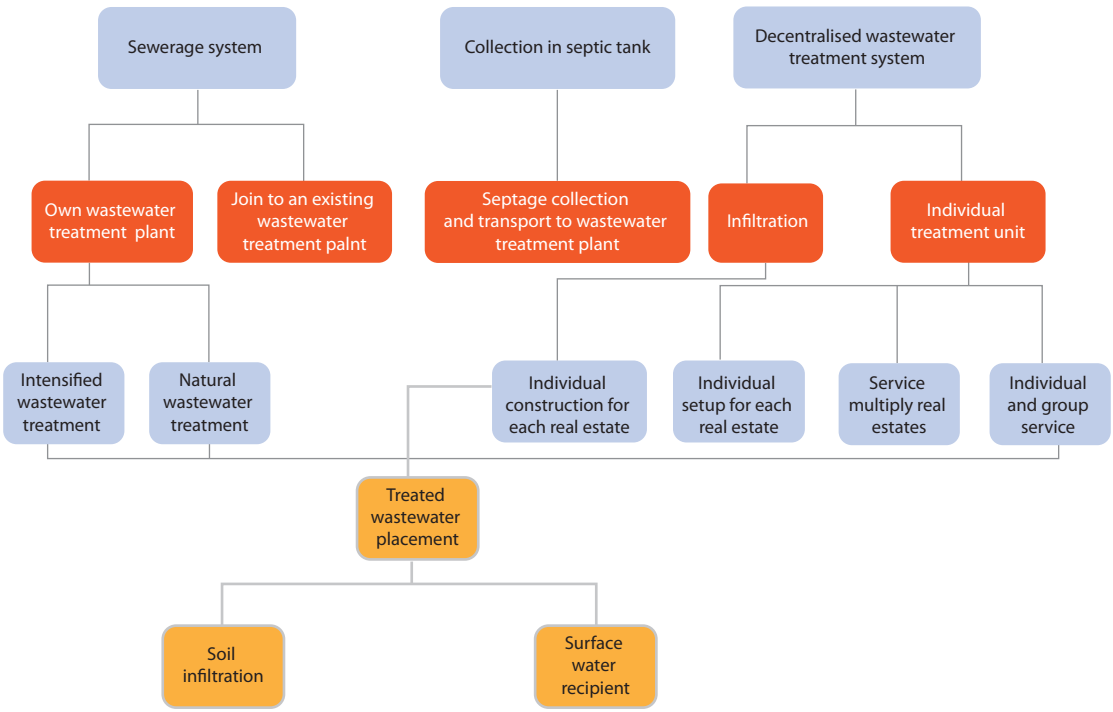

Figure 2

Wastewater treatment systems (compiled by the authors)

Decentralised wastewater treatment

Decentralised wastewater management is based on the principle of treating wastewater at the source. Wastewater should be collected in the same way, but without long pipelines, thus eliminating significant groundwork and reducing operating costs.

Generally, the design should take into account the current:

– regulations for the quality protection of surface waters
– regulation on the quality of groundwater and geological media
– regulations on emission limit values for wastewater

Although no longer in force, but Government Decree No. 174/2003 (X.28.) on the National Implementation Program for Unique Wastewater Treatment for Uncultivated Areas of Utility Drainage and Purification provided a very good classification and definition to which numerous references have been made since then. For areas where decentralised wastewater treatment is economically feasible, the regulation identifies three groups of options:

- treatment with small facilities
- use of small wastewater treatment unit
- treatment of septage (collection and disposal)

The Regulation clarifies the concepts of installations for decentralised wastewater treatment:

