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Small Wastewater Treatment Systems, Sewage Disposal Facilities

Legal background of construction and operation of small wastewater treatment plants

Legislative progress of wastewater treatment and disposal

The first Water Law and its Implementing Regulation, with a dedicated chapter on quantitative and qualitative protection of waters, were entered into force after the war, in 1964. The law specified obligations for the establishment and operation of wastewater treatment system only in connection with facilities, possibly excluding wastewater treatment plants (WWTP). To penalise the pollution of recipients, including groundwater, wastewater penalty was signed into law, essentially for factory wastewater discharges. It was based on the amount of pollutants discharged, while taking into account the effect of wastewater on the quality and self-purification of the recipient in determining the amount of fines.

The limit values for pollution and the level of fines were specified with a delay of five years by a legislation in 1969, last amended in 1978. The National Water Association published Regulation 1/1973, then the National Water Management Code, a collection of minimum requirements for water management activities, as amended by Decree No. 4/1981, which was repealed in 2008. The Code stated that the amount and quality of treated wastewater to be introduced into the recipient should be determined on the basis of the recipient's load capacity. As a precondition for draining purified wastewater, the soil should be suitable for drainage; the use of groundwater should not be restricted by drainage and should not adversely affect the groundwater body.

Based on the load capacity of the recipients, since 1978 the country has been classified into six water quality protection categories (I–VI). Priority water quality protection areas (I–V) include Lake Balaton as a priority, drinking water sources and recreational areas (II), industrial areas (III), irrigation water sources (IV), non-priority segments of the Danube and Tisza (V). The other areas were classified into the non-priority (VI) category. For each category, various limits have been set for a total of thirty pollutants. The pollutant list contains COD (not BOD) as the aggregate parameter for organic pollutants, pollutants causing eutrophication including ammonium, nitrate and total phosphorus, as well as toxic substances, i.e. cyanides and ten heavy metals.

New concepts and principles have been introduced in Act No. LIII of 1995 on the General Rules of Environmental Protection, e.g. the environmental fee system.

New concepts introduced in the Act on Wastewater Treatment are the following:

- environmental load: the direct or indirect release of a substance or energy into the environment
- requisition limit: the use of the environment or its element above a level defined in law or in official decisions which, if exceeded may cause environmental damage, according to current scientific knowledge

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– best available techniques: a state-of-the-art technology and sustainable development method, operating procedure, equipment to prevent emissions, where this is not feasible, to reduce environmental impact, as well as to mitigate the impact on the environment as a whole, and serves as the basis for establishing limit values or the level of emission

In the same year, the Water Management Act came into force, replacing the Water Law of 30 years. The law was created, among others, in compliance with EU Council Directive 91/271/EEC. The law already used the term "on-site wastewater treatment" for the collection of wastewater that is not discharged into a recipient after wastewater treatment, and declared the need for an On-site Wastewater Treatment National Implementation Program concerning areas that cannot be economically equipped with public utility sewerage system and treatment plant.

Since 2000, to reduce pollutant loads affecting surface water quality, eutrophic surface waters or those vulnerable to eutrophication have been designated as "sensitive surface waters", i.e. Lake Balaton, Lake Velence and Lake Fertő [Government Decree 240/2000 (XII.23.)]. From the same year until 2008, legislation on activities that affect the quality of groundwater and geological formations were in force [Government Decree 33/2000 (III.17.)], that, among others, defined several new concepts, e.g. hazardous material, which is "a substance derived from human activities which, when entering the geological environment or groundwater, it presents a risk to the environment, human health, and environmental use due to its toxic, carcinogenic, teratogenic, mutagenic, bioaccumulative or other adverse effects".

The previous immission approach, taking into account the condition and the capacity of the recipients, has changed since 2001 and the emission-based water protection has been promoted. For the protection of surface waters – in order to comply with the European Union Wastewater Treatment Directive (91/271/EEC) – materials from technologies have been categorised according to their hazard. Depending on the hazard, first the release of certain substances from the technology was prohibited by law [Government Decree 203/2001 (X.26.)], secondly, it required the reduction of emissions of certain substances, and, thirdly, it set technological limits for a significant number of substances that could be discharged into surface water and authorised the water authority to establish a catchment specific limit depending on the susceptibility of the recipient.

Government Decree 174/2003 (X.28.) withdrawn in 2010 defined several concepts in its On-site Wastewater Treatment National Implementation Program concerning areas that cannot be economically equipped with public utility sewerage system and treatment plant:

The law defined the on-site wastewater treatment system (OWTS) within the framework of non-public utility services as the use of installations for "municipal wastewater treatment and/or final disposal, or for temporary collection and storage" if their capacity is equivalent to 1–25 population equivalent (PE).

Such installations include:

a) conventional on-site systems

b) small wastewater treatment units

c) closed sewage storage tanks

Of the three installations, the first two had a common feature of "providing environmental protection and quality of life equivalent to public wastewater drainage and treatment", but the septic tank performs pollutants degradation without energy input, while the on-site wastewater treatment system requires energy input. The legislation also defined conventional on-site systems: the septic tank and soil absorption system.

In the evolution of the emission approach in water protection, as a next step the legislator also set limit values for wastewater treatment as a process related to emission activity in the form of BOD_5, COD, TSS, TN and TP parameters. The main principle for establishing limit values was that smaller capacity units had to meet higher, while larger capacity units had to meet lower limits [Decree 28/2004 (XII.25.) of the Ministry of Environment and Water].

Emission limit values for on-site wastewater treatment plants have only been established from the end of 2012 [Decree 30/2008 (XII.31.) of the Ministry of Environment and Water).

Current legal status of wastewater treatment and disposal

Act No. LVII/1995 on water management assigned the arrangement of collection, disposal and collection control of non-sewage wastewater, i.e. collected by other means, to the municipal council's public services. As a general principle, wastewater that has not been discharged into the sewage system must be treated and then either discharged into a receiving body or collected and handed over to a public utility authorised for collection. The same applies to the disposal of sludge from OWTS.

The law defines "public water facility" as a "water utility service". The term "self-contained water facility" is used for non-utility services including the collection, treatment, utilisation and disposal of wastewater not constituting a public water facility.

For the protection of surface waters and to comply with various European Council directives, Decree 28/2004 (XII.25.) of the Ministry of Environment and Water has been in force since 2004. With regard to water protection, the legislation has introduced a triple limit system for purified wastewater, similarly to the principles of preventive regulation, combining the emission and immission approach. Emission of pollutants and emissions from various activities, including household and municipal operations, are subject to technological limits. From the point of view of the protection of the recipients, regarding the reception and immission of water pollutants, local limits must be adhered depending on the water quality protection categories. As a third element of protection, the water authority can set specific limits for specific water protection.

If the treated wastewater is discharged into surface water, wastewater treatment plants with a capacity of less than 2,000 PE must comply with the technological emission limits given in the table below. There is no limit for phosphorus and nitrogen in this equipment size, in most cases, individual limits can be set for these installations.

In case of sewage disposal agglomerations with less than 2,000 PE and surface water recipient, limit values in Table 1 apply to the quality of water discharged after treatment in:

- semi-natural wastewater treatment
- wastewater treatment at small wastewater treatment plants
- wastewater treatment with on-site wastewater treatment systems

However, the same legislation completely exempted individual wastewater discharges from the scope of the above legislation.

Table 1
Technological emission limit values for surface water recipient (compiled by the author)

Load capacity (PE)	Limit values for pollutant components[I] given in concentration (mg/l) or minimum removal efficiency (%)									
	Dichromate oxygen demand (COD_k)[III]		Biochemical Oxygen Demand[II, III] (BOD_5)		Total suspended solids (TSS)[III] From May 1 until November 15 From November 16 until April 30		Total Phosphorus (TP)		Total Nitrogen (TN)	
	as mg/l	%	as mg/l	%	as mg/l	%	as mg/l	%	as mg/l	as mg/l
< 600	300	70	80	75	100	–	–(4)	–(4)	–(4)	–(4)
601–2,000	200	75	50	80	75	–	–(4)	–(4)	–(4)	–(4)

Note: [I] Of the limit value given in concentration (daily average value) and the limit value based on removal efficiency, only one of the criteria specified in the permit shall be met. The percentage reduction should be interpreted in relation to the concentration of raw wastewater influent. [II] BOD can be replaced by another parameter: total organic carbon (TOC) or total oxygen demand (TOD) if correlation can be established between BOD_5 and the substitution parameter. [III] Water samples taken after wetland treatment of wastewater – COD_k, for BOD_5 components – should be filtered prior to water quality testing, but the total suspended solids content of unfiltered water should not exceed 150 mg/l. [IV] The authority may set a specific limit in the interest of water protection.

According to this legislation, near-surface wastewater treatment plants cannot be installed in areas belonging to the 1st and 2nd water quality protection categories, while in nitrate sensitive areas they can be installed with a special permission from the authority.

Important concepts, establishment and operational conditions regarding decentralised wastewater treatment are included in Government Decree 147/2010 (IV.29.) on the actions and installations for the usage and protection of water and water damage prevention. The law replaced the former concept of on-site sewage facilities and on-site small wastewater treatment systems and provided a legal definition of known terms:

- *on-site wastewater treatment* is the treatment, disposal and even temporary collection and storage of municipal wastewater equivalent to 1–50 PE of wastewater load
- *on-site small wastewater treatment unit* is a water facility that performs non-utility, biological treatment of urban wastewater with the input of energy
- *semi-natural wastewater treatment* is a biological wastewater treatment process whereby pollutant degradation is performed by aerobic or anaerobic microorganisms attached to the substrate, sand, gravel and to the roots of plants as well as wetland solutions
- *septic tank equipped with a soil absorption system* is a treatment facility consisting of a septic tank and a septic drain field for non-utility drainage; disposal of municipal wastewater and pollutants degradation is performed without energy input

The law sets a quantitative limit for the establishment of septic tanks with soil absorption system and for on-site wastewater treatment units if the recipient of the treated wastewater is a geological formation. Such facilities can only be installed above 500 m^3/d effluent. This amount is approximately 1.37 m^3/d, i.e. approximately the average of the wastewater discharge of 10 inhabitants. Thus, according to the legislation, in the case of an emission lower than that, treated wastewater could only be discharged into a surface water recipient or could be collected and transported on axis, or a semi-natural wastewater treatment technology should be used. According to the same legislation, “depending on the amount of wastewater, efforts should be made to apply semi-natural wastewater treatment solutions”. As a conclusion, below 8–10 people (about the same PE, LE) the legislator aims to prioritise the installation of semi-natural treatment systems.

From the end of 2012, the legislation [Government Decree 30/2008 (XII.31.)] set limit values depending on whether the effluent from on-site wastewater treatment facility was discharged into surface water or into the soil. This legislation can also be interpreted to mean that in case of a surface water recipient the situation has become more complex with regards to discharges from decentralised wastewater treatment plants, while it is very unlikely that this was the intention of the legislation.

Table 2

Limit values for treated wastewater from on-site wastewater treatment unit (compiled by the author)

Pollutants	Limit (mg/l) when discharged into surface water
Dichromate oxygen depletion COD_k	150
Ammonium nitrogen NH_4-N	40

Table 3

Limit values for treated wastewater from a septic system when discharged into geological formation (compiled by the author)

Pollutants	Type of sampling	Limit values for groundwater when wastewater is discharged into geological formation	
		In an area with highly sensitive groundwater and high water table as mg/l	In a non-sensitive area[1] as mg/l
Dichromate Oxygen Consumption COD	qualified point pattern	–	150
	24 hour average sample	75	100
Ammonium nitrogen NH_4-N	qualified point pattern	–	–
	24 hour average sample	10	–
All inorganic nitrogen TN_{inorg}	qualified point pattern	–	–
	24 hour average sample	25	–

Note: [1] The type of sampling may be specified in the alternative, both should not be used together.

According to the legislation, in areas of high sensitivity groundwater or with high water table, only on-site wastewater treatment unit achieving denitrification can be installed.

On-site wastewater treatment installation can be programmatic, if the settlement adopts a program for decentralised wastewater treatment in a wastewater treatment agglomeration and delimits part of the settlements where it will be implemented in place of a public sewer. In case of a programmatic installation, a monitoring system must be established and operated in the affected area [Government Decree 147/2010 (IV.29.)].

The authorisation of the installation, operation, existence and disposal of decentralised wastewater treatment plants depends on the amount of annual wastewater discharges. The licensing authority, if the discharge does not exceed 500 m/year, is the notary of the settlement, in other cases the water authority of first instance [Government Decree 72/1996 (V.22.)].

German legislations on small equipment

The installation, operation and maintenance of small equipment can be carried out in accordance with the German Water Management Act (Wasserhaushaltsgesetz), taking into account requirements for treatment and disposal of wastewater. As a general principle, the amount and contamination of treated wastewater into surface water should be maintained at a level that can be achieved by the best available techniques. In addition to the concepts, the Wastewater Decree (Abwasserverordnung) also establishes the requirements that can be achieved by the best available techniques. In case of surface water, the decree classifies wastewater treatment plants into 5 classes, depending on BOD_5 load. Small equipment with a capacity of up to 8 m^3/d fall into the category of wastewater treatment plants with a capacity of less than 60 kg/d (i.e. 1,000 PE equivalent), therefore their emission limit values are also the same, i.e. 150 mg/l COD and 40 mg/l BOD_5. If the additional load caused by the discharge would be unfavourable, more stringent requirements should be imposed and discharge from small equipment at particularly sensitive parts of a watercourse may be prohibited.

In areas with decentralised wastewater treatment, the property owner should treat the domestic wastewater generated on the property with small equipment. The obligation to dispose sludge produced in small equipment and in septic tanks is generally in the hands of local governments, according to provincial legislations.

In the framework of decentralised wastewater treatment and disposal, only biological small sewage treatment systems can be installed. Old equipment could be transformed into a biological treatment system by a date set by provincial legislators.

For quality requirements of treated wastewater, federal states may enact legislation for displacement in soil.

These are mostly:

BOD_5	25 mg/l
COD	90 mg/l
TOC	max. 30 mg/l
30 minutes sedimentation	0.3 ml/l
NH_4-N (above 12°C)	max. 10 mg/l

Special requirements apply to ready-made sewage treatment plants. Since 2005, in order to obtain a marketing authorisation from the Deutsche Institut für Bautechnik (German Institute of Building Technology), small wastewater treatment plants are classified into five classes (see Table 4). All equipment must be suitable for the decomposition of organic matter. Class C treatment equipment must only comply with COD and BOD limit values. If criteria for recipient requires, equipment suitable for reducing nitrogen or phosphorus may be used (Classes N and D). Equipment with phosphorus removal technology is rated as class +P, and equipment for reducing fecal coliforms is +H.

Equipment that fulfils tertiary treatment requirements is generally prefabricated construction and must be approved by the Institute. In addition, their technological emissions must be verified by a test performed under operating conditions for a year.

The Swiss Association of Water Management (VSA) has issued guidelines for wastewater discharges of aerobic small equipment below 200 PE. Although they are less sophisticated than German regulations, they set stricter requirements for some discharge parameters.

Table 4

Emission requirements for different classes of equipment (compiled by the author)

$40^{I}/25^{II}$ 75^{I}Class	COD as mg/l	(BOD_5) as mg/l	NH_4-N as mg/l	N_{anorg} as mg/l	P as mg/l	fecal coliforms i/100 ml	TSS as mg/l
$N150^{I}/100^{II}$ C	$90^{I}/75^{II}$	$20^{I}/15^{II}$	10^{II}				50^{I}
D	$90^{I}/75^{II}$	$20^{I}/15^{II}$	10^{II}	25^{II}			50^{I}
+P					2^{II}		
+H						100^{II}	

Note: ^{I} From qualified point sample, simple point sample for fecal coliform. ^{II} 24-hour composite sample; NH_4-N and N_{anorg} $T \geq 12°C$ wastewater temperature.

Table 5

Aerobic small equipment discharge guideline values (VSA) (compiled by the author)

Parameter	Small equipment without nitrification	Nitrification equipment
TSS (mg/l)	30	20
BOD5 (mg/l)	30	20
COD	90	60
DOC (mg/l)	20	10
Visual acuity (Snellen) (cm)	> 30	> 30
NH_4-N (mg/l)	–	3
TP (mg/l)	–	–

Small equipment standards, technical specifications, guidelines

The domestic standardisation technical directive and the professional practice are traditionally consistent with the German (German–Austrian) approach, often following it. The first standard for domestic wastewater treatment equipment in Germany was published in 1942. The standard could rather be used as a guide and described sizing rules for treatment units. Domestic WWTS meant a simple settler, or a septic tank suitable for long-term sewage storage and digestion, subsoil irrigation, trickling filter and infiltration shaft. For sizing 150 l/person/day "normative" wastewater emissions were included in the standard. A small equipment in the post-war standard meant treatment units capable of serving up to 500 inhabitants.

In the title of the 1970 edition of the DIN 4261-1 standard, a clarification of "equipment without wastewater aeration" appeared, indicating, on the one hand, it was time for the introduction of aeration technology into small equipment as well, and on the other hand an upcoming new standard. The standard (DIN 4261-2) was indeed published, although, only after 14 years.

In 1952, the Ministry of Construction issued a mandatory sewer design and sizing regulation for domestic wastewater treatment equipment as a technical specification, clearly based on the German regulatory model that had already been accepted among Hungarian professionals. The regulation dealt with small appliances for domestic wastewater treatment and has not yet used the term small equipment or other related generic term. By the term of mechanical treatment appliances, the regulation meant two, or three-chamber engineering structures and the two-tier settler. Biological digesters meant an expanded septic tank, the infiltration shaft and the trickling filter. The regulation defined minimal editing rules for engineering structure design and also provided sample drawings. For the treated wastewater to be suitable to be discharged into surface water recipient, depending on the type of equipment, the regulation defined various guideline values (500–100-fold), in case of biological treatment with "post-settler" a 50-fold dilution was defined. With regards to discharge into soil, infiltration can only be planned if there is at least 1 m difference between the lower plane of drainage and the water table. At the same time, it also mentioned the "infiltration wells" as the equipment for the disposal of biologically treated wastewater into "deeper soil layers", though with the comment that it cannot result in dangerous groundwater contamination.

In 1962, the MSZ 15302 standard "Sewer Design and Sizing – Wastewater Treatment" related to small domestic wastewater treatment equipment still referred to the previous regulation. The object of the standard is the engineering structure of soil absorption systems, their sizing and design, as well as the rules of their placement. According to the standard, the soil filter meant a disposal on an agricultural area. The concept of "oxidising power" of soil appears in the standard for the first (and last) time, which provides the basis for sizing the filter along with permeability. For the BOD_5 to be removed by the sand filter, the values for the oxidation capacity expressed in g O_2/m^2 and the emission expressed in m^3/d.ha for various soils the following values are included:

Table 6

Oxidising capacity and load capacity of different soils (compiled by the author)

	Oxidising potential g/m²	**Load m³/d.ha**
Sand	4–8	100–300
Sludge	2–4	50–100
Cob	1–2	25–50
Clay	0.5–1.0	15–25

The standard provided methods for discharging treated wastewater into recipients, and methods for calculating the load-bearing capacity based on oxygen consumption measurement, furthermore, as a simplification for treatment technologies, various dilution rates and estimation methods were provided.

In 1971, the National Water Agency issued sector-specific technical guidelines related to domestic wastewater treatment structures for the design and technical solution of septic tanks, two-tier settlers, biological trickling filters and sand filters. Sand filter was considered an alternative to septic tank. The concept of "population equivalence" (PE) appeared in the directive, but in terms of discharge (1 PE = 100 l/person). If wastewater was biologically treated (for example, by a sand filter after septic tank), lakes with at least 10 m^2/PE water surface were also considered suitable recipients if their load capacity otherwise allowed it.

