Deutscher Verein des
Gas- und Wasserfaches e.V.

DVGW

REGELWERK

www.dvgw-regelwerk.de

Technical Rule – Standard
DVGW W 213-1 (A) July 2023

Filtration Methods for Particle Removal;
Part 1: Basic Concepts and Principles

Filtrationsverfahren zur Partikelentfernung;
Teil 1: Grundlagen und Grundbegriffe

WATER

The DVGW is the technical and scientific association of gas and water engineers and comprises approximately 14,000 members. For 160 years, the DVGW has been setting the technical standards for the safe, secure and reliable supply of gas and water, actively initiating the exchange of ideas and information in the gas and water sectors and encouraging and promoting on-going progress in the sectors through practical guidance.

The DVGW is an independent non-profit organisation free from economic lobbyism and political influence.

The DVGW Set of Rules is a key instrument for the DVGW to meet its statutable purpose and accomplish its tasks. The DVGW Set of Rules notably defines, on the basis of statutory regulations, the requirements on technical safety, hygiene, environmental protection, fitness for use and consumer protection and organisation for the supply and use of gas and water. The DVGW Set of Rules ensures that the DVGW complies with the statutory principle of self-responsibility of the utilities, for the benefit of technical safety and hygiene as well as environmental and consumer protection.

Note for users

The DVGW Set of Rules rests on the following principles:

- The DVGW Set of Rules has been elaborated in an honorary capacity in accordance with the applicable principles (DVGW Constitution, Rules of Procedure GW 100). On the basis of jurisdiction, both the content and the technical information can be assumed to be correct.
- Everybody can use the DVGW Set of Rules. Duties and obligations may arise from legal or administrative regulations or from a contract or from other legal grounds.
- Nobody can abdicate their responsibility for correct action when applying the DVGW Set of Rules. Anyone applying the DVGW Set of Rules shall ensure its correct application in each concrete case.
- While the DVGW Set of Rules is not the only source of knowledge when looking for professional solutions, it does constitute an important source of such knowledge. It cannot however cover all possible special cases that may require more comprehensive or restrictive measures.

Warning

This English-language version is an informal translation from the German original. However, only the original German language version has been exclusively authorised by the DVGW and its Technical Bodies. The DVGW reserves the right to revise this version at any time due to possible translation errors.
Anybody is free to use the DVGW system of rules. Users are responsible for the proper use of the DVGW system of rules in each individual case.

ISSN 0176-3504

Price group: 3

DVGW German Technical and Scientific Association for Gas and Water

Josef-Wirmer-Straße 1–3
D-53123 Bonn

Phone: +49 228 9188-5
Fax: +49 228 9188-990
Email: info@dvgw.de
Internet: www.dvgw.de

Distribution: Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Josef-Wirmer-Str. 3, D-53123 Bonn
Phone: +49 228 9191-40 · Fax: +49 228 9191-499
Email: info@wvgw.de · Internet: shop.wvgw.de
Art. Nr.: 312641 W

Contents

Foreward

This standard has been prepared by the “Filtration” project group of the DIN-DVGW-Working Group NA 119-07-14 AA “Wasseraufbereitungsverfahren”. It covers the basic concepts of water treatment for the removal of particles. Particle removal via filtration plays a key role in water treatment. The ability of filters to retain harmful (micro)biological substances, in particular, ensures high standards of water hygiene. DVGW Standard W 213-1 defines the basic concepts and principles of particle removal and, therefore, forms an important basis for DVGW Series of Standards W 213 Part 2 through Part 6. In the future, DVGW Guideline W 213 Part 7 will also cover microscreens and protective filters used both for pre-treatment and as a process step in its own right and discuss them in greater detail. Said DVGW Guideline is currently being prepared.

This Standard supersedes DVGW Standard W 213-1:2005-06.

Amendments

The following amendments have been made compared to DVGW Standard W 213-1:2005-06:

a) Update of references to the Drinking Water Ordinance, the white list ”Liste zulässiger Aufbereitungsstoffe und Desinfektionsverfahren”, issued by the Umweltbundesamt (German Environment Agency), and to the DVGW Set of Rules

b) Update of monitoring, sensor and maintenance possibilities in respect of water treatment methods for particle removal

c) Amendment of the definitions of technical terms relating to filtration methods for particle removal

d) Greater coverage of micro- and ultrafiltration techniques

Earlier editions

DVGW W 210:1983-08

DVGW W 211:1987-09

DVGW W 213-1:2005-06

1 Scope

This Standard covers the principles of particle removal in the treatment of drinking water for public supply. It focuses on the removal of particles in the treatment of waters that may be susceptible to interference from surface waters, in particular river, lake, dam, spring, karst and fissure waters or water obtained from riverbank filtration.