- *Individual wastewater treatment:* the use of individual wastewater treatment facilities, which are used for the treatment and/or final disposal or temporary collection and storage of municipal wastewater with 1 to 25 population equivalent. Depending on the environmental and water management aspects and the building density, these may include: on-site sewage facilities, individual small wastewater treatment units and closed wastewater storages. Disposal and handling of liquid, sludge and construction waste from individual wastewater treatment facilities must be carried out in accordance with a separate legislation.
- *On-site sewage facility:* A facility that reduces the environmental load of the municipal wastewater not connected to the public sewage system and disposal, but able to ensure the same degree of treatment as the large-scale wastewater treatment systems. The small wastewater disposal unit performs the decomposition of pollutants without energy input. Elements: septic tank, gravel/sand filters, which, on the whole, allow the utilisation of the residual nutrient content of the treated wastewater for the vegetation and soil in case of final release into the geological medium or harmless placement in surface waters.
- *On-site individual wastewater treatment unit:* an installation that serves for the non-utility drainage and disposal of municipal wastewater, and provides an environmental solution equivalent to the municipal wastewater drainage and treatment. The individual wastewater treatment plant carrying out the treatment of the sewage by means of energy input shall ensure the removal of the pollutants of the wastewater according to a separate legislation, recipient can be the surface water or soil.
- *Closed wastewater storage:* an installation consisting of one or more closed and watertight tanks; for the non-hazardous collection of wastewater and for the temporary storage of municipal liquid waste; the non-hazardous disposal of municipal waste collected in this area is provided after regular disposal and further treatment in accordance with specific waste management legislation.

Elements of the Hungarian regulation

Legal conditions for the application of professional individual wastewater treatment and disposal:

(1) The main rules for the application and permitting of professional individual sewage disposal are contained in the following two government decrees:
   - Government Decree 174/2003 (X.28.)
   - Government Decree 72/1996 (V.22.) on the exercise of the authority of water management authorities

(2) Pursuant to Section 2 (b) of Government Decree 174/2003 (X.28.), individual wastewater treatment is the application of individual wastewater treatment facilities (structures) that serve the treatment and/or final disposal, or temporary collection and storage of municipal wastewater corresponding to 1–25 population equivalents (persons). This may be:
   a) individual small wastewater disposal facilities (septic tank and gravel or sand filter, including built aquaculture solutions, where it is possible to utilise the residual nutrient content of treated wastewater for vegetation and soil, without energy input)
   b) individual small wastewater treatment units (mostly prefabricated small units where pollutants are decomposed by energy input)
   c) individual closed sewage tanks (closed and watertight basins for the harmless collection of sewage and the periodic storage of municipal liquid waste [septage] from sewage)

(3) Areas delimited by legislation for individual wastewater treatment:
   - settlements that are not covered by the National Municipal Sewage Drainage and Treatment Implementation Program 25/2002 (II.27.) to sewage agglomerations covered by a government decree
   - 25/2002 (II.27.) the parts of the territory of the settlements belonging to the sewerage agglomeration according to Government Decree 26/2002. (II.27.), where the establishment of sewage works is not justified on the basis of inspections according to a government decree

(4) During individual wastewater treatment and disposal, it must be ensured that the individual pollutants are removed to at least the extent that the recipient is surface water or geological medium (soil) so that their quality does not deteriorate, but rather improves. To this end, the provisions of the following legislation in force must be taken into account:
   - Government Decree 203/2001 (X.26.) on certain rules for the protection of surface water quality
   - KöM-KöViM 9/2002 (III.22.) joint decree on emission limit values for wastewater and rules for their application
   - Government Decree 33/2000 (III.17.) on certain tasks related to groundwater quality activities
   - KöM-EüM-FVM-KHVM 10/2000 (VI.2.) joint decree on limit values for the quality protection of groundwater and geological media

(5) The facility (structure) for individual sewage disposal can only be established with a separate permit from the clerk of the municipality. The involvement of environmental and water management authorities – in case of group implementation – in Government Decree 174/2003 (X.28.) on the approval of the Municipal Wastewater Treatment Program in accordance with Article 72/1996 (V.22.) is necessary according to §24 and §25 of the Government Decree.

(6) During the permitting process, the applicability of individual wastewater disposal should be considered separately with respect to sensitive and protected areas.

(7) According to Government Decree 123/1997 (VI.18.) Annex 5 on the protection of water bases, long-term water bases and water facilities for drinking water supply, the use of individual wastewater disposal (domestic wastewater filtration) in the internal and external protection zones of surface and groundwater bases is prohibited.