In 1976, the Construction Sector Standard entitled *Wastewater Treatment and Design Requirements for Wastewater Treatment Facilities* came into force, in which a separate section was dedicated for small wastewater treatment equipment with a capacity of up to 1,250 m^3/d, they were denominated as domestic wastewater treatment equipment with $Q_{dmax} \leq 15$ m^3/d, compact wastewater treatment equipment with 3–75 m^3/d, and small wastewater treatment equipment with 75–1,250 m^3/d. Soil absorption is once again emerging in the standard, now combined with high-speed filters and micro drum filters in the physical post-treatment category. Soil oxidation capacity previously used for sizing the soil filter has been removed from the standard, while the guideline values of load capacity have increased significantly compared to the previous standard: for sandy soil 400–1,200 m^3/d.ha, for silty soil 200–400 m^3/d.ha. There are no guiding values for impermeable soils, but the load capacity for drained sand filter appears as 4,000 m^3/ha.d. The concepts of biological treatment, equipment with complete oxidation technology and immersed disc structures have appeared in the standard. In connection with these, as a criterion for biologically treated wastewater, 25 mg/l BOI_5 concentration should be applied.

As part of the Municipal Wastewater Treatment Plants' technical directive series, in 1984 a separate edition was published for septic systems, which is a revision of the previous sectoral technical directive. The directive defined an upper limit of 75 m^3/d for small structures and small appliances treating domestic wastewater. The subjects of the directive were essentially the simple and extended septic tanks as well as the sizing and design of drainage and sand filter trenches, with only a faint reference to manufactured small wastewater treatment units already applied.

The Hungarian Standards Institution issued a standard in 2000 entitled *Municipal Wastewater Treatment Plants. Small Wastewater Treatment Structures and Small Appliances,* which is also in force at the time of writing this manuscript. The scope of the standard is the treatment of domestic wastewater not exceeding 75 m^3/d. In the standard the (simple) septic tank and extended septic tank are listed as pretreatment structures, together with the grease traps. Although the world "biological" does not precede the heading of *Treatment of Wastewater,* the chapter deals with biological treatment methods, indicating that the content of suspended solids, the amount of dissolved pollutants should be reduced and the anaerobic nature of wastewater must be eliminated. Among biological treatment technologies, sand filter trenches and fields are discussed among conventional treatment processes. The standard describes the place of application of activated sludge, trickling filter and immersed disc equipment, but their sizing and design features are not discussed. The standard mentions "natural technologies", essentially meaning root zone and lake treatment. Root zone technology is described as a "closed-loop" technology; cassette and lake treatment technologies are considered applicable only at higher loads. Soil drainage structures appeared in the spirit of previous technical publications. Regarding the so-called drainage coefficient, it can be considered a significant change that is based on the drainage capacity of the soil recipient; less favourable soils were also designated as applicable. (The drainage coefficient is the water-absorbing capacity of the soil as determined by an on-site drainage test.)

Table 7
Changes in the infiltration factor in the former Hungarian technical regulatory publications (compiled by the author)

Drainage factor min/cm	OVHMI 146/7-71	MI 10-127/9-84	MSZ 15287: 2000
	Infiltration surface needed for 1 m^3/d wastewater m^2		
Up to 1	14	14–15	14–15
1–2	18	16–17	16–17
2–4	25	18–26	18–26
4–12	28 (4–6 min/cm) 37 (6–12 min/cm)	Avoid if possible	27–39
Above 12	45 (12–18 min/cm) 50 (18–24 min/cm) Not suitable for drainage (> 24 min/cm)>		Avoid if possible

According to the standard, only biologically treated wastewater can be discharged into surface water.

Since 2000, we have introduced the EU standards for small equipment in Hungary. The process lasted until 2013, when the last standard was released, while the already published pages have changed several times.

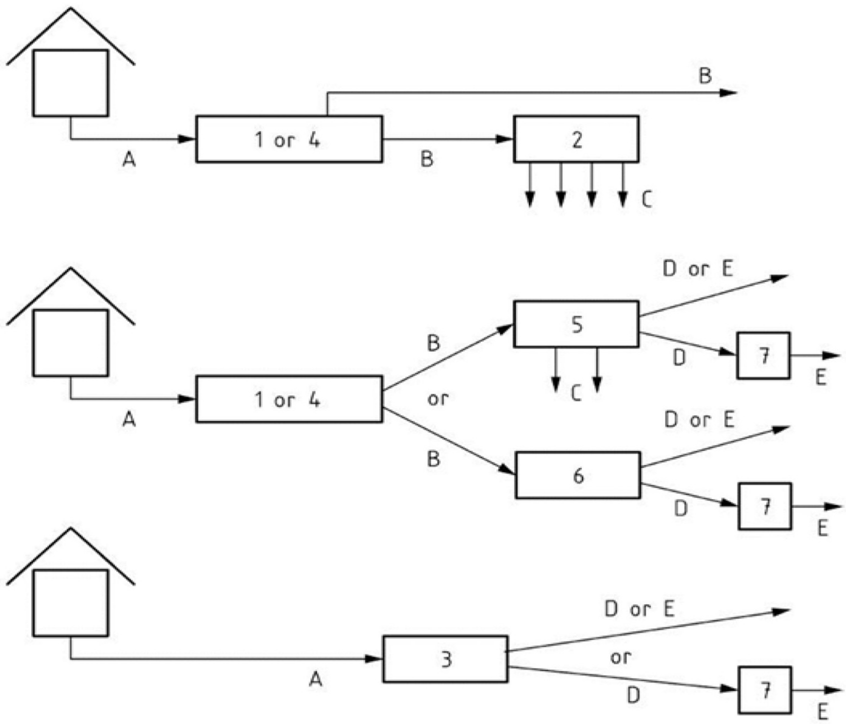
The EU-harmonised standard entitled *Wastewater Treatment Systems up to 50 Total Population Equivalent,* consists of five parts:

Part 1: Prefabricated septic tanks
Part 3: Ready-made and/or site-assembled domestic wastewater treatment units
Part 4: Septic tanks assembled on-site from prefabricated elements
Part 6: Prefabricated treatment units for septic tank effluents
Part 7: Prefabricated, tertiary treatment units

They appeared as MSZ (Hungarian Standard) EN, but they are in English. As their translations – like many other standards – have not been performed, many engineers and lawyers question their legal relevance, especially because English is not an official language in Hungary.

The standard series contains requirements for testing of small appliances that are prefabricated or assembled on site using prefabricated elements. Tests required are aimed at permeability, structural-dynamic features, durability, fire resistance, hazardous material compliance and control of operational efficiency. In the case of septic tanks, the standard requires a test of "hydraulic efficiency", i.e. testing sedimentation efficiency. Appendix B of the third section of the standard series deals with the conditions for testing the technological operation of small appliances prefabricated or assembled on-site using prefabricated elements. The standard describes in detail the criteria for selecting test sites, lower and upper limits of wastewater quality parameters discharged into the equipment, the duration of the tests at various loads (nominal as well as upper and lower load limits), the daily schedule of wastewater feed, sampling methods and number, and the parameters to be tested. It also deals with peak loads as special operating conditions, such as a 24-hour power failure at nominal load, at a load analogous to a single or multiple bathtubs draining, as well as under conditions without load.

Conformity of the product with the standard is certified by the manufacturer with a CE certificate, which contains the following information: name of the manufacturer, year of CE conformity, the mark of the relevant standard, general product characteristics, and data related to cleaning efficiency, size and capacity, water tightness, stability, durability, and resistance to fire and hazardous materials.



Explanation of Symbols

A domestic sewage
B Sewage from septic tank
C desiccation of treated wastewater
D Treated wastewater
E tertiary treatment of wastewater

1. Pre-fabricated septic tank
2. Soil absorption system
3. Prefabricated and / or on - site assembly of domestic sewage treatment plants
4. On - site septic tank of prefabricated elements
5. Soil absorption system for pre-treated domestic sewage
6. Prefabricated treatment units for effluent from septic tank
7. Prefabricated tertiary tretament units

Figure 1
Application Scheme for EN 12566 series (compiled by the author)

CE

9876

Any Co Ltd, P.O. Box 21, B-1050

16

0012014-09-30

EN 12566-6:2016

Prefabricated treatment units for septic tank effluent

— - Product's reference code: "BWV 41"

— - Material: CONCRETE

To be used outside buildings for septic tank effluent

Effectiveness of treatment:

Treatment efficiency (at tested organic daily load BOD_5 = 0,9 kg/d)	COD: 80 %
	BOD_5: 80 % SS: 70 % P NPD KN NPD
Number of desludging during CE test	0
Power consumption	0,2 kWh/d
Microorganism reduction	E. Coli: 1 000 cfu/100 ml 2 log unit Intestinal enterococci: 1 000 cf/100 ml 1,5 log unit
Treatment capacity (nominal designation):	4 PT
Watertightness: (water test)	Pass

Crushing resistance:

Load bearing capacity	Height of backfill 0,5 m WET 1,20 m

Figure 2
Example of CE conformity certificate (compiled by the author)

The numbering of the parts of the standard shows that there are holes in the system. The Standing Committee has published two documents for filling the gaps, one for soil drainage systems (Part 2) and one for filtration systems of pretreated sewage (Part 5), which can be considered a Code of Practices.

Screens

There is no separate screen function unit installed in small equipment. Materials that are removed from the grid in larger municipal wastewater treatment plants are deposited in the sludge or slurry in the sedimentation unit in small equipment and are discharged together with sewage sludge. For small wastewater treatment plants of more than 50 PE, a separate screen unit as well as design and operation of the screen should be considered.

With today's technical capabilities and operational attitudes, it is indisputable that there is a rationale for mechanical screens in installations with a capacity of 50–500 PE near the upper limit. It is practical to choose a mechanical screen that is compact and suitable for dewatering and compacting the mesh. Near the lower capacity limit, simpler basket screens or manual coarse screens could also be considered.

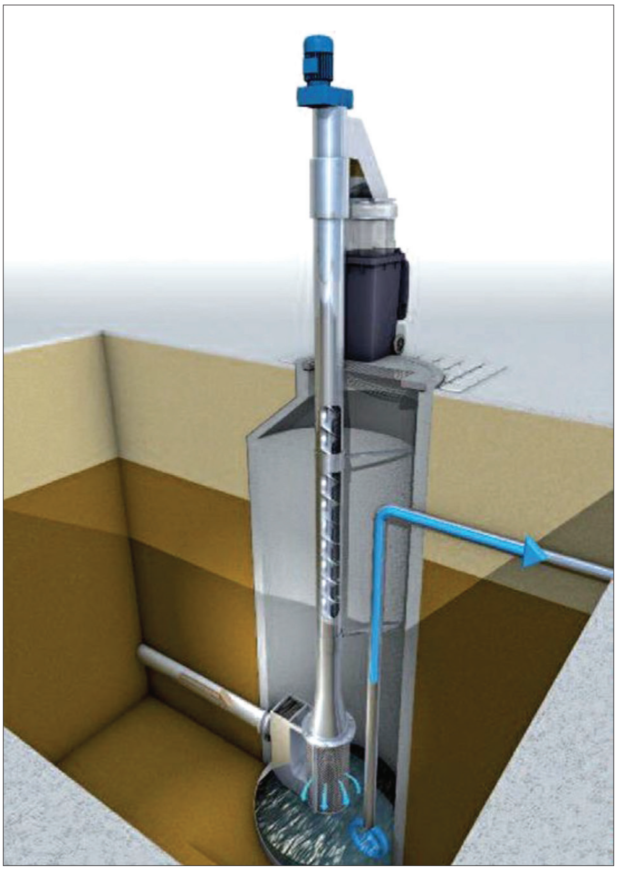


Figure 3
Fine screens installed into shafts (Huber) (compiled by the author)

Floating oil skimmers

Floating skimmers are designed to remove fats, oils, waxes, soap, free fatty acids, wood and cork pieces, vegetable oil, etc. Such materials come in larger quantities from kitchens and restaurants.

The floating structure must be designed to allow lighter materials to float to the surface, and deposits to settle on the bottom, while wastewater should be drained from above the bottom sludge space or below the training wall.

The construction of such a structure can be reasonable for small appliances over 50 PE, but even in these cases, it should be constructed near or at the source as a pretreatment unit before draining into the external base canal.

Simple and expanded septic tanks

For small treatment units, the screen, the oil skimmer and the pre-settler are incorporated into a multi-chamber structure. In septic tanks, wastewater particles sediment to the bottom of the tank, and substances with a density lower than water float to the surface. The settled sludge, which mainly contains organic matter, starts to rot due to significant residence time.

In the expanded septic tank, the flow rate drops to 0. The coarse materials remain in the first chamber.

As a result of sedimentation and floating, sludge – bottom sludge – is formed in the expanded septic tank. The bottom sludge forms two zones with different oxygen supplies: the upper layer is rich in oxygen (aerobic), the deeper layers are anaerobic.

In the upper, oxygen rich layer, very little organic matter is decomposed. Nutrients decompose by rotting in the anaerobic sludge. The gas produced gets into the air. The sludge that is formed in the expanded septic tank is also referred to as faecal sludge, referring to its faecal origin. In the term "septic tank", the term "septic" refers to the fact that the floating organic matter that can be settled is substantially hydrolysed during residence time and converted into dissolved organic matter. The settled sludge partially decomposes, which – in biochemical terms – means the degradation of organic matter under anaerobic conditions. The degradation of organic matter, the stabilisation of the sludge, i.e. the reduction of its rotting capacity in the expanded septic tanks is not complete. Partial stabilisation of organic matter can also be measured as a reduction of BOD_5. BOD decrease is due to high – more than a half or a whole year – residence time. Despite the high rotting time, organic matter degradation is only partial, mainly due to low temperature (< 25°C) and the lack of sludge homogeneity, leading to the development of inhibitory environment (e.g. acidification) and processes preventing organic matter decomposition. As a result, the anaerobic bacteria consortium that could effectively perform organic matter degradation cannot develop.

The advantages of septic tanks, besides their efficiency of reducing floating materials and debris, are their reliability, their favourable quantitative and qualitative balancing effect for the next treatment stage.

Expanded septic tanks have been used as pretreatment for sand filters and wastewater ponds; today they can still be used as a pretreatment for semi-natural treatment technologies (ponds, root zone) and for aerobic small equipment providing full biological treatment.

Simple septic tanks have a relatively short residence time (theoretically three days). In order to reduce sludge drift, the structure is divided into chambers; the first chamber takes up two-thirds of the useful volume of the structure.

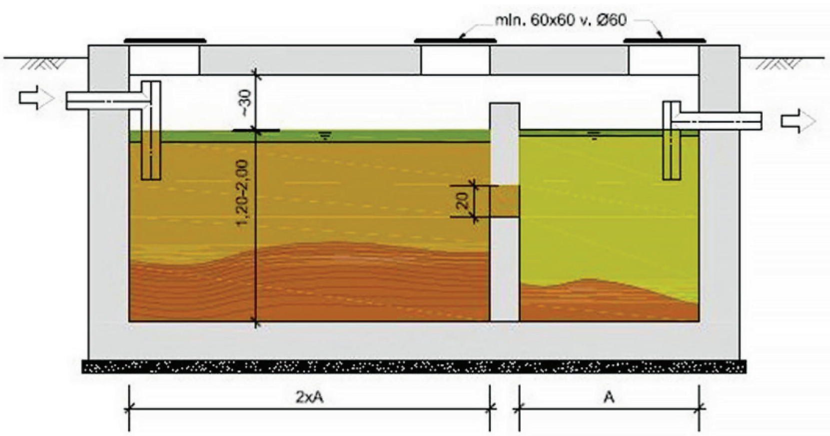


Figure 4
Traditional simple septic tank design (compiled by the author)

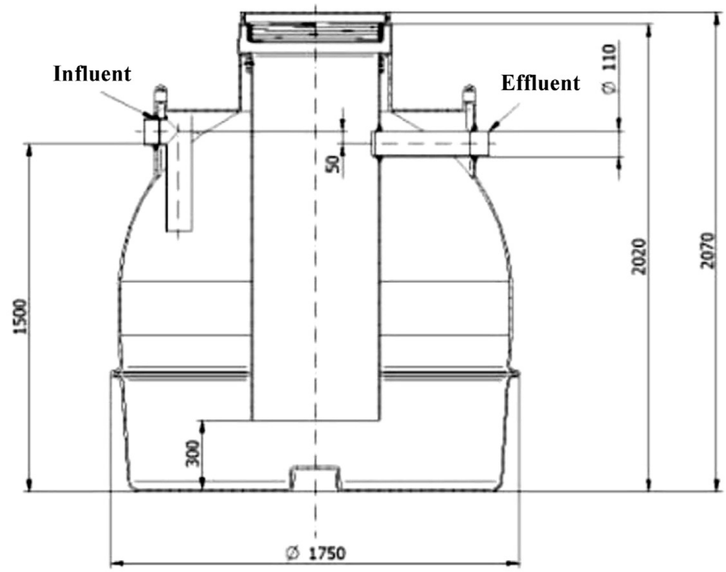


Figure 5
Simple septic tank from Polyethylene (Polyduct) (compiled by the author)

In the expanded septic tank, residence time is significantly higher (6–10 days), which promises better floating and organic matter removal efficiency. They are mostly three-chambered, with the first chamber accounting for half of the total useful volume, while the other two account for a quarter each.

The inlet must be at least 5 cm above the water level inside the structure, thus preventing back swelling in the sewer in case water level increases. In addition, wastewater should be directed to the upper third of the useful height by a submerging wall or a vertical "T" pipe. A transfer hole with a size of approximately 20 cm should be at around the upper third of the water level. Wastewater must also be discharged from the last chamber to prevent drifting away of floating solids by means of a "T" pipe or a submerging wall, in a way that wastewater is removed from the upper water layer with the lowest suspended solids content. If the effluent discharged from the septic tank is fed to a sand filter, it is advisable to install a filter with a pore size of 1.5 to 2 mm into the outlet pipe, inside or outside of the septic tank.

Useful water depths are, according to practice, 1.2 to 2.0 m above the water level with at least 30 cm air space. Beside of these parameters, if the installation depth of the inlet sewer is about the preferred 80 cm, the structure can be installed above groundwater. For good management (debris removal, sludge removal), reinforced concrete structures must be constructed with openings of at least 60 × 60 cm, or rather of 80 × 80 cm at the inlets and outlets, or at transfer holes between the chambers for handling. The openings can be closed with a cast iron or ribbed plate (usually light) cover with a load bearing capacity fit to the expected load at the site.

If the structures are built with proper sewage design, a separate ventilation is not necessary; the structure could be ventilated through a pipe located on the vertical side of the sewage with an outlet above the roof.

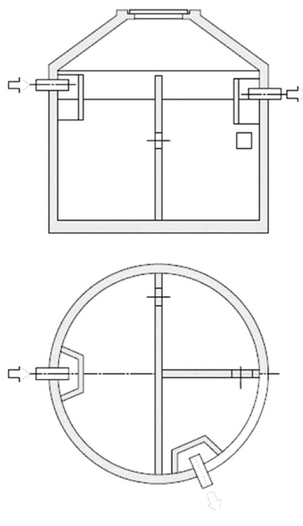


Figure 6
Expanded septic tank construction (compiled by the author)

Continuous flow activated sludge systems

The two main units of the equipment are the aeration tank and settling tank. Wastewater enters the aeration tank gravitationally or by pumping after a simple filtration (e.g. basket screen). Aeration required for activated sludge function, decomposition of organic matter, or for the stabilisation of nitrification or activated sludge is mostly performed by fine bubble diffusers.

During aeration, not only the maintenance of aerobic conditions required for biomass function occurs, but also homogenisation and "mixing" of the wastewater-activated sludge mixture to prevent settling of the activated sludge in the reactor.

From the aerated space, wastewater-activated sludge mixture flows into the settling tank gravitationally, where the separation of activated sludge and wastewater takes place gravitationally. The flow in the settling space is vertical hydraulically. This is the most space-saving settling tank design, conditions for the gravitational sedimentation of activated sludge are favourable and the settled sludge can be collected under favourable conditions (sufficient dry matter content).

Most of the settled sludge must be returned to the aerated tank to ensure that there is always sufficient functional biomass available for the biological degradation processes. During biomass function, pollutants in the wastewater are partly integrated into the biomass upon their degradation, increasing the amount of biomass. From the point of view of stable operation, it is practical to maintain the activated sludge at a quasi-constant concentration, thus, the produced excess sludge (surplus sludge) should be removed.

The passage from the aerated tank to the settling tank is either on the top or on the bottom. In the top passage, the mixture with the least dissolved oxygen content is deposited in the settling tank and the floating foam is also skimmed.