DVGW Series of Standards W 213 Part 3 through Part 5 describe water treatment methods that have been specifically designed for particle removal. DVGW Standard W 213-2 and DVGW Standard W 213-6, respectively, cover the assessment and application of granular filter media and the monitoring of water treatment methods for particle removal.

This series of standards does not cover artificial groundwater recharge, which is described in DVGW Standard W 126 "Design, Construction and Operation of Plants for Artificial Groundwater Recharge for Drinking Water Abstraction".

Likewise, this Standard at hand does not cover processes aimed at e. g. adjusting the pH value of water or removing iron, manganese, organic substances or heavy metals. Such processes also employ the use of filters and can, in certain circumstances, run simultaneously with the particle removal process. These processes are covered in the DVGW Standard series W 223 (Removal of Iron and Manganese) and in DVGW Standards W 214-2 (pH Adjustment), W 239 (Organic Matter Removal) and W 249 (Removal of Heavy Metals).

2 Normative references

The following documents cited are required for the application of this document. For dated references, only the referenced edition shall apply. However, parties making use of this part of the DVGW Set of Rules are encouraged to consider the most recent editions of the normative documents indicated below. For undated references, the latest edition of the referenced document shall apply (including any amendments). Listed DIN standards can be part of the DVGW Set of Rules.

DVGW W 126 (A), *Design, Construction and Operation of Artificial Groundwater Recharge Facilities for Drinking Water Abstraction*

DVGW W 202 (A), *Technical Rules Water Treatment (TRWT) – Planning, Construction, Operation and Maintenance of Drinking water Treatment Plants*

DVGW W 204 (A), *Treatment chemicals in Drinking Water Supply – Rules for Selection, Provision and Quality Assurance*

DVGW W 213-2 (A), *Filtration Processes for Particle Removal; Part 2: Assessment and Application of Granular Filter Media*

DVGW W 213-3 (A), *Filtration Processes for Particle Removal; Part 3: Rapid Sand Filtration*

DVGW W 213-4 (A), *Filtration Processes for Particle Removal; Part 4: Slow Sand Filtration*

DVGW W 213-5 (A), *Filtration Processes for Particle Removal; Part 5: Membrane Filtration*

DVGW W 213-6 (A), *Filtration Processes for Particle Removal; Part 6: Monitoring via Turbidity and Particle Measurement*

DVGW W 214-2 (A), *pH-Adjustment in Drinking Water Treatment; Part 2: Planning and Operating of Filter Systems*

DVGW W 217 (A), *Flocculation in Water Treatment*

DVGW W 219 (A), *Use of Anionic and Non-ionic Polyacrylamides as Flocculation Aids in Water Treatment*

DVGW W 221-1 (A), *Residues and By-products from Drinking Water Treatment Plants; Part 1: Principles for Planning and Operation*

DVGW W 222 (M), *Introducing Residues from Water Treatment Plants into Wastewater Treatment Plants*

DVGW W 223-1 (A), *Removal of Iron and Manganese; Part 1: Basic Principles and Methods*

DVGW W 239 (A), *Application of Activated Carbon for Organic Matter Removal in Drinking Water Treatment*

DVGW W 249 (A), *Removal of Arsenic, Nickel and Uranium during Water Treatment*

DVGW W 254 (A), *Principles of Raw Water Surveys*

DVGW W 290 (A), *Disinfection of Drinking Water; Requirements and Conditions of Application*

DVGW W 291 (A), *Cleaning and Disinfection of Drinking Water Distribution Systems*

DVGW W 1000 (A), *Requirements on the Qualification and Organisation of Drinking Water Utilities*

DVGW W 1001 (M), *Security of Drinking Water Supply – Risk and Crisis Management*