(8) A separate study on the applicability of individual sewage disposal is required in the following areas:
   a) in order to protect groundwater, Government Decree 33/2000 (III.17.) 2/1 in karstic areas, according to point (c) of Highly Sensitive Areas "A", where limestone, dolomite, limestone and dolomite marl formations are present on or within 10 metres above the surface
   b) in order to protect groundwater, Government Decree 33/2000 (III.17.) 2/1 in the hydrogeological protection zones A and B of operational and long-term drinking water bases, mineral and medicinal water utilisation bases according to point "d" of Highly Sensitive Areas "A" and point (c) of "B" Sensitive Areas
   c) in areas 250 metres wide from the shoreline of environmentally sensitive surface waters in accordance with Government Decree 240/2000 (XIII.23.) on the designation of surface waters sensitive to urban wastewater treatment and their catchment area
   d) in a 250 meters wide area from the shoreline of surface waters included in other protected areas in accordance with KöM-KöViM 9/2002 (III.22.) joint decree
   e) in areas with high groundwater levels (where the groundwater level is permanent – for at least 10 years above –2.0 m depth)

(9) Act LVII of 1995 on water management. Pursuant to Section 6 (4) (d) of Act No. 174/2003. Pursuant to Section 4 of the Government Decree, a Municipal Wastewater Treatment Program must be submitted in order to obtain central support. (This is not necessary to support the reference, it should be done in the first report.) It should include, inter alia:
   a) the parts of the area delimited for professional individual wastewater treatment within the settlement
   b) the types of facilities to be used and the parts of the settlement affected by each type, with justification
   c) the parts of the territory within the settlement where professional individual wastewater treatment cannot be applied
   d) local environmental requirements, main technical data and regulations for individual wastewater treatment plants
   e) development of a monitoring system (observation wells, etc.) based on scientific and technical aspects

The Municipal Wastewater Treatment Program should be based on detailed environmental assessments.

(10) Individual wastewater treatment plants are subject to a water permit (Act LVII of 1995). KHVM Resolution 18/1996 (VI.13.) Annex II on the application and annexes required for the water rights permitting procedure. Pursuant to Section 6 (i) of the EIA Decree, in case of individual wastewater drainage, the application for *water rights operation* or its annex must contain operating and maintenance instructions related to the applied technology, as well as technical and organisational data on damage preparedness and operational regulations.

(11) The removal and treatment of contaminated water, sludge and construction material waste generated during the maintenance of individual wastewater treatment facilities is regulated by Act XLIII of 2000 on waste management. Act No. 16/2002 (IV.10.) Coll., on Public Health Requirements for Municipal Solid and Liquid Waste. It must be carried out in accordance with the provisions of the EüM decree.

Government Decree 379/2015 (XIII.8.) on the List of Settlements and the Information List on the Settlement of Municipal Sewage Drainage and Treatment in Hungary, as well as on the delimitation of sewage agglomerations, states that for all settlements in Hungary, the data related to the sewage sludge – with the content according to the data provision specified in Annex 2 – shall be registered in the List of Settlements (hereinafter: List of Settlements). The notary of the agglomeration centre and the system serving the only settlement (island plant), the individual wastewater treatment plant and the individual closed wastewater storage shall send the data according to Annex 2 to the territorially competent water directorate by 30 April of the following year.

Present and future of decentralised wastewater treatment in Hungary

On 21 March 2019, a conference entitled Decentralised Wastewater Treatment was held at the Faculty of Water Sciences at the National University of Public Service, the results of which were included in recommendations by the participants, as follows.

Proposals concerning the legal, economic and wastewater strategy:

- In all cases, detailed economic and efficiency studies are required, in the framework of which the investment, subsequent operation and maintenance costs, as well as the solvency of the population must be taken into account.
- The National Municipal Drainage and Treatment Implementation Program should be reviewed and, where the program has been discontinued, an alternative solution should be proposed to continue.
- The settlements and parts of settlements where individual wastewater treatment can/should be applied instead of the traditional wastewater collection and treatment technology should be designated.
- Legislation should provide for the operation of properties provided in this way, and at the same time integrate them into the system of water utility services.
- The application system running in the Rural Development Operational Program needs to be reviewed in order to make it even more efficient and attractive for small settlements.
- The cross-sectoral and state management of the projects would be handed over to one hand and, where appropriate, to a government commissioner/ministerial commissioner by the ministry responsible for the project.
- We recommend grouping the settlements according to the average housing density, the average number of inhabitants per property and the age composition. When tendering, preference should be given to settlements that are younger and more densely populated based on their age composition, and to the provision of real estate with a larger population within the settlement. In the applicant municipalities, the municipalities also provide the number of people living on the property of the residents participating in the program.
- The application conditions for individual treatment units, small facilities and natural wastewater treatment should be regulated on a property-specific basis, taking into account that the planning unit of decentralised wastewater treatment, even in case of group-operated equipment, is the property and not the settlement.
- Each plan should include, as a comparative baseline, the estimated investment cost of sewerage. The investment and operating costs per inhabitant form the basis of comparison with the cost of decentralised wastewater treatment submitted for implementation.

- In addition to the investment cost, the application must also show the operating cost for each of the technical solutions used. Cost items should include: 1. energy costs; 2. investment and depreciation costs for transport equipment related to the collection and transport of sludge/stored wastewater to the receiving site; 3. operator wages; and 4. consumables (lyophilised bacterial culture, disinfectant, aeration membrane) replacement. Of the total costs thus incurred, the cost per inhabitant must be compared with the specific cost of the sewerage solution.
- We recommend developing a legal environment for the supervision and maintenance of built-in wastewater treatment units.

The technological solutions:

- For individual, property-by-property solutions, up to 25–30% of the uncovered surface of the property may be occupied by treatment and disposal units. (In case of a septic tank together with a spare desiccant field!) If this cannot be ensured, one of the solutions based on the separation of domestic wastewater should be used. For example, dry toilets and gray sewage dessication.
- A decentralised solution with group service (with a capacity of up to 50 PE) should be preferred to individual placement.
- In settlements with a housing density of up to 6 persons per hectare (60% of the settlements concerned belong to this category), if the number of permanent residents of the property is 1 person or 2 people are no longer of reproductive age (over 50 years), as an individual solution only soil filtration or watertight, closed wastewater storage and shaft transport can be applied for. Alternative: only black wastewater (toilet and sink water) should be fed into the tank, gray wastewater can be drained on site.
- In settlements with a housing density of less than 250 inhabitants and a maximum of 6 people/hectare, we recommend the use of a closed wastewater storage and transport to a treatment plant, with the addition that only toilet and sink water should be connected to the storage and the rest should be drained. Eligible costs must include the conversion of the internal building services outlet, without the cost of restoration work.
- In settlements with a housing density of more than 6 people/hectare, the designer must always examine the sub-areas of the settlement where small group-operated equipment can be used instead of individual cleaning. If the total cost of the ducts and small equipment leading to the equipment is not more than 20–25% higher than the total cost of the small equipment with individual placement, the group service version shall be used. (Pipes up to 150 mm can be used for the duct and the shaft/cleaning fitting on the property boundary must be fitted with a filter basket.)
- Among the requirements of the technical and professional content of the tender, it must be modified that the development must have a total capacity of at least 50 PE, regardless of the size of the settlement. In settlements with up to 500 inhabitants, it is advisable to reduce the limit to 25 PE, otherwise the original capacity can be left.
- The technical specification of small air-operated equipment must specify the ventilation with electronics that monitor its operation and send a fault signal in the event of a fault.
- In the case of septic tank-soil filtration, the technical specification should also provide for the possibility of sampling for treated effluent and the possibility of disinfection.
- The full range of technical solutions for decentralised wastewater treatment needs to be developed, with user-related advantages and disadvantages of content that can be used by municipalities, the general public and planners alike.

Decentralised Wastewater Treatment Systems (DEWATS) in developing countries

The system presented in this section is intended to summarise wastewater treatment solutions in developing countries through an integrative and system-oriented planning aid. Although it is not designed for domestic use, its approach and focus on sustainability can be an example to follow when choosing and designing any decentralised system. Water is an essential element of sustainable social and economic development. Urbanisation, industrial development and the expansion of agricultural production have a significant impact on the quantity and quality of water resources. More than half of the world's major rivers are exhausted and polluted, destroying the surrounding ecosystems, threatening the health and livelihoods of those who depend on it. It is estimated that about half of the population is exposed to contaminated water, which increases the incidence of disease; most of these people live in Africa and Asia.