At the bottom passage, the wastewater-activated sludge mixture passes through the lower part of the partition wall located between the aeration and settling tanks. In this case, there is no need for a flow deflector (e.g. damping cylinder), the wastewater flows right up while sludge flakes settle. Due to higher sludge density at the bottom of the settling tank, an equilibrium develops between the lower parts of the settler and the activated sludge reactor; as a result, there is no need for mechanical sludge recirculation – an auto recirculation develops.

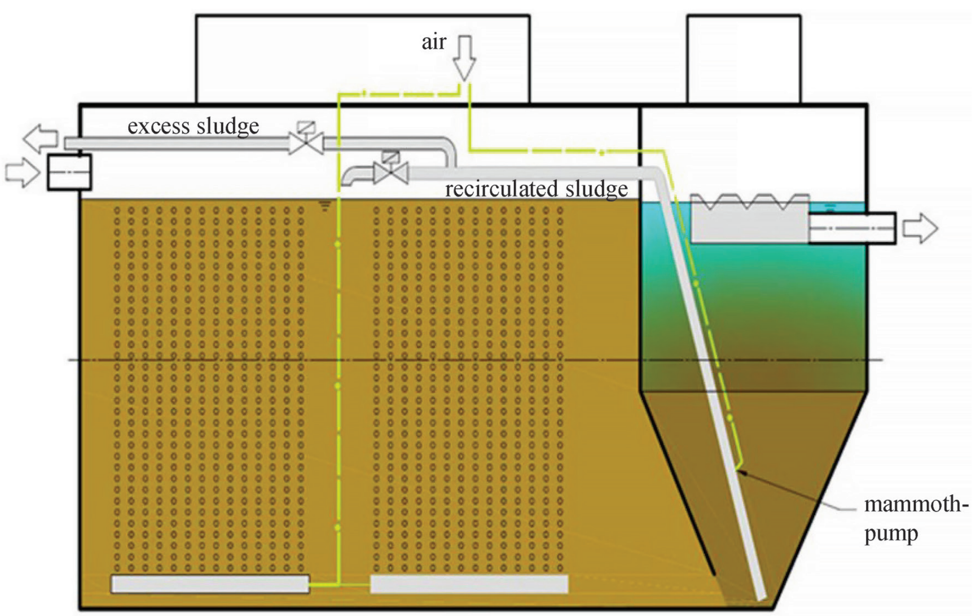


Figure 7

Activated sludge system with bottom passage and auto sludge recirculation (compiled by the author)

The sludge growth and surplus sludge can be directed to the settling tank and stored with the primary sludge. If there is no settling tank, a separate storage unit should be provided for the surplus sludge, either as a standalone structure or in a dedicated compartment of the small equipment.

Air injection technologies are most suitable for biomass aeration, which are fed by air blowers using low-pressure air.

The fine bubble diffuser is mostly in the form of disc, plate, tube and hose.

Figure 8
Plate diffuser (Lausitzer Klärtechnik) (compiled by the author)

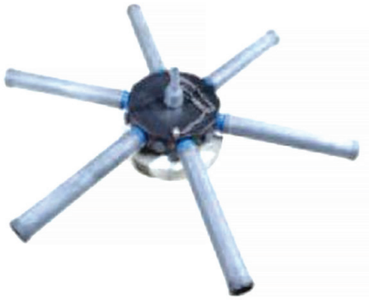


Figure 9
Radial pipe diffuser (Lausitzer Klärtechnik) (compiled by the author)

Silent membrane blowers can be used in small treatment units. Depending on the type, the airflow of the small membrane blower is approximately 30 l/min to 250 l/min, the pressure range is 10 to 20 kPa, the power consumption is 30 to 130 W. Their air nozzle is suitable for connecting a small hose. Their size (~ 200 × 200 mm – 200 × 400 mm), their weight is below 10 kg.

Figure 10
Air membrane blower (Nitto Kohki) (compiled by the author)

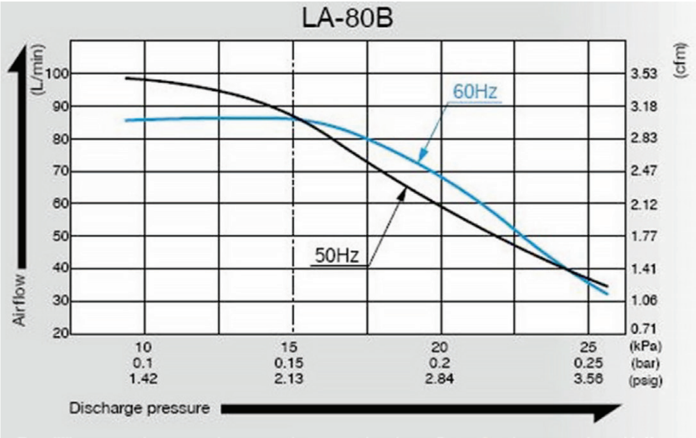


Figure 11
Air blower air delivery (Nitto Kohki) (compiled by the author)

Small units with SBR

Until the 1990s, OWTS were built and installed with continuous flow mode of operation and were hydraulically gravitational (apart from sludge recirculation). In order to make better use of the reactor volume available in the equipment, the SBR systems used in large wastewater treatment plants also appeared in the world of small units. The SBR is an acronym for Sequencing Batch Reactor and refers to the subsequent technological processes occurring in the same reactor space. Due to the cyclic operation of the biological unit, there is no need for a settler to separate the sludge from the sludge-wastewater mixture.

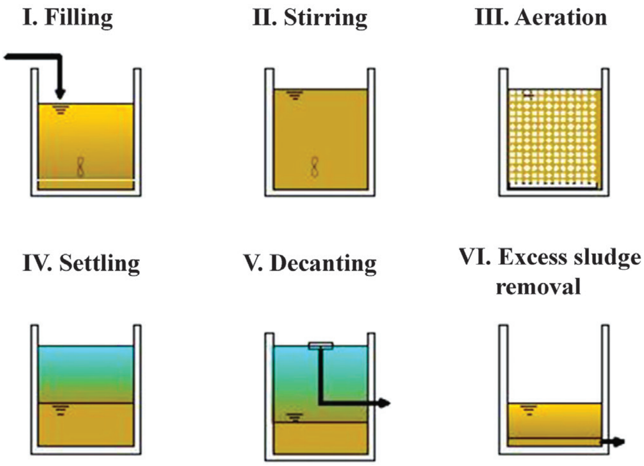


Figure 12
Operating cycles of an SBR system (compiled by the author)

The cyclical operation of the SBR reactor is also favourable for reducing fluctuations in wastewater yields. This effect primarily occurs during wastewater pretreatment (settling) stage, while the pretreatment area also functions as a wastewater reservoir.

Small equipment with SBR technology usually operates with three or four time-controlled cycles per day.

Within this, several versions of wastewater discharge are possible.

a) wastewater is discharged once per cycle from the settling tank to the SBR reactor after settled sewage is removed

b) wastewater is discharged several times per cycle between several internal aeration stages

In addition to cycle-based operation, there is also state-controlled operation as well as the combination of time and status control. A typical case of state control is that wastewater discharge from the settling unit is continuous until it reaches a maximum level. It results in the followings: 1. residence times in the reactor space will always be varied, at lower wastewater yields residence times are longer, while during days with higher wastewater yields the opposite happens; 2. the quality of treated wastewater will also vary accordingly; 3. it is practical to design the pretreatment reactor space for substantial balancing capacity.

For this type of operation, the unit must be equipped with a level switch or sensor or a pressure sensor built into the aeration system.

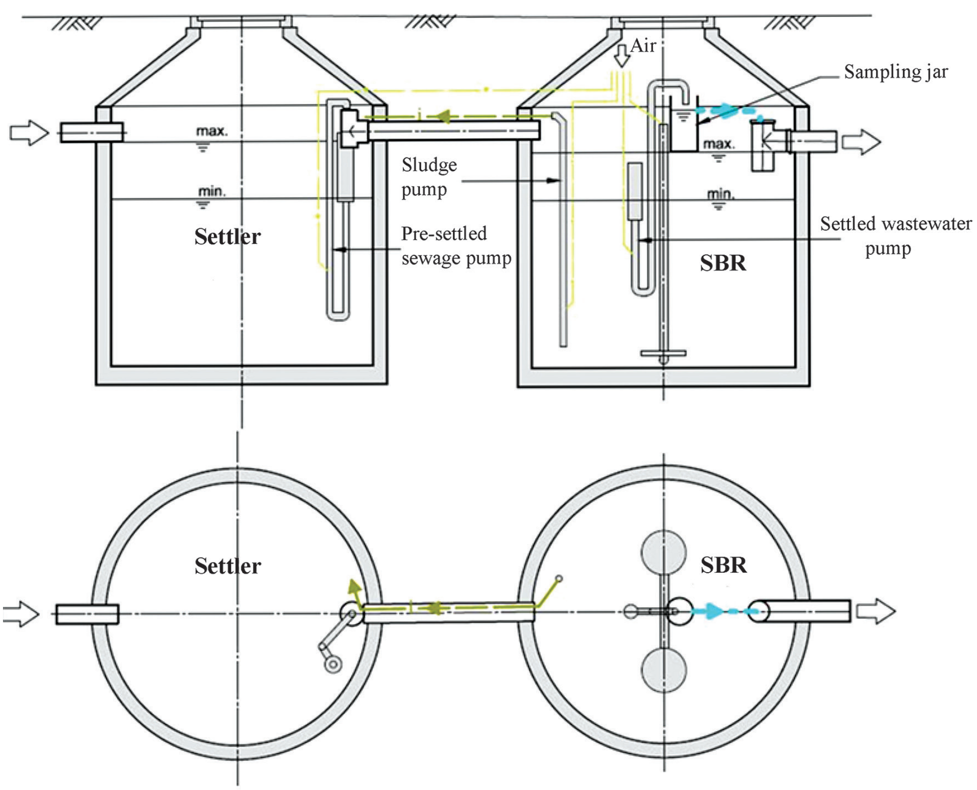


Figure 13
SBR design with two structures (compiled by the author)

Small equipment with SBR system consists of two units: the (pre) settler and the SBR reactor. For the smallest equipment, the two units are developed in a single structure, in the larger ones the primary settler and the SBR unit are located in separate engineered structures. The settler is also a buffer space with varying water levels, so the settled sewage can be pumped to the SBR unit. From there, the (post) settled sewage can be decanted by a pump into the sampling vessel, from which it can be directed gravitationally to the post-clarifier or the receiver. Time to time, the excess sludge is pumped back into the primary settler. Similarly to the continuous flow sludge systems, in small SBR equipment mammoth pumps are used, aeration elements and blowers are also similar to those used in activated sludge systems.

Small equipment with trickling filters

Trickling filter treatment is an aerobic treatment process, in which the microorganisms performing the biological degradation are bound to a surface and form biofilms. The media carrying the biofilm is a rock material or a ring-shaped plastic element. For small equipment, mostly basalt, lava and similar rocks are used. The mechanically pretreated wastewater can be evenly distributed over the surface of the media. The effluent that drains through the media gets into contact with the biological membrane while absorbing dissolved oxygen from the air flowing through the gaps. Microorganisms in the biofilm primarily decompose organic materials and incorporate them into their bodies. During these processes, the biofilm thickens, the inner layers of the biofilm are less oxygenated, die slowly and the biofilm sometimes detaches. This detachment process is also supported by the wash-down effect of the wastewater. The detached biomass can be pumped out by pumping it into the settler after the trickling filter. The sludge (and settled sewage) settled in the sump will be transferred to the mechanical pretreatment unit by an intermittent operation pump installed in the sump. By recirculating the wastewater, the hydraulic load increases, wastewater dilutes and shock loads are also reduced. The sludge is stored with the settled raw sludge. In more sophisticated means of recirculation, a separate pump located in a pump area after the trickling filter pumps the wastewater back to the trickling filter and to the primary settler.

The medium is supported by a slotted bottom, which is permeable for air and wastewater containing the detached biofilm. Due to the chimney effect, the air directed under the bottom flows through the medium. Flow direction depends on the temperature of the outer area and of the temperature inside the medium.

In smaller appliances (up to 8–10 PE), trickling filters are located in a single structure together with the secondary settler, while in larger equipment the two technological units are separated into two structures.

On the surface of the trickling filter, wastewater must be evenly distributed. In small equipment with a diameter of a few meters, water dispensers with jointed arm common in large trickling filters cannot be installed. Instead, they use simpler water dispensers, plate dispensers, tipping tray, manifolds, etc.

The wastewater flowing through the medium is pumped to the post-settler from which the settled wastewater can be discharged gravitationally. The settled sludge is pumped into the pretreatment unit (e.g. expanded septic tank), which is an essential part of the trickling filter technology.

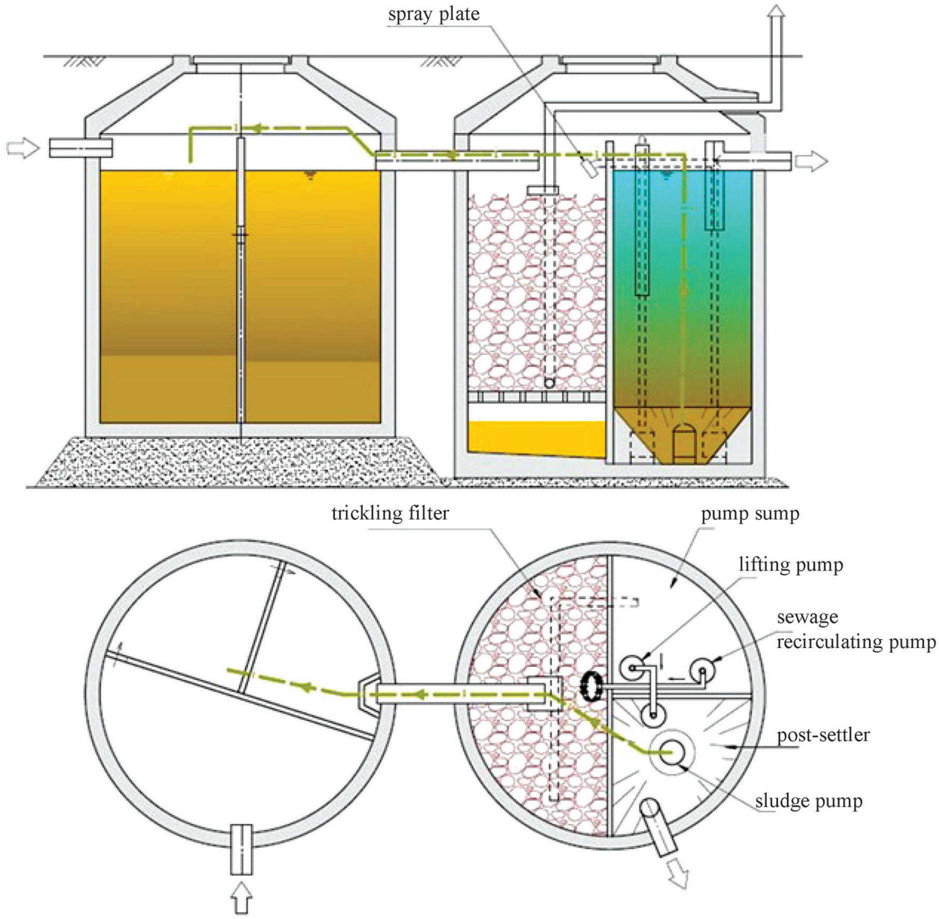


Figure 14
Designing a small equipment trickling filter with two engineered structures (compiled by the author)

Rotating contactors with immersed disc

Rotating contactors with immersed disc consist of discs 15–20 mm apart or clustered plastic medium mounted onto a common axis. The axis of the immersed bodies is located above the water to allow one-third of them to be immersed in the wastewater. During rotation, discs are alternately submerged into the wastewater or are above water. When immersed in wastewater, the biofilm attached to surfaces absorbs dissolved organic matter, and, when in contact with air, absorbs the oxygen needed for biodegradation. During operation, the thickening biofilm detaches from time to time, partly remaining in the reactor space as an active biomass, partly settling into the secondary settler and being taken away as a quasi-humified biomass. The sludge can be pumped back into the pre-settler.

The raw wastewater first flows into the pre-settler, where a large proportion of the suspended solids settles, and the settled wastewater flows – usually gravitationally – to the immersion disk unit. The wastewater is transferred from the primary settler of the structure to the biological reactor with a uniform load, in which organic material degradation occurs. Trickling filters with immersed disc are configured in a two-step way in small appliances in the upper capacity range or over of 50 PE. In the second biological stage, primarily nitrification should take place. The secondary settler is the last element of the technology line, which is, in case of small equipment, a chamber after the trickling filter, while in larger equipment, a separate secondary settler structure is built. In the solution shown in Figure 15, wastewater is supplied to the primary settler or to the recirculation well by a chain pump. With recirculation, the treated wastewater and waste particles are returned to the primary settler. This is necessary for the continuous operation of biological processes during periods without load as well as for levelling irregularities of wastewater discharges.

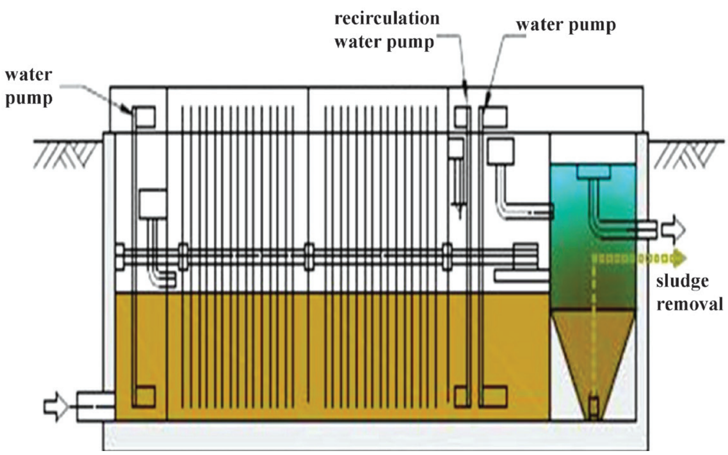


Figure 15
Technology design scheme for trickling filter with immersed disc (compiled by the author)

Treatment technology using immersed body and floating bed

In these biological appliances, microorganisms that settle on the surface of plastic media with high specific surface area and voids volume perform the biological treatment of wastewater. The plastic elements are designed with inner sinuses allowing the wastewater to move freely while it comes into contact with the biofilm attached to the surface of the medium.

The aeration is carried out by fine bubble aeration elements diffusers located under the immersion body. In addition to continuous aeration and long sludge age, the technology is suitable for organic matter decomposition and nitrification. It can also be adapted for denitrification by applying batch-type aeration. In aeration-free periods, anoxic condition required for denitrification processes develops.

The floating bad technology is a microbiologically similar operating principle. In this case, mostly ring-shaped plastic elements with a structured surface float in the pre-settled wastewater. Plastic elements also have a high specific surface area and large biofilm develops on them. Floating away of plastic media forming the floating bed is prevented by a filter located at the pipe draining into the secondary settler.

The secondary settler and sludge recirculation are part both of the fixed and floating bed reactor technologies.

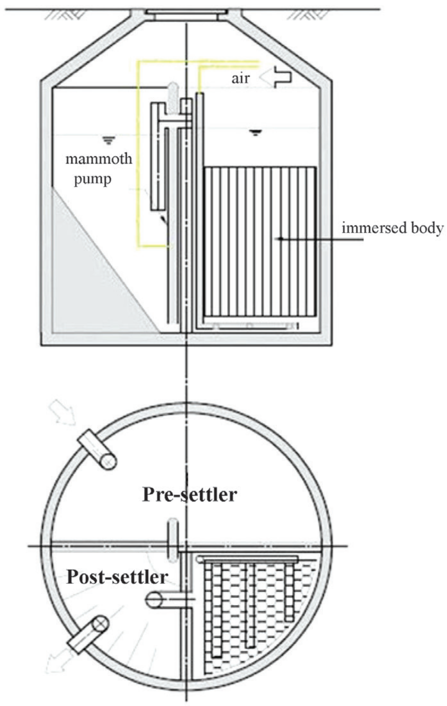


Figure 16
Technological design scheme for small equipment with immersed body (compiled by the author)

Figure 17
Immersion body (compiled by the author)

Membrane bioreactors (MBR)

Membrane bioreactors are a combination of continuous flow sludge technology and membrane filtration. In principle, a biological reactor can mean any activated sludge technology – e.g. simultaneous sludge stabilisation, aerated, pre- or post-nitrification, biological excess phosphorus removal, etc., but the secondary settler used as the last unit of a conventional biological treatment is replaced by a membrane filter. As there is no need for a secondary settler, this space-saving technology is also well suited for its application in small equipment. Mass production of membranes aids their use in small equipment. Most of the manufacturers of prefabricated small equipment also incorporated membrane bioreactor engineered structures into their portfolio; technically, it is not problematic to subsequently incorporate a membrane filter unit into a small appliance composed of several structures or chambers.