DVGW W 1060 (M), *IT-Security – Standard for Water Supply/Wastewater Utilities*

DIN 2000, *Central drinking water supply – Guidelines regarding requirements for drinking water, planning, construction, operation and maintenance of supply plants*

DIN 19605, *Fixed bed filters for water treatment – Structure and components*

DIN EN 12901, *Products used for treatment of water intended for human consumption – Inorganic supporting and filtering materials – Definitions*

DIN EN 15975-1, *Security of drinking water supply – Guidelines for risk and crisis management – Part 1: Crisis management*

DIN EN 15975-2, *Security of drinking water supply – Guidelines for risk and crisis management – Part 2: Risk management*

Verordnung über die Qualität von Wasser für den menschlichen Gebrauch (Trinkwasserverordnung – TrinkwV) [Ordinance on the Quality of Water Intended for Human Consumption, Drinking Water Ordinance – DWO]

Empfehlung zur Vermeidung von Kontaminationen des Trinkwassers mit Parasiten – Empfehlung des

Umweltbundesamtes nach Anhörung der Trinkwasserkommission des Umweltbundesamtes (BGBI. 2001 44:406–408 © Springer-Verlag 2001) [Recommendation on the Prevention of Drinking Water Contamination with Parasites – Recommendation of the German Environment Agency after Consultation with the Drinking Water Committee of the German Environment Agency]

List of approved substances for the treatment and disinfection of drinking water in accordance with the Drinking Water Ordinance issued by the German Environment Agency

Vergabe- und Vertragsordnung für Bauleistungen (VOB) [Construction Tendering and Contract Regulations]

3 Definitions

3.1 Differential pressure

Difference in pressure between the filter intake and the filtrate side

3.2 First filtrate (pre-filtrate)

Filtrate of a filter with granular filter media that is discharged immediately after the filter has been cleaned (see sub-Clause 3.8) and that does not meet the specified quality requirements

3.3 Filter

An apparatus for filtration (see sub-Clause 3.14), including the necessary water supply and discharge equipment, the equipment required for filter cleaning and the ICA instruments

3.4 Filtration area

a) Filters with granular filter media: Inner cross-sectional area of the filter, excluding the area of filter fixtures

b) Membrane filters: Membrane area through which the water passes during filtration

NOTE: Usually given in m²

3.5 Filtration runtime

Operating time of a filter between two consecutive filter cleaning operations

3.6 Filtration run volume

The total amount of water flowing through the filter between two filtration runs

NOTE: The terms “total throughput” or “filtration quantity” are used synonymously in the field.

3.7 Filter medium

Filtration layer of a filter

NOTE: The filter medium may consist of granular materials or, alternatively, of porous membranes.

3.8 Filter cleaning

Umbrella term describing all measures employed to restore the efficiency of a filter

3.9 Filter backwashing

Filter cleaning method involving flushing the filter medium – usually in the opposite direction of filtration – with water (backwashing with water), air (backwashing with air) or a combination of the two (water/air backwashing). Other backwashing options exist for membranes.

3.10 Filter resistance

Differential pressure produced during the operation of a filter

3.11 Filter efficiency

Particle removal efficiency of a filter, usually defined by the change in particle concentration or turbidity

NOTE: Given as a percentage of retention or in logarithmic scale

3.12 Feed

The water supplied to the filter

3.13 Filtrate (filter outlet)

The water that has passed through the filter medium and runs off

3.14 Filtration

Reduction of particle concentration as a fluid is passing through a filter medium

3.15 Filtration rate

Filtrate volume flow rate per unit area of the filter

NOTE 1: In membrane filters the filtration rate is also called flux, surface loading and filtrate flux rate.

NOTE 2: Usually given in $m^3/m^2/h$ = m/h or $l/m^2/h$.

3.16 Slow sand filter

Hydraulically open, in operation permanently submerged filters with granular filter media and large filter areas without an integrated flushing device, that operate at low filtration rates (0.05 m/h – 0.3 m/h)

NOTE: Unlike infiltration basins (see also DVGW W 126 (A)), which are not covered in this standard, slow sand filters collect and discharge the filtrate in a controlled manner.

3.17 Membrane filter

Filter with porous membranes as filter media

3.18 Microscreens

Strainers with a mesh size of approx. 5 µm – 300 µm.

NOTE: This standard mentions microscreens only as pre-treatment devices. DVGW W 213-7 (M) will cover microscreens in the future.