At the international level, in the 1990s, a lack of development in decentralised wastewater treatment was recognised and, in response, DEWATS (Decentralised Wastewater Treatment System) was created. DEWATS systems are suitable for the treatment of both domestic and industrial wastewater with a flow rate of 1–1000 m^3/day. Such a comprehensive system can only be appropriate if it provides a reliable and efficient treatment of residential and technological wastewater in a variety of local conditions, requires short planning and execution, has medium investment costs, and has limited maintenance and operational requirements.

CBS Programmes

The program basically relies on community-based wastewater treatment, also known as CBS (Community-Based Sanitation). Each CBS must be environment-specific. The primary goal is long-term sustainability. Effective, economically sound and sustainable implementation requires the systematic involvement of stakeholder groups. The following levels can be distinguished between groups:

- primary stakeholders – residents and direct users of the intervention implemented
- secondary stakeholders – groups with direct or indirect responsibility for the program; this includes investors, planners, authorities, health and environmental institutions
- tertiary stakeholders – service providers – construction, maintenance and sludge management organisations

These programs meet the needs of people living in a particular area. In most cases, programs are targeted at people in poorer areas. As primary stakeholders, they will use the wastewater treatment plant; therefore, it must be adapted to the needs and habits that arise. In addition, they make a significant contribution to the system, whether we think of the material part of the construction, or the operation and maintenance after the construction.

The success of implementation and subsequent maintenance is based on the coordinated implementation of the work and its integration into all relevant processes. At the outset of the process, the purpose of the program should be clarified, the current situation assessed, the experience gained in similar fields gathered, the relevant stakeholder groups identified and their involvement in the project planned.

Key tasks should include:
- program management, including process monitoring
- feasibility study
- adequate information to those involved in the field, including tasks related to future operation and maintenance
- planning the construction process
- operation and maintenance tasks
- sludge management
- planning environmental monitoring

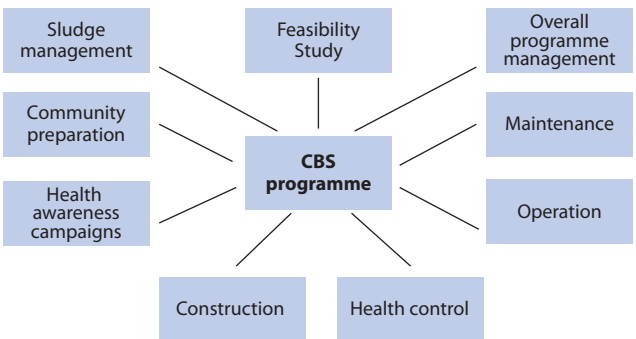

Figure 3
Main tasks of the CBS program [2]

Technological configurations of DEWATS modules

DEWATS is a modular approach to efficient wastewater treatment. The approach combines the experience of centralised and decentralised wastewater management systems, thus contributing to addressing the growing need for decentralised wastewater treatment. Not only is it a technology package, but it also includes an approach in addition to technical and engineering approaches, taking into account the local economic and social situation. It can handle both domestic and industrial wastewater, providing first, second and third treatment grades as required. In addition, the system should be considered a part of a comprehensive wastewater treatment strategy. The technology is also capable of providing a renewable source of energy through the appropriate choice of modules by utilising the resulting sewage sludge. Its purpose is to minimise external energy input during operation. The modular concept enables optimal planning based on efficiency requirements, costs and available space. The DEWATS criterion is to install units that meet a high quality standard, with construction and design by specialist chambers, thereby ensuring that wastewater treatment systems meet regulatory criteria.