The use of MBR small equipment is obvious in light of the current requirements of water protection and legal provisions, the release of treated water into surface water used for recreational purposes, for certain water utilisation purposes or to achieve water reuse.

Appliances using membrane technology consist of four technological units: a mechanical filter, a settler, an activated sludge biological reactor and a membrane filter chamber. For small appliances, these four technological units can be created in a single engineered structure, while in small wastewater treatment plants it can be built into three separate units. The mechanical filter retains physically easy-to-filter pieces and fibres in the millimetre range. The filter is inserted in the settling unit at the end of the inlet pipe. In the settler mostly organic sludge, that easily settles gravitationally, and floating materials settle. Wastewater flows into the subsequent activated sludge reactor gravitationally. According to its operation principle, it can be a conventional, floating, as well as fixed bed reactor. A diffuser is used for the aeration of wastewater-biomass mixture; the compressed air is supplied by a fine bubble membrane diffuser. The next unit is the membrane filtration chamber into which the wastewater-biomass also flows gravitationally. Dip membrane filter unit(s) used for separating wastewater and biomass are located in the membrane filter chamber. The biomass continuously remaining on and detaching from the filter is retained in the reactor space, resulting in a significantly higher activated sludge concentration compared to conventional sludge technologies, typically 8–12 g/l, which is beneficial for nitrification and also for denitrification if the reactor is configured properly.

Based on their pore size, membranes are classified into micro-, ultra-, nanofilters, as well as into reverse osmosis category. In activated sludge biological treatment, ultrafiltration membranes can be used to filter out a wide range of wastewater materials.

The range of pore size of micro- and ultrafilters is approximately 0.1 and 5 μm, which not only allows filtering of flaky activated sludge, but effectively removes bacteria and viruses as well. The goodness of separation is basically determined by the nominal pore size, but during continuous operation, a dynamic biofilm layer develops on the membrane surface as a result of the quasi-continuous operation, which increases membrane performance.

The membrane design is interesting from several aspects, i.e. separation, the amount of fluid flowing through the membrane (fluxes) and the energy use required for membrane performance. The energy demand on the two sides of the membrane depends on the transmembrane pressure – the in-pressure difference between activated sludge concentrates and filtrates or permeates. In case of micro- and ultrafilters, the pressure required for operation is theoretically between 0.1 and 10 bars, but the flux used for sludge separation is near the lower value.

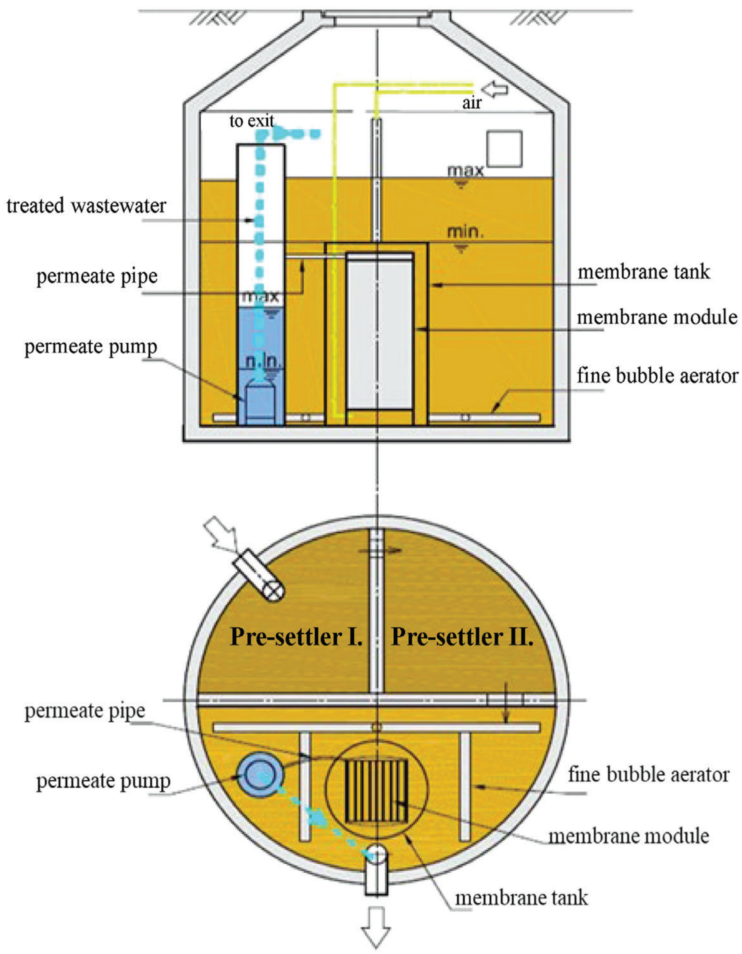


Figure 18
Small membrane bioreactors (compiled by the author)

The membranes are geometrically filamentous or flat membranes. For small appliances, most manufacturers prefer flat sheet membranes. The membrane sheets are assembled vertically with a distance of 2–6 mm between them. The assembled membrane sheets form a filter module that is immersed on the legs into the activated sludge reactor. The wastewater-sludge mix flows between the sheets from the bottom to the top in the module. Wastewater flows through the filter sheets from the outside to the inside. From the permeate channel within the membrane sheet, filtered wastewater enters a collecting duct wrapping around the module from which a pump sucks it out, or the hydrostatic pressure difference between the reactor water level and the end of the collecting tube forces it into the permeate collection chamber.

On the surface of the membrane, a thin layer of film is quickly formed from the biomass decreasing the membrane flux. The membrane permeate performance can be maintained by continuous and intense air supply. The blown air bubbles keep the effluent sludge mixture in motion during up wash; the membrane surface is continuously cleared by the turbulence, while in case of filamentous membranes, the wavy movement of membrane fibres aid in cleaning the membrane.

Figure 19
Membrane module (Huber Catalogue) (compiled by the author)

The activated sludge stored temporarily in the activated sludge reactor should also be removed on occasion. The excess sludge can be moved back to the mechanical settler.

The BOD_5 and COD concentration of treated wastewater can be well below legal limits and can be discharged into microbiologically sensitive surface water recipient or can be reused.

The microbiological efficacy of membrane filters can be characterised by a decrease in total coliforms indicating the degree of microbial contamination. Depending on the pore size, decrease in coliforms is in the order of 5 to 10, and its effectiveness greatly depends on the pore size of the membrane used.

Coliform removal capacity of membrane filters can be qualified depending on the load defined by the recipient or the purpose for which treated wastewater is used. For surface waters, either total coliform number or *E. coli* colony number is tested depending on the purpose of the application. In case of a surface water recipient, if it is used for bathing, quality requirements laid down in the Bathing Water Directive 2006/7/EC and in the corresponding Government Decree should be applied.

Table 8
Water quality requirements for natural bathing water (compiled by the author)

Parameter	Excellent quality	Good quality	Tolerable quality
Fecal Enterococci (cfu/100 ml)	200[I]	400[I]	330[II]
Escherichia coli (cfu/100 ml)	500[I]	1,000[I]	900[II]

Note: [I] 95-percentile. [II] 90-percentile

Semi-natural wastewater treatment is a biological wastewater treatment, in which microorganisms attached to the soil, granular aggregate, root of plants perform the biological (either aerobic or anaerobic) treatment and it includes wastewater lagoon system solutions as well.

Under domestic conditions, wastewater lagoon treatment is a viable solution for agglomerations below 2,000 inhabitants.

Types of wastewater lagoon treatment plants include:

- sedimentation lake
- non-aerated wastewater lagoon
- aerated wastewater lagoon
- conditioning lake

Sedimentation wastewater lagoons are lakes used in front of aerated or non-aerated wastewater lagoons to settle the settable materials of raw wastewater.

Non-aerated wastewater lagoons are also called lakes with facultative or naturally aired ponds, because air can only get into the water through the water surface. In principle, they are also suitable for biodegradation of organic materials. In the near-surface water layer aerobic and anaerobic microorganisms, while above the bottom mostly anaerobic microorganisms perform the treatment of wastewater. Oxygen intake and photosynthesis take place naturally through the water surface, mixing can be initiated by wind and temperature stratification.

Aerated wastewater lagoons are suitable for treating raw wastewater, but they are more suited for the biological treatment of mechanically purified, settled wastewater.

Conditioning lakes can be used as a post-treatment stage for biological wastewater treatment.

In practice, for decentralised wastewater treatment facilities aerated or conditioning ponds can be considered, the previous ones above 50 PE and the latter under 50 PE.

Microorganisms located in the water-mud interface, in the bottom, or on the bench as well as floating microbes participate in organic matter decomposition. By aeration, biodegradation can be significantly improved compared to non-aerated ponds. The aeration can also be controlled; thus the quality of the treated wastewater can be controlled to a certain extent.

Wastewater lagoons must be insulated with e.g. local soil that is at least 30 cm thick with at least $\leq 10^{-9}$ m /s water permeability. Alternatively, a thick (at least 1 mm), UV- and root-resistant foil could be used instead. Foil insulation should be laid on a fine-grained bedding or straining cloth. The insulating foil should be fixed into the soil above the water level or to the edge of the bank.

Sewage inlet is above water level, possibly stretching away from the edge of the bench, this way the inflowing water is aerated.

Wastewater inlet and outlet must be designed at a location where short circuit cannot develop; water exchange should be as even as possible in all parts of the pond. Wastewater outlet must be designed in a way that water is removed from below the surface water, surface debris should be prevented from floating away, and plugging should also be prevented if the water surface is covered with vegetation. A sampling point should be selected downstream of water withdrawal.

One of the options for converting wastewater ponds into aerated lagoons is to develop an SBR technology (Constant Waterlevel Sequencing Batch Reactor) with constant water level. The technology is a technological implementation of SBR in a wastewater pond. In this technology, the pond with constant water level is divided into a primary reservoir, an SBR reactor, and a balancing area by foil curtains anchored to swimmers. Depending on the size of the wastewater inlet, or on the pump controlled filling and discharge among areas, foil curtains move horizontally and the size of the areas with different functions varies, while the water level remains quite constant in each area.

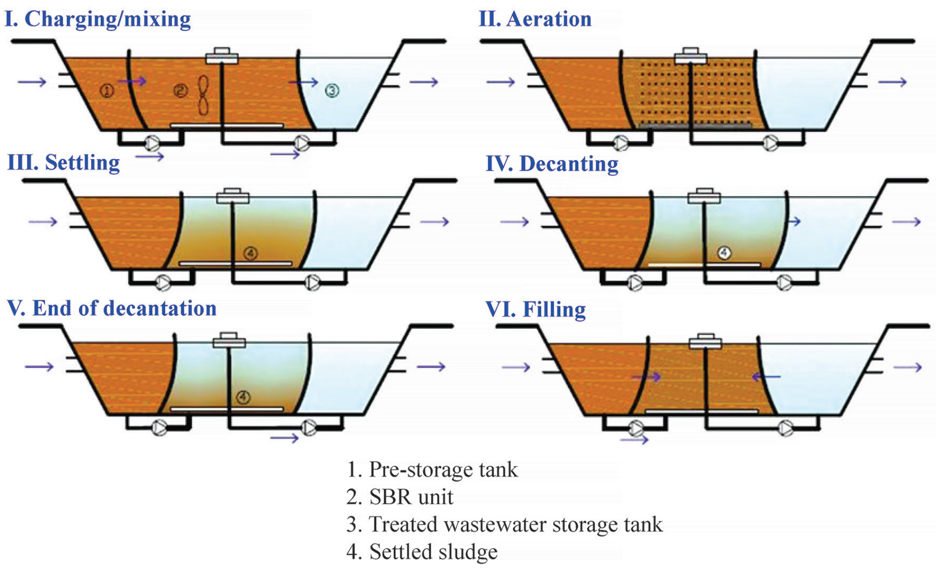


Figure 20
Implementation of constant level SBR technology in aerated wastewater lagoon (compiled by the author)

The purpose of conditioning lakes is to improve the quality of wastewater purified at least biologically. The expected improvement in quality is characterised by the reduction of residual BOD and COD representing organic matter that cannot be eliminated in previous stages, nutrients that can be absorbed by aquatic plants, as well as filterable suspended solids causing turbidity.

For proper functioning of a conditioning lake, microorganism diversity as well as favourable volumetric and geometric design is required, i.e. preferably, it should have large volume and surface and water depth should be low to favour light conditions.

Sand filter fields and ditches

In order to discharge wastewater that has been treated mechanically or partially anaerobically from septic tanks into the recipient, it was necessary to further reduce the amount of suspended solids and organic matter in wastewater, by accelerating and intensifying processes similar to natural drainage in soil, artificial sand filters have been built in the soil to further protect surface water, soil, or groundwater. In fact, sand filters have to perform a second aerobic biological treatment after the anaerobic stage, along with decreasing suspended solids. Applying it after a septic tank, it performs biological treatment as a biofilter.

In order to better protect the environment, using the best available techniques, biological treatment systems should be used. To further reduce residual BOD, COD and suspended solids in the effluent, the above-mentioned artificial, underground sand filters could also be used, not as a second biological treatment step but as dedicated post-treatment step.

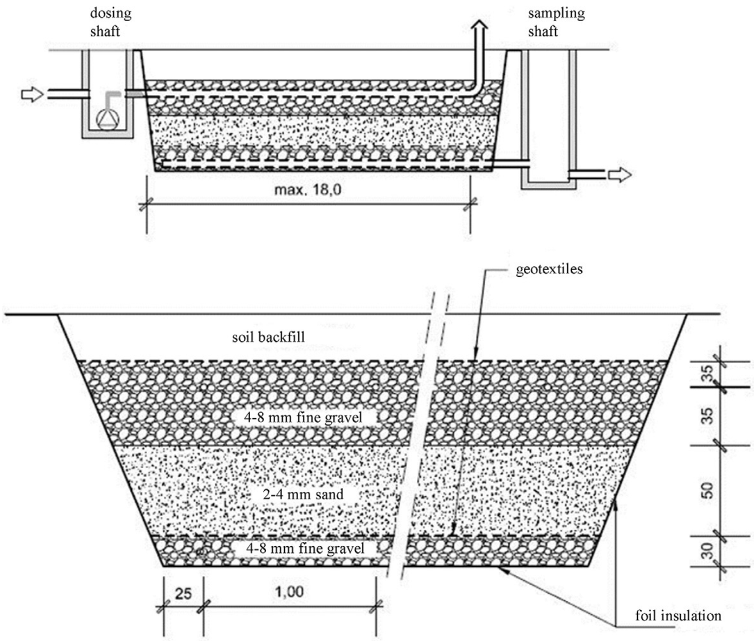


Figure 21
Sand filter field (compiled by the author)

The drains can have vertical and sloped design. The minimum width of the drains is 1.8 m and the bottom width is 0.5 m. The length of the ditches should be 18 m the most for good ventilation.

The drainpipe must be installed in a way to distribute wastewater as evenly as possible into the infiltration body below. Therefore, the slope of the drainpipe should be around 2‰. The recommended size of the drainpipe is DN 100. Wastewater loaded into the drainage system should fill at least the quarter of the pipe to allow uniform distribution. This condition can be met if wastewater discharge is intermittent. The intermittent discharge is also recommended because the drainage body can be aerated between wastewater discharges. For ventilation, the end of the drainpipes should be placed above the surface level.

Some manufacturers offer wind-powered fans that can be installed at the end of the ventilation pipe and requires no extra energy.

Figure 22
Wind powered ventilation fan (compiled by the author)

For designing filter trenches and fields, design data according to changing domestic regulatory documents are summarised in the table below, supplemented with values defined in the DIN standard.

Table 9
Design data for filter trenches and fields according to different guidelines (compiled by the author)

	MSZ 15302-1962	OVHMI 146/1-71	ÉSZ 5 11-75	MI 10-127/9-84	MSZ 15287: 2000	German recommendations
Sand filter trench width	–	1.20–1.50 m	–	–	1.20 m	0.5/1.8 m
Filter layer thickness Grain size	–	0.65–0.70 m 0.5–2 mm	–	0.55–1.0 m 1–3 mm	0.75–1.0 m 1–3 mm	1.0 m 4–8 mm (0.5 m) 2–4 mm (0.5 m)
Max. ditch length	–	25m	–	–	25m	18m

The filter systems are intermittent to support aerobic biological treatment and to reduce clogging of the filter layers and becoming anaerobic. To do this, a dosing shaft is installed driving the pretreated wastewater to the drainage-filtering unit. The dosing is carried out by a pump installed in the structure, by a siphon or a tipper. Today, the least demanding, reliable operation is pumping.

Constructed wetland technology

Plant beds, root zone technology are natural biofilters, utilising micro- and macroorganisms, occasionally plants and sunlight, based on natural self-purification processes without artificial oxygen supply to decompose contaminants.

Plant-based wastewater treatment systems are semi-natural wastewater treatment plants. The two main characteristics of semi-natural treatments are that the majority of wastewater contaminants are degraded while penetrating through the granular medium and the plants and their root system also define this process.

Artificial plant-based wastewater treatment plants can be divided into three groups:

– horizontal subsurface flow systems, when wastewater flows horizontally between the inlet and outlet below the plant bed
– vertical subsurface flow systems, when the wastewater is directed to the surface of the plant bed flowing through the root zone vertically and the filtered sewage is collected at the bottom of the plant bed and discharged
– flooded, i.e. free water-surface systems also belong to plant beds

These main solutions may differ from each other in the geometry of the plant bed, in the filling materials used, in the composition of the plants used, and also in their mode of operation (e.g. intermittent flooding, filling-discharge operation).

Plant bed systems should be preceded by a high-efficiency mechanical and partial biological treatment. The basic prerequisite for their proper functioning is the low suspended solid content of the inlet wastewater in order to avoid colmation. It can function well as a post-treatment unit after a biological sewage treatment system. Plant bed systems are not recommended without a mechanical pretreatment, but applied frequently for biological cleaning.

Horizontal subsurface flow systems are also suitable for nitrification along with decomposition of dissolved organic materials. Their wastewater supply can be continuous, but if possible, it is better to have intermittent influent.

The plant bed must be insulated at the bottom and at the side. For insulation a sloped wall is preferred. The best way of insulation is the use of UV resistant, at least 1 mm thick foil with a high enough resistance against puncture. Foil insulation should be made preferably by using a wide, seamless roll. In case of narrow foil rolls, welding at overlaps should be done carefully according to the manufacturer's instructions. The foil on the slopes must be fixed 20–30 cm above the bed in the surrounding soil, covered with earth. The insulation can also be made of insulating materials based on minerals. Insulation may only be omitted if it is certified that at the site of the installation at least the upper 1 m of soil has a water permeability of less than 10^{-8} m/s. Insulation compliance must be verified by a water retention test. No insulation is required if the plant bed is placed in a prefabricated plastic container, which is suitable for wastewater up until a few PE.

In horizontal subsurface flow plant beds, an inlet-distributor section is developed on one side of the plant bed, mostly of coarse particulate material with or without a distributor drain. On the opposite side of the bed, the treated wastewater is collected by a drained section with gravel and discharged into the sampling shaft, and then the purified wastewater can be drained into the soil or discharged into surface water.

It is practical to design the length of the effective plant bed between 3–6 m. At least 50 cm thick filter layer is needed for effective biological treatment. The 0.5–1.0 m thick layer can be filled with fine gravel of fine particle size, or with medium-sized, washed sand. The filter body should have a good water permeability; it can be considered to be adequate if the permeability coefficient is between 10^{-3}–10^{-4} m/s. The filter layer can be constructed by using sand of 1–4 mm size, gravel of 4–16 mm size, if in each fraction the $U = d_{60}/d_{10}$ inequality coefficient is less than 5. Prior to installation, the particle-size distribution should be checked by the sieve analysis used in geotechnics.