3.19 Surface filtration

Filtration process that traps most particles on the top surface of the filtration layer (area of the filter media exposed to the flow of liquid)

3.20 Particles

Solid substances in water, suspended matter, suspended solids, colloids

NOTE: See also DVGW W 213-6 (A)

3.21 Particle breakthrough

Deterioration of the filtrate quality that begins when the particles to be removed are no longer fully retained by the filter medium

NOTE: The term “filter breakthrough” is used synonymously in the field.

3.22 Sludge containing water

Water that accumulates when a filter is cleaned

3.23 Rapid sand filters

Filters with granular filter media that operate at filtration rates of several metres per hour, and with an integrated flushing function

3.24 Volume filtration (deep sand bed filtration)

Filtration process where particles are normally not retained at the surface of the filter medium but deep inside the filtration layer

3.25 Turbidity

Scattering of light, caused by particles, that reduces the transparency of the water

NOTE: See also DVGW W 213-6 (A)

4 Particle removal – necessity and objective

4.1 General

The requirements on the hygienic integrity and aesthetic quality of drinking water in respect of microorganisms and other particles shall be considered met if this Standard and the normative references (see Clause 2) are given due regard, and if the procedures described below are followed in combination with suitable steps of pre and after-treatment, if necessary.

4.2 Hygienic relevance of particles in raw water

While some particles suspended in raw water can be harmless substances, others can be pathogens or other undesirable microorganisms. Such organisms may also occur attached to or trapped inside particles. Similarly, chemical pollutants can occur either in the form of particles or attached to particles.

The particles described in this Standard at hand also include microplastic, whose hazard to health has not yet been conclusively determined.

Particles can potentially supply nutrients to microorganisms and contaminate the water distribution network through microbial growth. Additionally, particles reduce the efficiency of both UV and chemical disinfection, resulting in an increased demand for disinfectants and an increase in the formation of undesirable by-products.

For the abovementioned reasons, one of the objectives of water treatment shall be the production of drinking water with the lowest possible concentration of particles.

Efficient particle removal shall therefore be ensured by integrating suitable methods or combinations of methods into the design, construction and operation of drinking water treatment plants.

4.3 Particle removal – target values

The efficiency of a filtration method in respect of particle removal can be checked by referring to the turbidity and particle concentration parameters. DVGW Standard W 213-6 applies to turbidity and particle measurement. Target values should be individually defined for each specific treatment method, making sure that the requirements of the Drinking Water Ordinance are met with an adequate safety margin when the water leaves the waterworks. According to the Drinking Water Ordinance, turbidity must be below 1.0 NTU in all samples, and 95 % of the samples shall have turbidity values of ≤ 0.3 NTU. This rule does not apply to central water utilities that treat groundwater whose turbidity is caused by iron and manganese.

Turbidity measurements or particle counting do not render obsolete any microbiological analyses required by the Drinking Water Ordinance.

Turbid matter or particles shall always be eliminated prior to disinfection when treating surface waters and groundwater influenced by surface waters to drinking water standards. In such cases, the turbidity values shall not exceed ≤ 0.2 NTU on the filtrate side downstream of the particle removal step (see DVGW W 290 (A)). The recommendation of the German Environment Agency on the prevention of contamination with parasites proposes a monitoring concept for such treatment plants (UBA, 2001). In accordance with this recommendation, the presence of *Escherichia coli* and coliform bacteria in the water prior to disinfection is tolerable only in exceptional circumstances and, if so, in low concentrations. The drinking water disinfection procedures outlined in DVGW Standard W 290 shall be applied.

The need to eliminate turbid matter and particles prior to disinfecting spring and groundwater depends on the degree of raw water contamination. It shall be determined by a thorough analysis of the quality of the raw water and the situation in the catchment area, to be performed by skilled persons and, if necessary, with the involvement of the local authority (see DVGW W 290 (A)).

Additional analyses for determining the concentration and size distribution of particles bigger than approx. 1 µm may be useful and necessary to analytically keep track of ongoing water treatment optimisation.

5 Particle removal – methods and equipment

5.1 General

A variety of filtration methods and filter media are available that are especially designed for the purpose of particle removal and operate on the principles of sieving and surface or volume filtration. Their applicability shall be determined on a case-by-case basis. An additional pre-treatment step may be necessary or expedient.