Technological configuration of a typical DEWATS system in a modular system:
- primary treatment – in sedimentation ponds, sedimentation tanks, septic tanks
- secondary treatment – in anaerobic reactors, in anaerobic filters or in anaerobic or facultative pond systems
- Secondary Aerobic/Facultative Treatment – Horizontal Gravel Filters
- post-treatment – further treatment in aerobic lakes

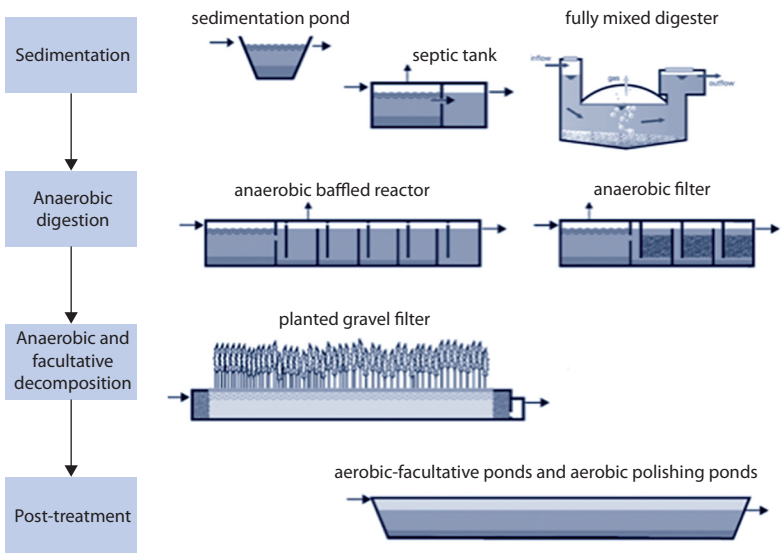

Figure 4
DEWATS Configuration Scheme [2]

When choosing the appropriate technological configuration, consider the following:

- wastewater discharge
- wastewater quality
- temperature
- soil, groundwater conditions
- available space
- costs
- legal background
- treated wastewater disposal
- social conditions

Laboratory analysis is required to determine the quantity and quality of the pollutant incoming, to determine the feasibility of treatment, to determine the impact on the environment and to determine whether the wastewater is suitable for biogas production. Because the quality of used water is constantly changing over time (e.g. seasonal variation), the analysis is never complete. Understanding the importance of each parameter during design is more important than knowing the exact formulas. In general, a design accuracy of ± 10% is sufficient for these systems with preliminary calculation of the runoff quality.

DEWATS employs the above-mentioned natural biological and physical treatments to reduce and eliminate contaminants in wastewater. Avoids the use of external power sources, chemical dosing, and the use of movable components to minimise potential malfunctions during maintenance and operation. A series of treatment units are used to meet the boundary conditions specific to various natural treatment processes and to ensure efficient operation. The stability of the system is ensured, by removing, at each treatment step, only the pollutants specified for that step.

In DEWATS, it is often easiest to provide longer retention times, so that slower microorganisms "find" their nutrients after the faster ones have undergone the necessary degradation.

DEWATS technologies respond relatively flexibly to incoming wastewater and environmental conditions. However, improper operation, improper maintenance or structural defects can cause problems. A malfunctioning system poses risks to both the environment and human health. It is important to address emerging local issues so that they do not pose a threat to the overall system over time. Accordingly, the DEWATS system also needs operator personnel who are able to measure the symptoms of malfunctions at an early stage, identify the causes of the problems, and take appropriate action to restore the system.

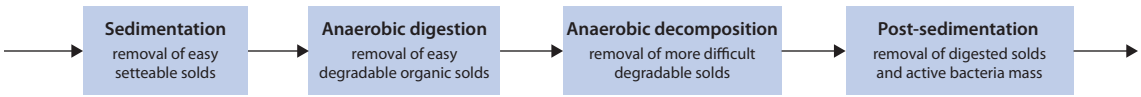

Figure 5
Multiple steps required for complete treatment [2]

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Questions

1. Compare the features of centralised and decentralised wastewater treatment!
2. Define the satellite treatment systems!
3. Define the term of individual wastewater treatment!
4. What conditions shall be met in order to apply individual wastewater treatment units?
5. What type of permission is needed for the operation of an individual wastewater treatment system?
6. What does the CBS program cover?
7. What are the unit processes of the individual wastewater treatment?