In the horizontal subsurface-flow system with two or more horizontal plant beds, layers can be developed in the direction of the flow, starting from the gravel layer distributing the wastewater; the first layer is composed of a gravel fraction followed by sand and the drain-collector layer.

For horizontal subsurface flow systems, the treated wastewater must be separated by a gravel layer spread in the entire width of the filter bed with a ratio of at least 1:3. The extended rectangular layout is more favourable for a more uniform flow and to prevent short circuits.

For horizontal subsurface flow systems, treated wastewater is collected by a gravel layer (e.g. 32–64 mm) filling the entire width of the filter bed and is drained with a drainpipe.

For horizontal subsurface flow systems, collecting slotted tubes should be laid on the bottom in longitudinal and transversal directions as a 20 cm thick drainage layer. The drainage system must be suitable for the complete drainage of the wastewater effluent from the filter layer above it; bulking should not develop.

For vertical flow plant beds, the filter bed from the water distribution system to the collecting drain system should be constructed on the same principle, to prevent stagnation and to allow the filter to drain.

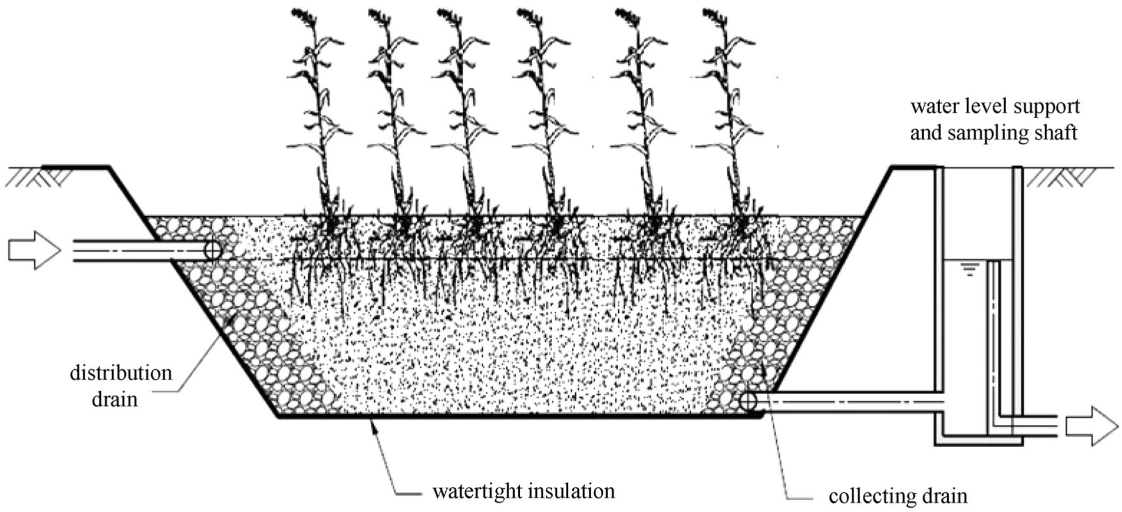


Figure 23
Horizontal subsurface flow plant beds (compiled by the author)

Vertical flow plant beds must be fed either in batches of small quantities or, if the system is completely flooded, sufficient time should be allowed for aeration after draining. With this system, nitrification is even more difficult in summer and the environment in the plant bed is not suitable for denitrification.

The bed must be loaded evenly with sewage in batch operation. The feeding system is a distribution drainage system located near the surface of the filler body. The drainage system is a drainpipe network laid on the bottom under the bed.

The drainage system should be developed with a vertical venting tube at the opposite side of the inflow or outflow to allow natural air exchange in the filter made of particulate material.

For horizontal subsurface flow plant beds, the inlet must be protected against winter freezing, a simple surface distribution duct is not recommended. The drain hose with a slot of at least 8–10 mm should be laid in the coarse gravel distribution bed.

For vertical-flow plant beds, slotted distribution pipes are laid close to the surface with longitudinal and transverse branches in a way to have a bed surface no larger than 5m^2 for outlet mouths. The vertical-flow systems must be fed intermittently with large wastewater doses.

For batch or shock-like feeding of plant beds, a dosing shaft (pumped, siphon) is a good solution. In case of pumping, pump is level controlled. To indicate pump failure, additional level switches must also be installed below the backwater level of the inlet pipe. If possible, the dispenser tank can be equipped with a reservoir for storing overflowing wastewater (in larger cleaners). The pump pressure pipe must be constructed with a rising angle, and the pressure pipe must not be equipped with fittings preventing backflow to allow the pipe to drain back into the feeding shaft after the pump has stopped (frost protection).

A monitoring well must be installed on the outlet pipe exiting the plant bed. For sampling the tube must be connected to the monitoring well at least 10 cm above the bottom. For larger installations, it is practical to design the well to measure flow rate, too.

The best plants for plant beds are halophytes with rhizomes and deep-roots. The plants can clean the wastewater with their large root systems, root hairs that can go down to greater depths (~ 1 m) of the substrate. Biological treatment is carried out by microorganisms living on the root system. Basic vegetation can be planted using common reed *(Phragmites australis).* In addition to common reed, other complementary plants are also preferred: yellow iris *(Iris pseudacorus),* broadleaf cattail or bulrush *(Typha latifolia),* water mint *(Mentha aquatica),* soft rush *(Juncus effusus),* etc.

There is efficient removal of organic matter in case of load with moderate BOD (v. COD). Phosphorus removal can also occur by adsorption in plant beds. The microbiological efficiency of the systems is good; coliforms are reduced by one or two orders of magnitude; in multistage systems even greater reduction can be achieved.

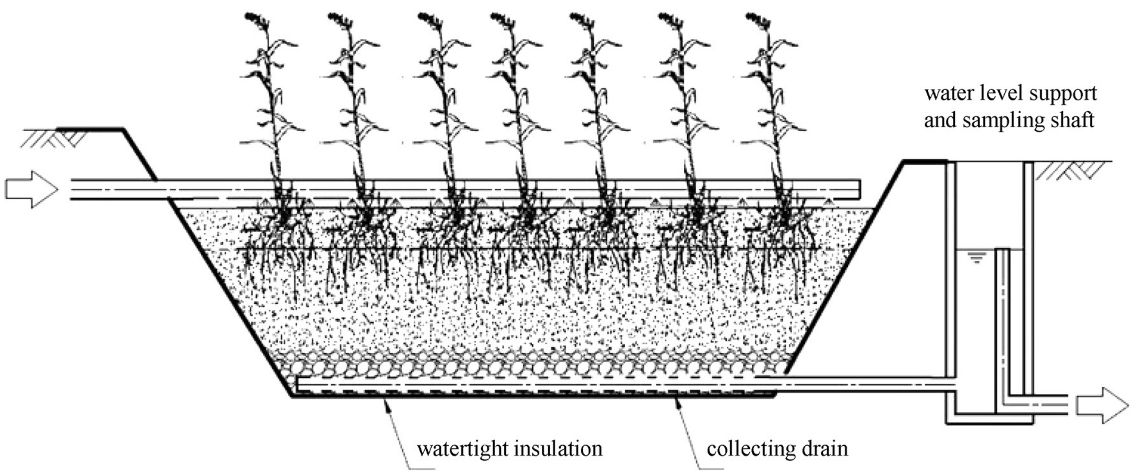


Figure 24
Vertical-flow plant beds (compiled by the author)

Disinfection

If the goal of wastewater treatment technology goes beyond organic matter removal, nitrification, denitrification and treated wastewater quality has to meet water quality requirements to be suitable for discharge into a surface water recipient, disinfection might be required.

Disinfection or pathogenicity reduction of treated wastewater may be necessary if the wastewater is highly pathogenic (wastewater from health institutions), or if wastewater is discharged into a running or stagnant water suitable for bathing, used as a drinking water source, or used for other purposes, e.g. service water or irrigation.

Even after mechanical-biological treatment – in case of a surface water recipient – a large number of relevant microorganisms can still occur. Coliforms indicating fecal contamination may still occur in the order of 10^4–10^6 colony forming units/100 ml, which exceeds legal quality requirement limits of natural bathing waters.

Based on various literature data, the number of *E. coli* bacteria present in treated effluent of each OWTS is expressed in colony forming units/100 ml in Table 10.

Table 10
Number of E. coli bacteria (colony forming unit/expressed in 100 ml) (compiled by the author)

Wastewater Treatment Unit	*E. coli* bacteria (TKE/100 ml)
Vertical flow plant bed	30 -> 4,000 >
SBR	> 20,000 -> 30,000 >>
Fixed bed	> 10,000 -> 30,000
Trickling filter	> 30,000
Membrane biology	< 100
Conditioning lake	0 -> 4,000

Note: Where the > sign is present, the number is an estimated value without an accurate count.

Different technologies remove pathogens present in wastewater to varying degrees. Wastewater treatment plants, with the exception of membrane technology of which the efficiency could be as high as 99.9%, are only modestly suitable for the removal of fecal bacteria. However, well-functioning plant beds perform well in coliform retention.

Various methods can be used to disinfect treated wastewater, if needed.

In case of small appliances, sodium hypochlorite and calcium hypochlorite disinfection are possible as a chemical option. They are typically used only occasionally.

Of physical disinfectants, UV light can be used for small equipment. UV light equipment is suitable for the continuous disinfection of wastewater, their use is warranted in surface water needing protection, and the remnants of chlorine disinfectants do not pose additional load to the recipient.

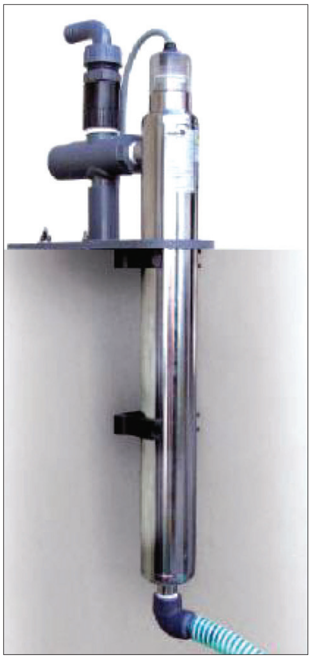


Figure 25
UV disinfection system (Lausitzer Catalogue) (compiled by the author)

Biologically treated wastewater flows through a UV lamp at 254 nm. UV lamps used are usually low-pressure UV emitters. If wastewater emission is intermittent (e.g. in SBR equipment), UV disinfectant should also be operated intermittently for cost savings. In other cases, it is advisable to pump the water to be disinfected from the intermediate storage unit to the UV unit to allow adequate load according to the nominal volume flow rate and to have proper radiation intensity. The UV lamp reaches its nominal power a few minutes after switching it on, thus pumping should start with a delay of 4–5 minutes. The UV equipment is particularly sensitive to the turbidity of treated wastewater, thus, it is necessary to install a mechanical filter in the pipeline before the UV disinfection unit and to clean it with a frequency defined based on turbidity measurements.

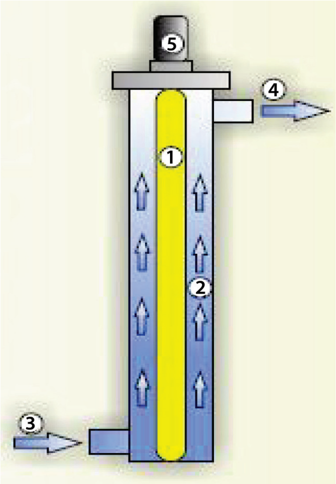


Figure 26

UV disinfection system structure (compiled by the author)

Note: 1 UV lamp, 2 irradiation area, 3 wastewater injection, 4 disinfected sewage, 5 UV housing with electrical connection.

Specific aspects of small sewage system design

When sizing small wastewater treatment plants, the methodologies used to determine basic design criteria shall be different from those used for conventional municipal wastewater treatment plants, due to the quantitative characteristics of effluents, especially their temporal variability as well as their quality and pollutant loads.

When considering water saving, water re-use should also be taken into account, new quality classifications should be added in addition to standard quality classes. These are the types of wastewater that can only be generated within a property or facility and interpreted accordingly.

Yellow water refers to urine with or without flush water, while brown water refers to toilet wastewater without urine. The yellow and brown water together are called blackwater that originates from the use of usual toilet types. Greywater is household wastewater without blackwater, i.e. originates from bathing, washing, cleaning and kitchen use. It should be noted that in the case of grey wastewater reuse, it is advisable to exclude kitchen wastewater from the concept of grey wastewater due to their grease, oil, etc. content, which is particularly disturbing in case of reuse.

The most prominent use of small appliances occurs in residential properties. The population size of settlements or parts of settlements to be provided with on-site wastewater treatment and disposal facilities should be taken into consideration during sewerage agglomeration surveys, studies, etc.

The classification of settlements by population may vary from country to country; e.g. according to the UN category, a settlement above 20,000 is considered a town, while the lowest limit of a city is 250 people in Denmark.

In Hungary, the settlements are classified by population number:

- city: over 100,000
- large town: 20,000–100,000
- small town: 5,000–20,000
- village: under 5,000

A more sophisticated classification of smaller settlements is the following:

- small village: 500–1,000
- extra small village: under 500 people
- hamlet: under 200 people

In Hungary, 25% of the total population lives in small and extra small villages. According to data from 2010, 178 people lived in hamlets.

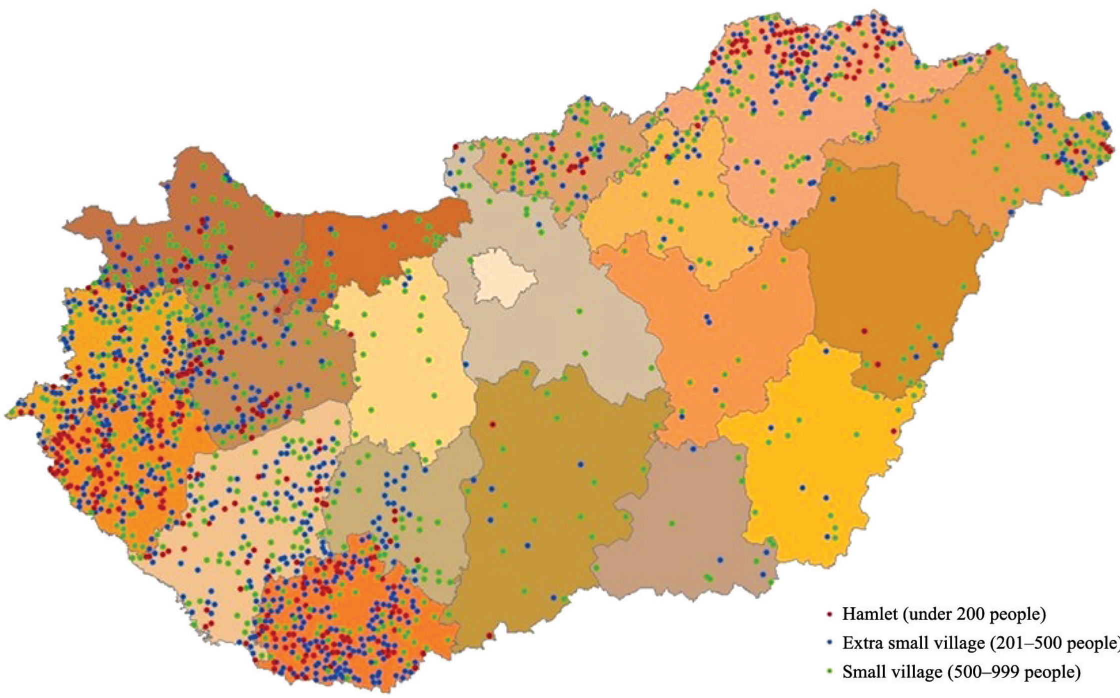


Figure 27
Small villages, extra small villages and hamlets in Hungary [1]

Among the factors determining the number of inhabitants per settlement and the number of inhabitants per property, only the followings are mentioned: age (the population of Hungary is aging), employment (there is a large number of settlements that can no longer be called either urban or agricultural).

Wastewater dischargers to be considered per property in large villages and towns are the following:

Table 11

Drinking water consumption per apartment by settlement types (compiled by the author based on [2])

Location Type	Specific number of residents [Person/Property]	Specific consumption [l/capita.d]
Large villages	4–3.1 3.1–2.7 2.7–2.2	**90–130** **80–110** **70–90**
Small towns	**3.5–3.1** **3.1–2.7** **2.7–2.2**	**110–140** **90–130** **80–110**

In case of small villages, the average number of people per property is around 2.5 and is mostly stagnant; in case of the smallest settlements, the population will probably be declining.

When examining a residential property as an individual sewage discharge unit, social and economic circumstances of a particular location should be taken into account. Furthermore, it should also be taken into consideration that the installation of public utility replacement equipment is a long-term investment and the decision to be made should have significance beyond the current population situation or the status of residential building(s) located on the property(s). If all of these things are considered and the installation of a small on-site treatment plant is justified, it is recommended to calculate with at least 2 people per a property of 60 m^2, and at least 4 people above it. The Hungarian Water Association (HWA) suggested otherwise, arguing that in settlements with a declining population, 2 elderly people would be a significant oversizing, resulting in an unnecessarily high investment and operation cost. On the other hand, as the capacity of the smallest on-site appliances is 4 PE, it is unlikely that manufacturers would be willing to produce smaller capacity appliances without large enough market needs.

The most reliable way to determine the discharge of individual properties is to use actual water consumption data if available. The method is based on statistical analysis of historical data of water consumption if water is supplied by a utility. The water consumption data of public utility water suppliers are sporadic and many service providers only perform water meter readings once a year. However, the largest daily consumption or the smallest daily consumption can be estimated by applying the inequality factors. If the property has its own water supply or if its water supply will be realised in the future, various values – e.g. elementary and total consumption values; total consumption values used in sanitary engineering; total consumption values derived by the nature of building use – or methods estimating the number of drainage equipment and their concomitant use could be applied to estimate the probable wastewater discharge.

The effluent values from small group wastewater appliances are traditionally calculated using the methods applied in sanitary engineering, considering the number of sanitary apparatus, the specific discharges and their simultaneous use. Alternatively, calculations can be made by using the number of discharging units (people, guests, etc.) and the related number of specific discharges as well as by using the factor for building function.

According to EN 12056, the peak characteristic yield *(Q_m)* is defined by the following equation:

$$Q_m = K.\sqrt{\sum DU} \qquad \text{l/s}$$

where K is the flow number l/s
DU is the sum of the values of the sanitary appliances

For major installations, EN 12056 contains specific values for sanitary appliances.

Table 12
Characteristics of sanitary equipment (compiled by the author)

Sewage sanitary appliances	**DU**
Wash basin	0.5
Bidet	0.5
Shower without drain valve	0.6
Shower with drain valve	0.8
Pissoir with a rinse tank	0.8
Pissoir with pressure rinse	0.5
Standing pissoir (pissoir wall)	0.2
Sewage sanitary appliances	**DU**
Bathtub	0.8
Kitchen sink	0.8
Household washing machine	0.8
Washing machine (max. 6 kg load)	0.8
Washing machine (6–12 kg charge)	1.5
Toilet with 4 l flush tank	n.a.
Toilet with 6 l flush tank	2.0
Toilet with 7.5 l flush tank	2.0
Toilet with 9 l flush tank	2.5
Floor drain DN 50	0.8
Floor drain DN 70	1.5
Floor drain DN 100	2.0

Note: Calculations based on the former Hungarian standard (MSZ 04-134) results in higher (~ 15%) values for residential buildings.

Under the auspices of the British Water, several environmental organisations have jointly published specific discharge values for BOD and ammonium N to calculate the load on small wastewater treatment plants, pocket plants (up to 1,000 PE). These values are indicative in the absence of domestic investigations.