5.2 Pre-treatment

5.2.1 Pre-filters exerting a sieving effect

Pre-filters that exert a sieving effect are primarily used as a pre-treatment prior to filtration in the treatment of surface waters, with the objective being to separate coarse particles like e. g. sand particles or plankton (unwieldy diatoms and/or zooplankton).

Pre-filters that exert a sieving effect may be e. g. drum, disc, split or edge split filters as well as screen baskets. They will in the future be covered by DVGW Guideline W 213-7.

5.2.2 Flocculation

Flocculation is a method that destabilises and coagulates particles so that they can be removed from the water. It is indispensable prior to the rapid sand filtration of raw waters contaminated with harmful substances and microorganisms. DVGW Standards W 217 and W 219 provide a detailed description of this process step. The following factors considerably affect the success of this and the downstream filtration steps:

- Type and dose of flocculants and flocculation aids,
- point of introduction of flocculants and flocculation aids,
- pH value of the flocculant, and

- energy input and dwelling time.

The optimal flocculation conditions shall be determined on a case-by-case basis.

In membrane filtration, an upstream flocculation step may positively affect filter runtimes and the effectiveness of filter backwash.

5.3 Filters

5.3.1 Rapid sand filters

A rapid sand filter (for a detailed description, see DVGW W 213-3 (A)) is basically an open or closed single-layer or multi-layer filter, with filtration rates of up to 30 m/h. Filtration rates above 15 m/h usually require pressure filters.

Generally speaking, the adequate removal of particles – including harmful particles of approx. 1 µm– with rapid sand filters is possible only in combination with a flocculant and at filtration rates significantly below 15 m/h.

Layers of granular materials are used as filter media in volume filtration (see DVGW W 213-2 (A)). Multiple-layer filters feature several materials of different density and granulation. The required thickness of the filter medium layer is, generally speaking, between 1 m and 3 m, and increases with grain size. Rapid sand filters are cleaned by backwashing with water and air, either simultaneously or consecutively,

The following factors affect particle removal efficiency:

- Particle properties,
- the filtration rate and its rate of change,
- filter media properties,
- filter layer thickness,
- filter medium structure,
- filter runtime, and
- backwash conditions.

The optimal operating parameters (filtration and backwashing) shall be determined on a case-by-case basis.

5.3.2 Slow sand filters

Slow sand filters (for a detailed description, see DVGW W 213-4 (A)) consist basically of sand (the filter medium) within a filter basin, with sand grain sizes of between 0.1 mm and 0.5 mm and a layer thickness of between approx. 0.8 m and 1.3 m. Slow sand filters operate at low filtration rates – between 0.05 m/h and 0.3 m/h – and can run for up to several months. The uppermost layer of sand is usually removed after a filter run in order to restore the efficiency of the filtration process.

For reasons relating to operating technology, it may be necessary to pre-treat the water in order to ensure sufficiently long filter runs.

The following factors affect particle removal efficiency:

- Particle properties,
- setting-in period,
- filtration rate,
- filtration runtime,
- filter media properties, and
- filter layer thickness.

5.3.3 Membrane filters

Membrane filters (for a detailed description, see DVGW W 213-5 (A)) basically consist of flat or tubular membranes, built into modules, that are made of organic polymers or inorganic material. Membranes can have different pore sizes, depending on the desired target and the particles to be removed:

- Microfiltration membranes (membranes capable of retaining most particles > 1 µm but not capable of retaining an adequate number of particles < 0.1 µm)

- Ultrafiltration membranes (membranes capable of retaining at least 99.99 % of particles between 0.02 µm and 0.03 µm [4 logarithmic scales])

Most ultrafiltration membranes are tubular polymer membranes. They block the passage of all particles that are larger than the membrane pore size, provided that the system integrity is given. The feed passes through the membranes either from the inside to the outside, or vice versa, depending on the type of membrane. The pressure gradient forces the water through the membrane.

Membrane filters are usually cleaned by backwashing with water, reversing the flow of water through the membrane. Disinfectants (e. g., chlorine) or acid/base may be added to prevent microbial growth. Additionally, more intense membrane cleaning and disinfection processes may be necessary after longer periods of time (see DVGW W 213-5 (A)).