Table 13

Specific values for home and other community discharges (compiled by the author)

Discharger	**BOD (g/person. or activity.d)**	**NH_4-N ([g/person. or activity.d)**	**Wastewater discharge l/person. or activity.d**
Homes			
Resident	60	8	200
Recreational vehicle with full comfort	75	8	180
Operational facilities			
Service/industry without kitchen	25	5	50
Service/industry with kitchen	38	5	100
Industrial area (e.g. under construction) without kitchen	25	5	60
Staff full time (8 h)	38	5	90
Staff part-time (4 h)	25	3	45
Educational institutes			
No boarding, with kitchen	38	5	90
No boarding, no kitchen	25	5	50
Boarding school			
Students	75	10	200
Staff	38	5	90
Catering services			
Hotel Guest (Luxury Hotel)	105	12	300
Hotel Guest (3 or 4 stars)	94	10	250
Guest (without meals)	50	6	80
Conference facility guest (full service)	150	15	350
Conference Facility Guest (without accommodation)	25	2.5	60
Beverage shop, pub, etc.	15	5	12
Holiday home with wooden houses	94	10	227
Housekeeping staff	75	10	180
Restaurant			
Luxury category	38	4	30
Heating kitchen	30	2.5	25
Snack-bar dishes	19	2.5	15
Separate room with buffet supply	19	2.5	15
Fast food (e.g. by road)	12	2.5	12
Fast food chain (burger, etc.)	15	4	12
Dormitory (accommodation only)	56	5	100
Recreational facilities			
Toilet block (per use)	12	2.5	10

Discharger	BOD (g/person. or activity.d)	NH_4-N ([g/person. or activity.d)	Wastewater discharge l/person. or activity.d
Toilet (per use)	12	2.5	10
Pissoir (per use)	12	2.5	5
Toilet block for daytime parking/truck parking	19	4	10
Shower (per use)	19	2	40
Golf Club	19	5	20
Local Sports Association (e.g. squash, football)	25	6	40
Swimming pool	12	2.5	10
Sport club/centre	19	4	50
Camping with tents	44	8	75
RV area			
Occasional visitors without other services	44	8	100
Permanent user without other services	44	8	100
Permanent user (full service)	75	8	180
Hospitals, sanatoriums			
Elderly Home, Nursing Home	110	13	350
Small hospital	140	n.a.	450

Table 14
Specific PE values of other discharge types according to German data (compiled by the author)

Discharger	Unit	PE value
School with showers	per student per student	0.2 0.1
Baths	per visitor	0.15–0.3
Cinema, sports ground	in some places	0.05
Restaurant, inn	in some places	1
Discharger	**Unit**	**PE value**
Highway motels	per bed	1.5–2.0
Ports	per ports	3.5
Campsite	per tent places	1.75
Hotel, resort	per bed	1
Office, shop	per employee	0.2–0.4
Workshop (without shower)	per employee	0.5
Industrial plant without industrial wastewater (with showers)	per employee	1
Bakery, confectionery, hairdresser	per employee	1–1.5
Butcher shop	per employee	15
Hospital	per bed	1.5–3.0
Barracks	per person	1.2–3.0

Some standards (e.g. DIN 4261) consider installations small equipment if the sewage load is no more than 8 m^3/d. According to the EU harmonised standard, the 50 PE limit results in LE_Q = 200 l/PE.d. However, according to the standard MSZ EN 12566, prefabricated small on-site appliances shall be designed for a specific effluent discharge of 150 l/person.d.

Table 15
Equivalents of various small group dischargers according to Mall AG (compiled by the author)

Description	Unit	PE
House, cottage	1 bed or 1 room	1
School	4 students	1
Sports hall	15m² hall area	1
Administrative building, office buildings, factories (without industrial wastewater)	3 employees	1
Catering, hotel	1 bed	1
Restaurant	3 slots	1
Great hall or garden of a restaurant	20 places	1
Frequent restaurants, e.g. highway rest area, guest house	1 seat	2
Movie	40 seats	1
Campsite	1 ha	80
Military housing	1 bed	1
Hospital, nursing institution	1 bed	2

Small appliances can be sized based on the number of residents. At least 4 people per > 60 m^2 and 2 per < 60 m^2 should be calculated. For other buildings (offices, workshops, taverns, etc.) the corresponding equivalents are calculated according to the tables above.

In the case of residential properties, no domestic measurements or research are available for intraday discharges. In accordance with the MSZ EN 12566 standard, the standard values of hourly discharges for homes and residential properties with few homes may be taken into account according to the figure below.

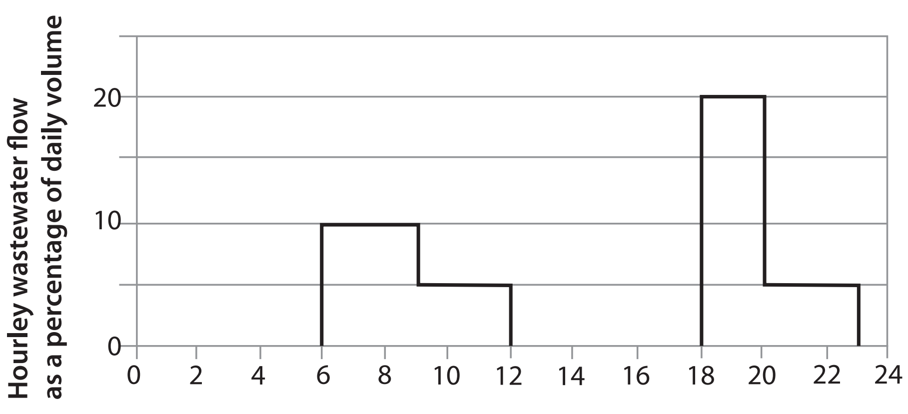


Figure 28
Intraday fluctuations of sewage yield (compiled by the author)

Up to 10–12 PE, bathtub draining – 200 l of water in 3 minutes – can be considered peak discharge, which is approximately 1.1 l/s or 4 m^3/h.

Specific quality characteristics of wastewater

The temperature of wastewater is basically determined by the temperature of the drinking water used. There are water basins in the Great Plain where the temperature of the extracted water is well above 20°C, sometimes near 30°C. Although water treatment, storage and distribution have temperature-reducing effects, due to domestic and institutional use, the temperature of wastewater, even in winter, is well above the normal temperature. Regardless, the temperature of wastewater entering the small equipment, or at least its first unit, is higher than that of the sewage entering wastewater treatment plants, because the transport route is no more than a few tens of meters inside the property and the amount of waters with temperature reducing capacity (precipitation, infiltration, etc.) is small, or, in case of expert channel design and use, it is negligible.

The temperature of wastewater affects oxygen solubility, which influences the oxygen delivery capacity of the aeration unit. Biological activity is also temperature dependent; a slightly higher temperature is favourable for biochemical processes.

The pH of fresh domestic sewage is slightly higher than that of the sewage in municipal sewage networks. However, in anaerobic cleaning units the rotten state lowers the pH.

The microbiological load of wastewater basically arises from human water use and wastewater discharge. Microbiological characteristics of wastewater are mainly characterised by two parameters: total coliform bacteria and fecal coliform (CFU/ml). These two parameters are highlighted because coliforms and fecal coliforms are indicators of pathogenicity, are routinely tested in microbiological laboratories, and are affordable. Additionally, there are a large number of various microorganisms in wastewater. Of these, only certain groups are identified as specific target groups, mostly pathogens, e.g. viruses and streptococci.

Some microbiological characteristics of raw and treated wastewater are summarised in Table 16.

Table 16
Concentration ranges for some microorganisms in raw and treated wastewater in industrialised countries (compiled by the author)

	Raw sewage (e/ml)	**Treated wastewater (e/ml)**
Total coliform	10,000–1,000,000	500–20,000
Fecal coliforms	3,000–500,000	100–15,000
Fecal streptococci	500–50,000	20–1,500
Viruses	100	–10

Pollutant loads on small wastewater treatment plants

The majority of wastewater generated in settlements is domestic wastewater. In terms of environmental load, the most significant is organic matter expressed as BOD_5 (or COD) in wastewater. The PE number is currently used to determine the capacity of sewage treatment plants. Currently, people equivalent (PE) of 60 g/person.d is considered for specific domestic discharge that has been set as a standard in the EU Water Protection Directive and has been included in the relevant Hungarian legislations. With this specificity, organic matter loads from non-residential wastewater discharger (e.g. industrial) can also be expressed.

Note that the population equivalent of BOD_5 is a specific non-universal constant that varies among countries and in time. In Hungary, in the 1960s, PE of 38 g/person.d was used, whereas in the United States it is 75 g/person.d today.

Further specific discharge parameters per capita used in Hungary and other EU countries expressed in g/PE.d are the following:

Table 17

Hungary specific pollutant emission parameters per 1 PE (compiled by the author)

BOD_5	COD	TSS	N	P
60	120	70	11	2–2.5

Table 18

Specific pollutant loads per population equivalent, according to MALL, a manufacturer of small appliances, probably based on U.S. data (compiled by the author)

Total solids	90 g TS/d
BOD_5	75 g/d
COD	150 g/d
TOC	50 g/d
TKN	14 g/d
NH_4-N	7g/d
TP	2.2 g/d

These data are above normal European standard values and should be treated with caution.

Concentrations depend on the amount of wastewater per capita. In Hungary, specific domestic wastewater discharge can be between 80 and 130 l/capita. Within these limits, for three specific wastewater discharges, the concentrations for the above five parameters are the following:

Table 19

Pollutant concentrations at different emissions (compiled by the author)

Wastewater discharge l/PE.d	BOD_5 as mg/l	COD as mg/l	TSS as mg/l	total N as mg/l	TP as mg/l
80	750	1,500	875	138	25–31
100	600	1,200	700	110	20–25
130	460	920	530	85	15–19

The specific pollutant discharges for segregated domestic wastewater may be taken into account according to Table 20.

Table 20

Discharge values for specific pollutants in greywater (compiled by the author)

Parameter	**Quantity g/PE.d**
BOD_5	24.6
COD	49.2
total N	0.33
TP	0.18

Table 21

Discharge values for specific pollutants in yellow water (compiled by the author)

Parameter	**Quantity g/PE.d**
BOD_5	7.2
COD	14.4
total N	9.57
TP	0.9

Table 22

Discharge values for specific pollutants in brown water (compiled by the author)

Parameter	**Quantity g/PE.d**
BOD_5	28.2
COD	56.4
total N	1.1
TP	0.72

For household wastewater parameters BOD_5, COD, total N and total P the following values could be considered, broken down by water use:

Table 23

Pollutant concentrations (g/m³) from discharges from different domestic water uses (compiled by the author)

Place of origin type of wastewater	**BOD_5**	**KOI_k**	**total N**	**TP**
Kitchen wastewater	10	13	0.5	0.7
Bathing, showering	4	4	–	0.05
Hand washing	3	4	–	0.05
Toilet use	36	84	11	1.6
Washing	7	15	0.5	0.1
Altogether	60	120	12	2.5

The above data refer to raw sewage. Even in case of small wastewater treatment plants, after mechanical pretreatment (settling tank, septic tank), wastewater quality changes and this should be considered.

Wastewater quality after mechanical treatment can be taken into account by using values given in Table 24 (Swiss data):

Table 24

Wastewater quality parameters after mechanical treatment (Mall) (compiled by the author)

Parameter	Concentration mg/l
TSS	120
Organic solids	80
BOD_5	150
COD	280
DOC	45
total N	32
TKN	30
Dissolved TKN	25
NH_4-N	20
NO_3-N	1
TP	7
Dissolved P	5

In case of settled wastewater, values in the following table may be taken into account for the relationship between the various parameters:

Table 25

Quality parameters of settled wastewater (compiled by the author)

Average values of settled wastewater (Switzerland)	as mg/l	Empirical values of Canton Schwyz mg/l
COD/TOC	3.4	3.7
COD/BOD_5	1.8	2.8
$KMnO_4$/BOI_5	2.8	
TOC/BOD_5	0.53	0.7

The average concentration of nutrients in raw sewage of domestic sewage: nitrogen ~ 100 g/m^3, phosphorus 20 g/m^3, potassium 60 g/m^3.

Ideal nutrient ratios for biological treatment:

COD: TKN: P = 100:5:1

BOD_5: NH_4-N:TP = 500:4:1

COD: NH_4-N:TP = 100:4:1

Non- or slowly degradable substances include salts, metals and toxic metals, surfactants, antibiotics, contraceptives, hormones and other drugs, as well as endocrine disruptors.

Salts – mostly chloride, sulphate, nitrate, and to a lesser extent phosphates – pass through sewage treatment processes without reduction, in fact, during the process of organic matter decomposition their concentration increases and burdens the recipients.

Surfactants can be found in laundry detergents, softeners, shampoos and reduce the surface tension of water. Their impact on wastewater treatment processes and soil is rather unknown. However, it is known that during the decomposition of surfactants other surfactants may be formed.

Municipal wastewater contains ions of various metals and heavy metals that are discharged from the wastewater treatment processes partly via treated wastewater effluent or incorporate into sewage sludge and get discharged with it. Domestic wastewater discharges are a minor source of metal and metal compounds. To the best of our knowledge, it is not a problem in small-scale treatment processes, but they are present in the sludge.

Pharmaceutical compounds and drug residues used in households can also be found in domestic wastewater. If they are not decomposed, they can clearly end up in the soil and groundwater as well as in sewage sludge.

Endocrine disrupting substances can enter the raw sewage from certain products (medicines, paints, etc.). They are numerous and their amount in the raw or on-site treated domestic wastewater is unknown.

The intraday fluctuations of pollutants vary depending on the pollutant parameter. Fluctuations can be taken into account according to Table 26.

Table 26

Intraday fluctuations in wastewater yields and pollutants (compiled by the author)

	Sewage yield	TSS	BOD_5	TKN
Max./min. load	3.1	6.3	7.6	5.5

Quality parameters of wastewater collected in the sewage tank can be taken into account according to Table 27 (based on the former ME 10 459-1 1994):

Table 27

Quality parameters of wastewater collected in wastewater storage tank (compiled by the author)

Parameter	Value as mg/l
BOD_5	110
COD	2,900
SS	2,200
NH_4-N	60
TP	34
pH	6.5–7.5

Loads for small appliances are usually expressed in BOD_5 (alternatively in COD). In the absence of either, the missing data can be replaced by the BOI_5/COD ratio, or they can be mutually verified knowing that BOD_5 concentrations have a high deviation.

The daily values of pollutant loads are given. In order to consider these values representative, the concentration should be measured by using 24-hour composite samples in proportion to volume or yield and to multiply it by the daily yield. Thus, for calculating daily pollutant loads, the point sample is inaccurate, misleading. In general practice, sampling every 2 hours and applying the associated 2 hours average yield are considered appropriate.

To dimension wastewater treatment equipment and to determine the concentration of each pollutant, the practice recommends using weekly averages that can be calculated based on four calendar days.

Targeted sampling can also be used to determine these data with a 4–6 week monitoring period, which should include winter (cold) periods and, if appropriate, seasonal large or low load periods.

If longer time series (up to one year) are available, analysis of wastewater temperature, COD, COD weekly average, COD/BOD_5, TKN/COD, TSS/COD, TP/COD ratios can help eliminate seasonal effects.

Dimensioning of settlers

Despite the fact that the size of settlers used in wastewater treatment is based on different sedimentation theories, routine calculation methods based on residence time and surface hydraulic loads are in principle applicable to decentralised wastewater treatment plants, too. At the same time, the intermittent nature of wastewater discharges must be taken into account, which does not occur in municipal sewage treatment plants with continuous-load settlers used. Furthermore, the geometry of settlers should also be considered which only takes building and manufacturing aspects into account as opposed to the geometric ratio required for large settlers' hydraulic conditions.

Therefore, septic tanks that are mostly non-partitioned and used for small wastewater treatment equipment can be dimensioned by using guide values of resident number or population equivalent as a rule of thumb. This time it is preferable to use values BOI_5 (LE_Q). In Hungary, the LE_Q value should be between 100–130 l/person.

The specific gravity of the settling tank can be added as follows:

- 500 l/LE_Q for standard equipment with a minimum working capacity of 2.0 m^3
- 500 l/LE_Q applied before a constructed wetland with a minimum working capacity of at least 4.0 m^3, or above 4 LEQ the volume can be further increased by 75–25%

In the upper capacity range of small wastewater treatment equipment or above 50 PE, a two-story settler could be a technical solution that pre-settles sewage in an engineered structure and is also suitable for storing and cold digesting settled sludge. The disadvantage of this application is high clear height, which is unfavourable from a construction point of view in areas with high groundwater levels and requires pumping power during installation.

If the settler or the sludge space is also used to receive and store excess sludge from biological treatment, the volume can be further increased depending on the technology of the biological equipment (see further chapters).

Table 28

Reference values for dimensioning two-level settlers based on former Hungarian technical standards and guidelines (compiled by the author)

	MS 15302-62	OVHMI 146 / 1-71	ÉSZ 511-75	MI 10-127 / 9-84
Specific useful volume of the settler l/PE	–	30	–	
Settling space min. useful volume m³	–	1.5	–	
Specific useful volume of digestion area l/PE	–	60	–	
Min. useful volume of digestion area m³		3	–	

Note: 1 PE = 100 l/person

Dimensioning of septic tanks

Septic tanks are traditionally designed based on per capita volumes. In case of a simple septic tank, the specific volume is 300 l/capita according to DIN. The smallest total volume is 2 m³, or 4 m³ in the case of two-chamber structures. The expanded septic tank serving up to 6 people has a specific volume of 1,500 l according to DIN 4261-1 and a minimum volume of 6 m³. At the same time, the DWA-A 262 gives a specific useful volume of an additional 750 l/capita up to 10 people and 5,000 l/person for over 10 people for plant beds.

For sizing the standard volume of septic tanks, the following relation is known (Ireland):

$$V = 0.15 \times N + 2.0 \ [m^3]$$

where N is the number of dischargers, with at least 4 people

From this relation, the useful volume of the smallest septic tank is 2.6 m³.

Table 29

Changes in design parameters of septic tanks in Hungarian regulatory publications (compiled by the author)

	MS 15302-62	OVHMI 146 / 1-71	MI 10-127 / 9-84
Specific useful volume l/PE	–	300	–
Minimum useful volume m³	–	3	3

Note: 1 PE = 100 l/person

According to DIN 4261-1, the decrease of organic matter expressed in BOD_5 can be considered by using the following values:

- for simple septic tanks 10 g/person.d
- for expanded septic tanks: 20 g/person.d

Small wastewater treatment systems with activated sludge

Small activated sludge systems can be scaled by methods used in wastewater treatment. However, in small SBR systems fluctuations in wastewater yields are not only much greater than those occurring at large SBR sites, but the lengths of both small and large discharge periods are long, can even be months. As a result, the importance of long-term equalising storage increases. However, to adequately scale the offsets, it is necessary to be able to estimate not only the fluctuations of discharges but also their length over time.

Trickling filters and immersion disc biological treatment equipment

Trickling filter technology can be scaled using techniques commonly used in wastewater treatment. When calculating the BOD_5 load of the trickling filter, BOD_5 decrease due to pretreatment should also be considered. The BOD_5 volumetric load value is usually low unless an equalising storage is available to provide uniform load.

As a guide value, a volumetric load of 0.15 kg BOD_5/m^3.d (or below) and a minimum fill height of 1.50 m may be considered.

In addition to the above method, a simplified method for sizing filters can be used; a specific filling volume of 150 l/PE is used, but to ensure non-clogging operation and comply with discharge requirements, a minimum of 2.0 m^3 of filling should be built in.

The table below summarises the specification recommendations of the former Hungarian technical regulatory publications, which essentially corresponds to DIN data.

Table 30
Changes in design parameters of septic tanks in Hungarian regulatory publications (compiled by the author)

	MS 15302-62	OVHMI 146 / 1-71
Specific filling volume	–	$0.3 m^3$/PE
Min. filling volume m^3	–	15 m^3
Filling height	–	1.5–2.5 m
Filling particle size	–	3–8 cm

Note: 1 PE = 100 l/person

Immersed disc trickling filters can be scaled based on specific surface loading of BOD_5. In case of immersed disc trickling filters, with equipment of less than 50 PE lower surface loads may be used compared to structures for 50–500 PE. The recommended surface BOD_5 load should not exceed 0.004 kg BOD_5/m^2.d.

The post-settling can be scaled for residence time and surface hydraulic load. Due to the balancing effect of antecedent structures (sedimentation-septic tank, biological reactor), 1/10 of the daily standard yield can be used. Recommended design parameters:

– residence time: ≥ 3.5 h
– surface hydraulic load: ≤ 0.4 m/h

Due to the usual engineering constructions, a minimum water depth of at least 1 m and a minimum sedimentation area of 0.7 m^2 are usually achieved.

In case of a separate storage compartment for the storage of excess sludge, its size can be calculated by using a specific volume of 100 l/PE.

Membrane bioreactors

In principle, equipment with membrane filtration and activated sludge system can be operated with up to 20 kg/m^3 of activated sludge, but in practice, due to rapid clogging of membranes and difficulties in quasi-continuous cleaning, they are scaled up to 8–12 kg/m^3 of activated sludge.

Other sizing parameters used in wastewater technology:

BOD_5 volume load	< 0.75 kg BOD_5/m^3
sludge load	< 0.05 kg BOD_5/kg dry matter/d

The guiding design value for determining the volume of the membrane reactor is 0.25–0.2 m^3/PE.d. The lower value should be used for small equipment for 50 PE, the higher value is for a few PE.

Otherwise, design methods applied for large facilities can be used for membrane technology with activated sludge systems.

The filtration capacity, the filtration performance of the membranes is expressed in flux. Flux is the volume flow rate of permeate flowing through a unit of membrane surface, generally expressed in l/m^2.h. The magnitude of the flux depends on the magnitude of the transmembrane pressure. Considering this, the term permeability is used, which is the flux at a given transmembrane pressure and is generally expressed in l/m^2.h.bar. Both parameters are characteristic of a given membrane, but the latter also indicates membrane blockage during operation.

For membranes used in small installations, the filtration capacity ranges between 2 and 10 l/m^2.h. Manufacturers also make membrane modules with a filter area of 3.5–6 m^2 for small equipment (4 PE). In small equipment with larger capacity, these modules are built in side by side or above each other. In engineered structures or container wastewater treatment equipment, large membrane modules are used.

Wastewater lagoons

The minimum depth of aerated wastewater lagoons is 1.2 m. There is no domestic regulation for sizing small wastewater treatment plants. The sizing is based on resident number, taking into account a lagoon surface of 15–20 m^2 per capita, as well as by using the following equation:

$$A = N\frac{185 - N}{9} \quad [\mathrm{m}^2]$$

where N is the population

To be on the safe side, the smallest lagoon is 100 m^2.

In non-aerated lagoons, residence time is about 20 days, in aerated lagoons it can be reduced to about one third (min. 6 days).

In case of lagoons replenished with roof water or storm water runoff, an additional lagoon surface of at least 10 m^2/100 m^2 can be calculated.

In sewage filtration and disposal systems using particulate matter (infiltration, sand filtering, wetlands, etc.), decomposition of residual organic matter treated at least biologically continues. The efficiency of decomposition depends on the aeration of the disposal system. Gaps in the three-phase particulate medium are filled with air along with water, which will be intermittently – preferably for most of the operating time – in contact with the atmosphere. Limiting factors of biochemical oxidation processes include biomass of microorganisms adhering to the surface of particulate medium or to suspended particles, as well as the transfer oxygen from the gaps of the filling medium. Characteristics of the gas phase, which is important for oxygen transfer, are influenced by geotechnical, biological and partly climatic conditions.

The gas phase is usually confined to coarse pores; water present in medium-sized pores represents usable water capacity, while fine pores are occupied by dead water.

When examining the change in the distribution of air along depth, it can be assumed that the ratio of the gas phase decreases by depth, possibly even by approaching groundwater. The reason for this is that water content increases downwards. The gas phase is distributed between air ducts in the inner air circulation connected to the atmosphere and blisters or so-called inclusions. The latter develop when sewage trickles from top to bottom and air ducts become clogged, making it difficult for or preventing the air to escape from the pores. Inclusion can also occur when anaerobic conditions are formed, provided that sufficient readily biodegradable organic material is available which, upon anaerobic decomposition, predominantly produces hydrogen and methane. Downwards in the infiltration or filter material mixture water content increases, the gas phase becomes increasingly significant in larger pores, and the proportion of air inclusions decreases.

The composition of air may differ significantly from that of atmospheric gases, mainly caused by organic matter decomposition. In wetlands, if the system is not anaerobic, along with aerobic processes, root respiration also plays a significant role in using oxygen and increasing carbon dioxide content.

The ratio of carbon dioxide to atmospheric air is significantly higher and the amount of oxygen is reduced to the same extent.

The relative humidity of the air in the pores is high, can be 100% in an operating system due to the large water-air interface relative to the size of the pore space.

The composition of air is also influenced by temperature, at lower temperatures, oxygen is more soluble in water and the oxygen content of the air is lower. Changes in air composition due to temperature fluctuations are significantly mitigated by the temperature equalising effect of continuous wastewater supply.

Oxygen transfer for organic matter decomposition in natural aeration sand filtration systems has been found to be 15–25 g O_2/m^2.d, while in reed systems it is 13–20g O_2/m^2. Oxygen demand is substantially influenced by oxidisable substances present in wastewater (organic matter, ammonium) in addition to the oxidising capacity of granular media in semi-natural wastewater systems.

Processes are fundamentally similar to those of trickling filters. However, there are significant differences. Wastewater is in contact with both the biomass and air for a short time, contact time is low and hydraulic load is relatively high due to intermittent feeding. These adverse effects cannot be counteracted by the theoretically stable functioning of sessile biomass.

By comparison, specific design values for residence time and population equivalents for each wastewater treatment system according to the literature are shown below:

Table 31
Some design data for different wastewater treatment systems (compiled by the author)

	Surface/PE m²/PE	Volume/PE m³/PE	Contact time
Non-aerated lagoon	10	15–20	> 20 d
Soil infiltration	4–20	7–12	–
Non-aerated lagoon	3	4–7	> 3–6 d
Sand filter	4–6	4–6	1 h – 7 d
Trickling filter with nitrification	0.17–0.3	0.45–0.6	6–10 min.
Activated sludge	0.12–0.25	0.35–0.6	1–3 d
SBR	0.1–0.2	0.3–0.5	1–3 d
Trickling filter tray with immersed disc and nitrification	0.1–0.18	0.17–0.25	10–20 h
Trickling filter without nitrification	0.05–0.08	0.13–0.18	3–6 min.
Trickling filter without nitrification	0.04–0.07	0.07–0.13	8–15h
Biofilter with nitrification	0.005–0.01	0.02–0.03	30–50 min.
Biofilter without nitrification	0.004–0.01	0.013–0.03	20–40 min.

In sand filtration systems, the efficiency of biological treatment, and thus the operational safety, can in principle be improved by increasing the filter medium volume, reducing the hydraulic and biological load and by intensifying aeration. A realistic increase in filling medium volume is possible by increasing the length of filter trenches and fields, which is often hindered by lack of space. Biological load can be reduced by recirculating the filtered water or by aerating the wastewater entering the filter. Aeration of the filling medium of the filter can be improved by auxiliary technical solutions aiding natural air exchange through drainpipes or by switching to artificial aeration.

Sand filter trench and field

The design of sand filter trenches or fields varies from country to country. It is designed by considering specific infiltration surface or ditch length for one resident or population equivalent, although we can see examples in Hungary for design based on surface load. Loading values of sand filter trenches related to the bottom surface area, bottom surface load or to the length of the filter bed are summarised in Table 32; for comparison, DIN standard values are also provided.

Table 32
Values of parameters for sizing sand filter trenches in national technical regulatory publications are shown below (compiled by the author)

MS 15302-62	–
OVHMI 146 / 1-71	$2m^2/PE^{I}$
ÉSZ 511-75	–
MI 10-127 / 9-84	0.25–0.35 m/d
MSZ 15287: 2000	0.1–0.15 m/d
German recommendation	6 m/per capita^{II}

Note: ^{I} 1 PE = 100 l/person. ^{II} Approximately corresponds to $3m^2$/per capita.

The values in the table show a rather varied picture of design principle and of the design data. The data has been incorporated into regulatory documents from engineering practice, and over time, filtering surfaces have become larger based on the parameters, pointing to a lower specific load. In practice, the most acceptable method is dimensioning for surface loading.

According to CEN/TR 12566-5, the load capacity of sand filters is 4 $l/m^2/d$, which is significantly lower compared to the data in the table.

Sizing of plant beds

It is very important to emphasise that only mechanically treated wastewater can be fed to plant beds. The conventional sizing of bed filters is based on per capita surface area, specific surface load expressed in COD and surface hydraulic load.

According to DWA-A 262 guidelines, design parameters applicable to effective bed thickness of at least 50 cm are summarised in Table 33.

Table 33
DWA-A 262 guidelines

	Constructed wetlands with horizontal subsurface flow	**Vertical flow constructed wetland**
Specific bed surface area m^2/per capita	≥ 5	≥ 4
Minimum bed surface area m^2	≥ 20	≥ 16
Surface organic matter load g $COD/m^2.d$	≤ 16	–
Surface hydraulic load $l/m^2.d$	≤ 40	≤ 80

UV disinfection

If UV equipment is used for disinfection, the UV dose for disinfection shall be 250–400 J/m^2. Irradiation time should not be less than 3 seconds under normal design conditions at maximum load.

The electrical power consumption of UV equipment is 10–13 W/m^3. Total power requirement must be calculated taking into account the power absorbed by the pump pumping water to the UV system, which can be calculated by using a specific value of 35–70 W/m^3.

Note: Higher specific values should always be considered for smaller capacity units.

Disposal of treated wastewater

Recipient of treated wastewater can be either surface water or soil (and through it groundwater). Among subsurface waters, principally groundwater found in the unconfined aquifer is affected.

Discharge of treated wastewater is prohibited if the location of the property is subjected to conditions of connection to the municipal sewage system; if discharge into surface water is not possible due to technical, economic, ecological or water hygiene criteria; if infiltration is close to drinking water or reserve water catchments; if the area is sensitive or highly sensitive to pollution; if water permeability of the soil layer or layers affected by infiltration is unfavourably low.

General requirements for infiltration of treated wastewater include:

- Wastewater with domestic wastewater quality is treated at least mechanically and biologically.
- Biological purification shall include at least nitrification technology. If groundwater is contaminated with nitrate (above the limit value), the treatment technology should also be capable of denitrification.
- Infiltration should be near-surface, but should not result in open water surface.
- Infiltration should preferably take place in a homogeneous soil layer.
- Infiltration should be designed to be protected against freezing in winter.
- Professional operation of the treatment and disposal system is ensured.

Design of soil absorption systems

Surface infiltration is elemental. Direct discharge of wastewater into groundwater is not permitted. There is no direct connection if the deepest point of the absorption system is at least 1 m above the highest groundwater level.

Options of soil infiltrations:

- infiltration
- surface infiltration trenches
- infiltration shaft
- infiltration shaft and field

In case of near-surface infiltration, water is evaporated into the atmosphere and is absorbed by surface vegetation and soil microorganisms, and predominantly, the sewage seeps into deeper soil layers and fills their gaps. Soil infiltration can be used if the soil is capable of infiltrating wastewater treated at least biologically.

For hygienic reasons, only biologically treated and at least post-filtered water can enter the infiltration unit.

Infiltration trench and field sewage disposal are sometimes referred to as underground irrigation. These solutions perform mechanical filtration and aerobic biological treatment before the effluent is filtered into the soil or possibly reaches groundwater.

Drainpipe is laid in a gravel layer that must be sealed at the top. Geotextile, which permeates water but prevents soil particles penetration, is suitable for this purpose. A layer of at least 10 to 20 cm thick soil is placed above the infiltration unit, into which short-rooted plants can be planted. The best solution is grassing, which is easily maintained and causes minimal damage to vegetation when the filter media is changed.

The purpose of a thicker infiltration body at the bottom of the infiltration trench is temporary storage of treated wastewater. It is beneficial to construct a thicker infiltration layer consisting of an upper coarse particle layer and a lower finer sharp grit. The slit drainpipe in the upper layer of the infiltration body serves the even distribution of wastewater. The drainpipe has a slit size of about 3 mm and the particle size of the surrounding infiltration layer should be selected according to the filter rule.

For the construction, ventilation and feeding of the drain line, the same rules apply as for sand filters.

The lower level of the infiltration unit must be 1 m above the highest groundwater level – according to national regulations. Internationally, mostly similar regulations are in effect.

Table 34 shows the most important parameters for designing infiltration trenches and fields based on Hungarian regulatory documents; for comparison DIN data are also shown.

Table 34
Evolution of design parameters for the formation of infiltration trenches in Hungarian regulatory publications (compiled by the author)

	MSZ 15302-62	OVHMI 146 / 7-71	ÉSZ 511-75	MI 10-127 / 9-84	MS 15287: 200	German recommendation
Min. bottom width	0.5 m	0.5 m	–	0.6	0.6 or 0.9 m	1.8–0.5 m
Drainpipe distance	min. 2 m[I] min. 3 m[II]	–	–	2 m	min. 2 m[I]	min. 1 m
Max. drain branch length	30 m	30 m	–	25 m	25 m	min. 7.5 m max. 15 m
Drain layers thickness particle size					min. 10 cm 5–10 mm	1.0 m 4–8 mm (0.5 m) 2–4 mm (0.5 m)

Note: [I] With 50 cm trench width. [II] With 90 cm trench width.

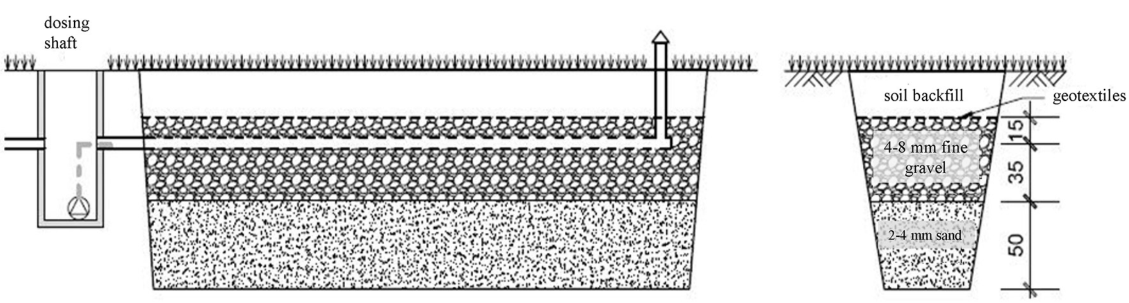


Figure 29
Design of infiltration ditches (compiled by the author)

The infiltration shaft is made of concrete or reinforced concrete of at least Ø 1 m, its wall is perforated at the bottom and its bottom is open. The perforated part is filled with fine gravel with at least 50 cm of sand on top of it. A concrete plate is placed under the inlet pipe to prevent leaching.

Infiltration blocks and tunnels originally used for the infiltration of rainwater are suitable for the infiltration of the treated sewage into soil. Both types of infiltration elements are hollow inside with a pierced surface on each side. The column-shaped infiltration elements can be optionally assembled, tunnel elements can be arranged in a longitudinal direction. Infiltration elements are assembled on a gravel bed at the bottom of the raised trenches, then the infiltration body is covered with geotextile and the space between the trench wall and the elements is filled with gravel. The infiltration body can be filled with a sewer pipe attached to its end or with a drainpipe installed above it.

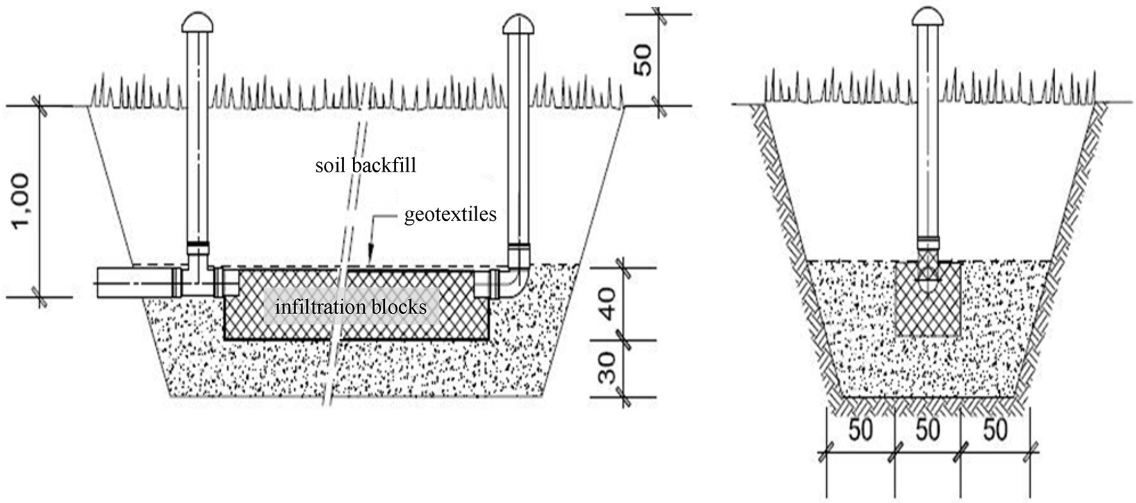


Figure 30
Infiltration unit with infiltration block (compiled by the author)

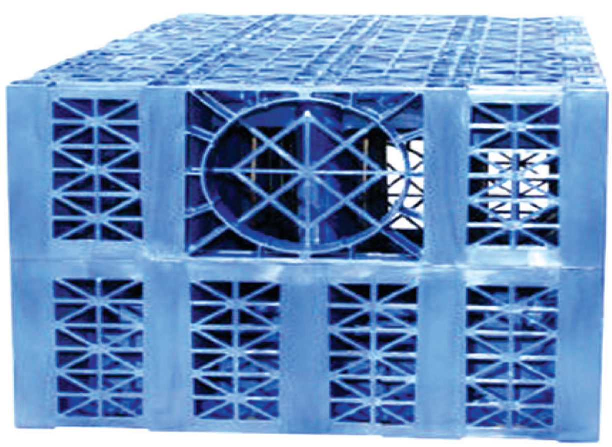


Figure 31
Plastic infiltration block (Mall AG) (compiled by the author)

Sizing of sewage disposal facilities

Calculating the deposition of treated wastewater in soil is based on the capacity of soil infiltration. The infiltration capacity of the soil can be tested. Water should infiltrate within an hour without leaving puddles. The infiltration surface can be determined from this, but it must be safely increased, this may differ among different sources, but we can find examples of up to 50% increase.

The Pönninger method is used for infiltration test. For performing the test, a research shaft must be opened at the site to a depth of the planned level of infiltration. At the bottom of the shaft, a 30 × 30 cm deep pit should be dug and filled with water. For pre-wetting the soil, two additional fillings are needed. The pit should then be filled with water up to a height of 25 cm. During infiltration, the level of water is measured every minute. The average value of data obtained from triplicate repetition of the test gives the infiltration factor in min./cm.

The infiltration factor should be assigned to the soil type of the infiltration layer according to the classification based on sand-sludge ratio.

Table 35
Specific load bearing capacity of trenches according to various regulatory documents (compiled by the author)

	MSZ 15302-62	OVHMI 146 / 7-71	ÉSZ 511-75	MI 10-127 / 9-84	MSZ 15287: 2000
Specific load $m^2/(m^3/d)$	In sandy soil 16 In clay sand 25 In light clay 50	See the relevant chapter (Small equipment standards, technical specifications, guidelines)			

The sizing of infiltration is used to determine the surface size of the infiltration area required. Horizontal and vertical parts of the infiltration surface can be considered as useful infiltration surfaces.

According to some regulations (e.g. MI 10-127 / -9), in addition to the size of the lower plane of the infiltration unit, if the soil adjacent to the side of the infiltration unit is also suitable for infiltration, 1/3 of the height above the bottom may be considered infiltration surface. For vertical infiltration surfaces, DIN standard defines a value of 1 m^2/per capita.

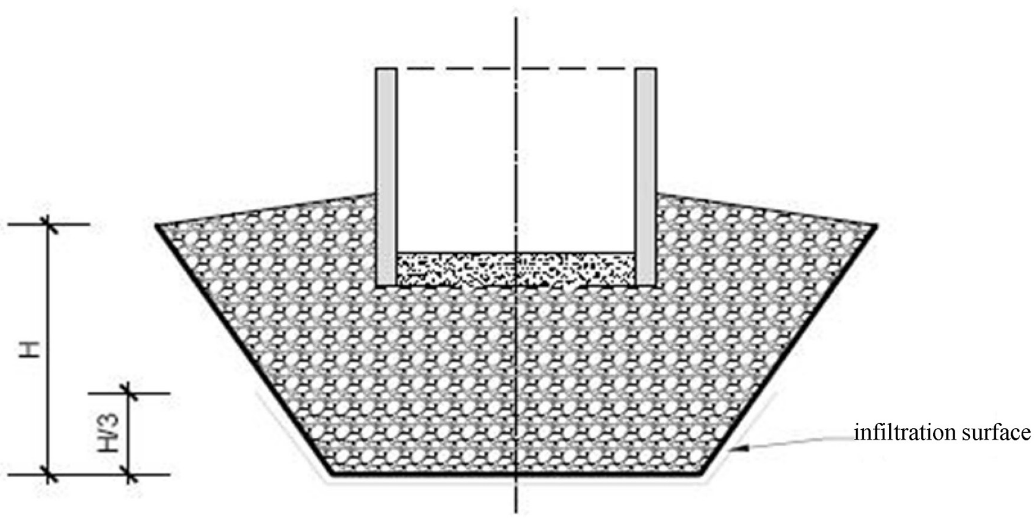


Figure 32
The infiltration surface to be considered (compiled by the author)

According to CEN / TR 12566-2: 2005, with a trench depth of 0.5 m at least 18 rm of infiltration trench per capita should be considered, irrespective of the soil infiltration capacity. The length of a trench is up to 18 m.

Disposal of wastewater treatment by-products

During wastewater treatment, by-products, such as screenings, sewage sludge and other substances such as plant residues in plant beds systems and lagoons remain.

Screening is waste containing a large amount of inorganic and relatively little organic matter (mostly polymers). Screen formed during mechanical treatment in small wastewater treatment equipment should be dewatered, compacted and stored in a container or bag, if the mechanical grid is of a suitable design.

Sewage sludge is a potentially significant source of water and nutrient as well as a potential source of environmentally harmful substances. In addition to heavy metals, other organic and inorganic materials may be present in sewage sludge.

Long-term, well over ten years sludge accumulation in aerated sewage lagoons is well stabilised and rotted. For this reason, it is only worth transporting it to a wastewater treatment plant for dewatering; further mineralisation at the wastewater treatment plant is not necessary.

Sludge produced from non-aeration lagoons can be used in agriculture. Compliance with the legislation on the use of sewage sludge in agriculture is needed. For agricultural utilisation, the composition of sewage sludge should be checked at regular intervals (every five years). If sewage sludge is of poor quality for agricultural use, other ways of disposal should be considered.

Regulations for installing small appliances

Wastewater flows from sanitary wares (washbasin, toilet, bath, shower, washing machine) through the branch line and drain line into the main line. Because these pipes need to be ventilated over the roof, air enters the water, thus, reducing concrete corrosion. In addition, due to the chimney effect, the small equipment is also aerated, especially at the pretreatment unit. For that, the duct and intermediate wires leading to the small unit should have a size of at least DN 100.

Sites that are sensitive to groundwater quality, areas with high groundwater status, water basins and future water basins, as well as karst areas, are not suitable for installing on-site wastewater treatment equipment. In these areas, it is a minimum requirement that the municipal wastewater treatment program allows their installation, or infiltration is not prohibited for reasons of water protection.

Choosing the site of installation: should be accessible at all times and transport of sludge can be achieved by conventional vehicles.

Operation and maintenance

General rules

Decentralised sewage treatment plants must, in principle, be operated by the owner, but the obligation is transferable. Where facilities are installed as part of a program in a well-defined area, the operation may be carried out by a responsible service provider with a high level of specialist training. The responsible service provider is responsible for keeping a logbook, maintaining, sampling and examining samples, sending the data to the water authority and performing any other operational tasks (e.g. repair).

If the installation is a single installation and the emissions exceed 500 m^3/year, the sampling should be performed annually and samples should be tested.

Modelling of on-site wastewater treatment plants

For on-site wastewater treatment plants, the method of wastewater sampling will depend on the nature of the recipient: for surface water a qualitative grab sample, for soil infiltration a qualitative grab sample or 24-hour composite sample should be used.

Qualified grab sample is a mixture of at least five grab samples with a sampling interval of at least 2 minutes taken within a maximum of two hours. For the 24-hour composite sample, grab samples should be taken at least every hour and a sample is taken from the mix, or continuous sampling (with an automatic sampler) may also be used.

In case of lagoon treatment, the sample should be free of algae and should therefore be filtered through a glass cloth.

Figure 33
Sampling vessel (Lausitzer Klärtechnik Catalogue) (compiled by the author)

Dichromatic oxygen consumption (COD_k) and ammonium nitrogen (NH_4-N) should be measured, while in case of soil infiltration, all inorganic nitrogen (TN_{inorg}) also has to be measured. Determination of other parameters is optional, the facility operator will decide on target parameters necessary for inspection.

These include in particular:

– dissolved oxygen
– temperature
– pH
– settable materials
– sludge level

Biological wastewater treatment plants are expected to decompose organic matter only, thus, its efficiency should be judged. Measuring nitrogen compounds and phosphates may be necessary to comply with regulatory requirements.

Operational tasks for OWTS

Substances interfering with the treatment process shall not be introduced into small equipment. For example, industrial wastewater (if their quality differs from that of domestic wastewater), other waters (drain water), cooling water, swimming pool drainage, rainwater, bulk materials, fats, oils, acids, untreated condensation water of fire protection systems, strong cleaning agents, disinfectants, medicines and other chemicals if their amount and concentration exceed that of found in domestic sewage.

In case of settlers and septic tanks, it is advisable to check the inlet more frequently in order to prevent backflow due to plugging.

It is sufficient to remove sedimented sludge from settlers and septic tanks once a year or, as a general rule, if half of the useful volume of the structures is filled with sludge. In case of septic tanks, at the time of removal approximately 20 cm of sludge layer should be left in the first compartment to “inoculate” the newly settled sludge. Floating sludge must be removed from each compartment during sludge removal. In settlers at sludge removal, the structure can be completely emptied; there is no need to leave sludge for inoculation.

The operational control of biological wastewater treatment plants is different, depending on, for example, whether the owner is a non-professional or a competent specialist with appropriate equipment.

The concentration of activated sludge is important for an experienced person. The right concentration of biomass in the system is an important condition for the operation of activated sludge equipment. This can be verified by a simple 30-minute sedimentation test by sampling the sewage sludge from the aeration into a 1 l measuring cylinder. During sedimentation, activated sludge and sewage must be separated by a sharp boundary. After 30 minutes of sedimentation, the amount of sediment should be recorded in ml, the result is the sludge volume concentration. The sludge is considered suitable when the volume is between 120 and 600 ml. Below 120 ml, sludge content is too low, for SBRs, 400–600 ml/l is the normal range, above 600 ml it is too high.

If sludge concentration is too high, a part of the sludge, the excess sludge must be removed. Sludge can be taken off by a pump and usually passed to the pretreatment unit.

Sufficient oxygen must be available in the reactor for proper biomass function. An oxygen concentration of 1–2 mg/l is suitable. Too low oxygen concentration can be caused by too high pollutant load; it can occur if too much influent wastewater reaches the equipment compared to its capacity or the organic matter content of the wastewater is too high. Such situation can occur very suddenly if a lot of organic matter is discharged into the sewage (blood from animal slaughter, alcohol from wine making, etc.). Oxygen concentration can only be measured by a suitable probe. The easiest way to test oxygen supply is to measure it shortly after the blower is turned on. In this case, air bubbles should be fine and evenly distributed on the water surface of the diffuser. If bubbles do not meet this requirement, it may be a result of improper function of the diffuser; most often, a part of the membrane is not permeable for air. If bubbles of cm size appear on the surface of the water, air may escape from the air inlet pipe at the connection, or the membrane is ruptured. The above problem can be solved by repairing the seal; in case of a membrane rupture, the diffuser must be replaced.

In SBR units, the activated sludge settles after the aeration cycle according to the set cycle time. After the settling phase, settled wastewater is pumped by a pump or syphon into the drainpipe or into a sampling container of a few litres preceding the drainpipe. Sedimentation is measured by measuring turbidity, or by visual inspection. Turbidity measurement requires a turbidity meter, which is usually only available in the laboratory. By visual inspection, the transparency of wastewater is easily measured. Transparency is a measure of the degree to which the water loses its transparency due to the presence of suspended solids.

In the settlers of aerobic equipment, deposit may develop as a result of the flotation of activated sludge flakes. Floating sludge can be removed with a simple pot with a handle. The sludge removed can be placed into the sludge space of the pretreatment unit.

In case of activated sludge systems, serious problems occur during periods without long-term wastewater supply. Most of the activated sludge systems recover from a 7 to 10 day period without wastewater supply. For that long or slightly longer periods without wastewater supply, a storage system with quantitative and qualitative balancing storage unit provides a good solution. But for longer periods, if small appliances supply one housing unit (e.g. 4 PE), e.g. residents during vacation, the equipment has to be switched to an economy mode. Economy mode means that during the wastewater-free period, a minimum amount of water and nutrients – at least some carbon source – for keeping the biomass functioning must be replenished. Replacement wastewater can be obtained from purified wastewater, but the system must have a smaller storage tank for treated wastewater of up to 100 l of useful volume, from where it can be recycled to the biological unit. This can be done with a pre-installed, low-flow, level-controlled pump. In principle, it is possible to obtain sludge water from a sludge storage tank (settler, septic tank), but it requires a technically costly and complex solution. A more convenient and technically simpler solution may be the intermittent introduction of an external carbon source (e.g. acetic acid) into the activated sludge reactor or to the recirculating water stream. The dosing unit consists of a dosing pump, a solution tank and a control unit (essentially a timer).

In case of a trickling filter system, conditions for achieving the appropriate wastewater quality are the following:

- wastewater with low suspended solid content can be led to the trickling filter, which requires high efficiency pretreatment (settling)
- wastewater shall be introduced intermittently onto the trickling filter and distributed evenly over the surface medium
- organic matter load should be kept low, the trickling filter should be prevented from drying out, and for both requirements treated wastewater should be recirculated intermittently
- for a proper ventilation of the filling medium, the right size of medium should be chosen

Development of puddles on the surface of the filling medium indicates blockage, which may be recovered by either washing the top layer with high-pressure water or by extracting the thicker layer of the medium and flushing the sludge clogging the gaps. The use of disinfectant (hypo) is contraindicated as it causes severe damage to the biofilm.

According to the law, the municipality is responsible for organising the safe disposal of sludge from the equipment.

Economic aspects

The spread of professionally designed and constructed small appliances can be expected if their installation and operation costs do not exceed specific installation costs of centralised sewage systems, or the standard sewage fees in the area. Central wastewater treatment and disposal systems are implemented only through some form of financial subsidy, thus, it can reasonably be expected from the government to develop and operate an equivalent system supporting the installation of small appliances. The creation of a joint unit of up to 50 PE for group sewage dischargers should be particularly supported, provided that operation is undertaken by the agglomeration sewer service provider.

The investment cost of developing a sewage pipe between the given property and the public sewage system, as well as the calculated unit cost of central sewage treatment capacity may be a theoretically feasible, rational financial support source for the installation of small equipment.

Operating costs include maintenance and restoration costs (e.g. replacement of filling medium, membrane, etc.), amortisation costs of the installation, energy costs where appropriate, costs of removal, treatment and disposal of sludge generated.

In case of small appliances, the life-cycle cost approach should also be emphasised.

The cost of installing small appliances is particularly difficult to estimate, especially due to the diversity of products, the wide range of supply by manufacturers, and the huge variation in installation and construction costs.

The approximate investment costs of 700–800 thousand HUF/property for the CE-certified septic tanks and 1,100–1,200 thousand HUF/property for small equipment are included in the 2016 recommendations of HWA for individual wastewater treatment and disposal. In the same recommendation, the operating costs of 450–500 HUF/property for septic tanks and 4–5 thousand HUF/property for small equipment are heavily underestimated, especially in the life cycle approach.

A chart based on 300 different small equipment, manufacturers' price lists and offers, as well as installation and operating costs provide a more sophisticated view of sewage treatment plants up to 50 PE (Germany, 2003). It is clear from the chart that unit costs have a wide range; there can be up to 1.5–2 times difference between the upper and lower values in smaller size equipment, while the difference is smaller, about 0.6–0.7, in larger equipment.

Major operating costs include maintenance costs, electricity costs and sludge removal costs. Maintenance costs include the cost of periodic inspections, wastewater analysis, warranty and repair costs. The costs of operating small equipment depend on the type of equipment and its size. For smaller units, the difference between the minimum and maximum unit costs can be up to three times, and for larger units this difference is two-fold. Electricity costs, according to 2003 figures, were well above 100 Euros for an average household, and much lower for semi-natural sewage treatment systems. The annual electricity cost per resident was around 10–30 Euros for engineering structures and 2–5 Euros for semi-natural systems.

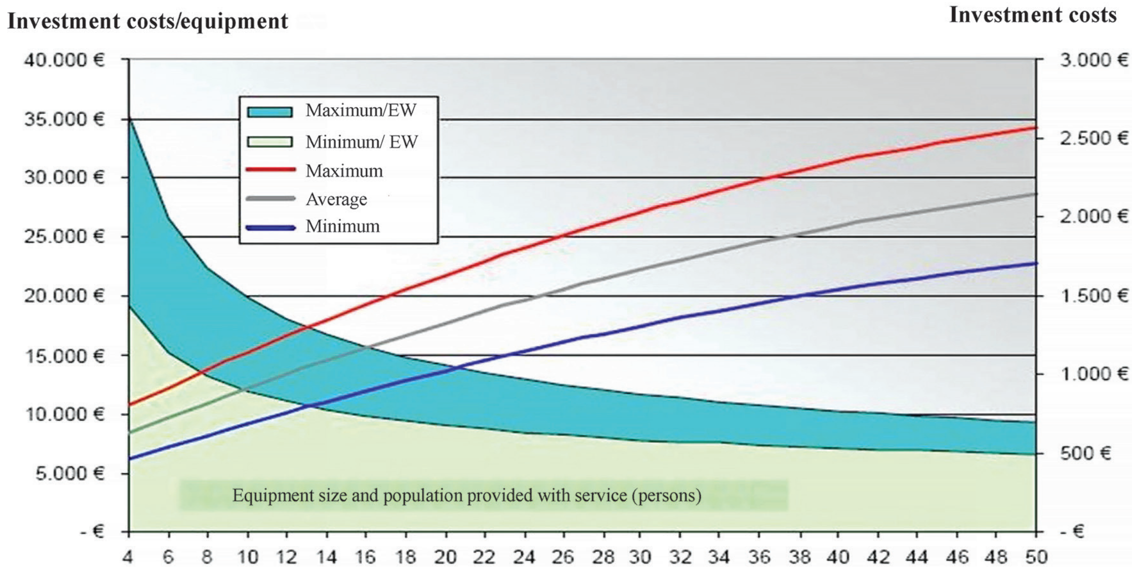


Figure 34
Specific investment costs (compiled by the author)

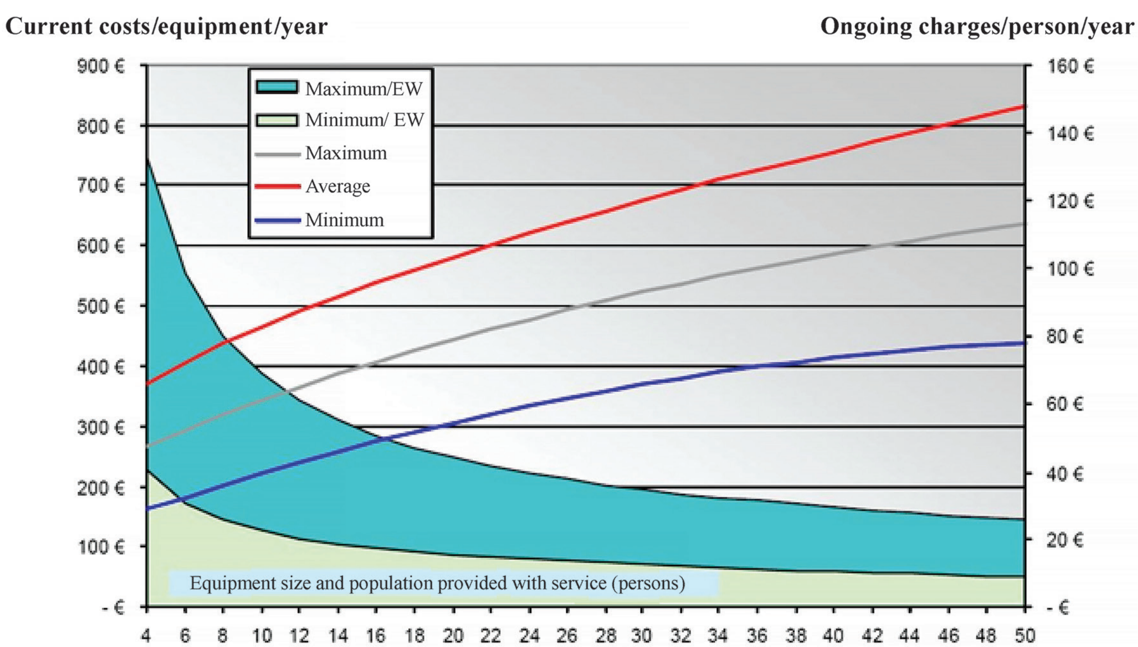


Figure 35
Running costs of small equipment operation (compiled by the author)

The following table shows energy requirements of small wastewater treatment equipment broken down by technology based on different U.S. sources:

Table 36
Energy requirements of small wastewater treatment plants depending on different technologies (compiled by the author)

Technology	Hydraulic load m³/d	Specific energy consumption kWh/m³
Facultative lagoons + rapid infiltration	3,786	0.11
Facultative lagoon + surface infiltration	33,786	0.16
Aerated plant beds	5,500	0.16
Intermittently flooded plant beds (filling–emptying)	1,000	0.18
Oxidation ditch	3,786	0.51
Trickling filter with nitrogen removal	3,786	0.61
With activated sludge nitrification	3,786	0.76
Complete oxidation equipment	3,786	1.06
SBR	303	1.13
Living machine	3,786	1.51

Table 37
Specific installation and operating costs (compiled by the author)

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Net per property</th><th rowspan="2">30 year net installation and operation costs (HUF)</th><th rowspan="2">Cost ratio compared to the most expensive 30 years net installation and operational cost (%)</th></tr>
<tr><th>Construction cost (HUF/ property)</th><th>Operating cost (HUF/ m³)</th><th>Operating cost (HUF/ year)</th></tr>
<tr><td colspan="2">Closed sewage storage system</td><td>500,000</td><td>1,580</td><td>156,000</td><td>2,726,263</td><td>100</td></tr>
<tr><td colspan="2">On-site small wastewater treatment unit</td><td>750,000</td><td>170</td><td>16,700</td><td>954,688</td><td>35</td></tr>
<tr><td rowspan="2">Sewerage + sewage treatment plant</td><td>< 600 PE</td><td>1,100,000</td><td>1,000</td><td>98,550</td><td>2,452,844</td><td>90</td></tr>
<tr><td>600–2,000 PE</td><td>980,000</td><td>920</td><td>90,400</td><td>2,255,054</td><td>83</td></tr>
<tr><td rowspan="2">Sewerage + semi-natural sewage treatment</td><td>< 600 PE</td><td>850,000</td><td>640</td><td>63,300</td><td>1,705,522</td><td>63</td></tr>
<tr><td>600–2,000 PE</td><td>750,000</td><td>570</td><td>55,800</td><td>1,519,574</td><td>56</td></tr>
</table>

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SE 511-75 Sewage treatment and sewage treatment structures. Design requirements.

MI 10 127 / 9-84 Treatment plants for municipal wastewater. Small wastewater treatment structures and appliances.

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Questions

1. What are the rules for designing simple and extended septic tanks?
2. Outline the conceptual design of a small continuous flow activated sludge unit by indicating each material flow.
3. What is the operating principle of the SBR system? Which specific operating alternatives would you use in small appliances?
4. What is the conceptual design of trickling filters and how do they work?
5. What is the conceptual design of immersion discs and how do they work?
6. How do membrane bioreactors work?
7. What are the small, semi-natural wastewater treatment plants and what are the main design methods?
8. How can treated wastewater be disposed of? What are the principles for sizing small wastewater disposal plants?