The following main factors affect particle removal efficiency:

- Particle properties,
- membrane properties, and
- system integrity.

6 Selection and design of filtration methods – basic principles

6.1 General

The following aspects shall be carefully considered when selecting a filtration method:

- Relevant data on the quality and quality variations of raw water, e. g.:

- Temperature,
- turbidity,
- particle count (if necessary, also the associated size distribution of the particles),
- TOC/DOC,
- SAK 254,
- plankton,
- microbiological parameters,
- filterable substances, and
- suspended substances,

- potential hazard sources that might affect the raw water, in particular shock loads caused by e. g. wastewater or runoff from agricultural land, potential hazards caused by the transportation of water-hazardous substances on rail or road,

- variations in throughput, considering future developments (e. g., available water resources, storage capacities, peak demand, water permits),

- security of supply (e. g., redundancy),

- reaching other targets related to water treatment (e. g., biodegradation, DOC removal).

- All treatment chemicals and filter media must have been approved by the German Environment Agency in accordance with the white list "Liste zulässiger Aufbereitungsstoffe und Desinfektionsverfahren" in accordance with the Drinking Water Ordinance.

Only persons possessing the pertinent skills and knowledge shall be permitted to design and construct filter systems. Subcontractors shall be able to provide adequately qualified and skilled technical staff and shall be demonstrably reliable and capable of performing the commissioned task.

6.2 Efficiency

The primary objective in selecting and designing suitable processes is to ensure sufficiently effective filtration to guarantee (micro)biologically safe drinking water. Since the available methods retain harmful particles at different rates, the focus of selection shall be primarily on whether the treatment's objective can also be achieved if several unfavourable conditions coincide (e. g. a high raw water contamination and rapid fluctuations in water demand). Filtration efficiency is also affected by, among other things, combining different methods and by the sequence of their use.

6.3 Process stability

The different degrees of sensitivity of the various methods in respect of rapidly changing raw water qualities and flow variations shall be considered when selecting a method.

6.4 Pre- and post-treatment

The scope and type of pre- and post-treatment steps associated with a selected treatment method shall be considered in the context of the raw water quality.

6.5 Automation capability

The automation capability of the different treatment methods shall be considered when selecting a method. This applies especially to facilities that are not permanently staffed with qualified personnel and experience considerable raw water quality and flow rate fluctuations.

6.6 Personnel requirements/personal qualifications

Personnel and personnel qualification requirements depend strongly on both the selected method and the local conditions, in particular the potential risk of contamination of raw water (see also DVGW W 1000 (A)). Other factors to be considered include the expenditure and effort required to implement e. g. the appropriate quality assurance and maintenance measures (inspection, maintenance including sensors, repair) in the treatment plant.

6.7 Area and space requirements

The different particle removal methods vary widely in terms of area and space requirements. D**etermining these requirements** necessitates considering, among other things, the systems required for pre-treatment, the systems required to treat sludge-containing water, and ancillary facilities.

Membrane filter systems have the most favourable area and space requirements compared to volume filtration systems under identical water quality and flow rate conditions. Membrane filter systems can frequently even be integrated into existing assets. Slow sand filters, by contrast, have comparatively large area requirements. The area requirements of rapid sand filter systems depend on their design and mode of operation and are somewhere between those of membrane and slow sand filters.

6.8 Residue disposal

The disposability of residues may be a critical factor in the selection of a treatment method or treatment variant. The DVGW W 221 Series of Standards and DVGW Guideline W 222 shall be considered.

6.9 Water required for filter cleaning

The water quantities required for cleaning the filters shall be taken into account.

It may be necessary to check whether the sludge-containing water that has accumulated during the filter cleaning process has to be treated separately and/or in several stages (see DVGW W 221-4 (A)) to make sure that it can be returned to the feed of the particle separator without risking compromising the microbiological integrity of the drinking water supply.

The volume of the first filtrate, which may have to be discarded, shall also be taken into account (see sub-Clause 7.4).

6.10 Energy requirements

All available filtration methods have to overcome a pressure difference and, therefore, require energy. The amount of energy required may vary between the different methods. The actual amount of energy required may vary depending on the framework conditions, as it depends on additional factors such as the quality of the feed water and the treatment goal as well as the configuration of the selected treatment method and the local conditions.

The amount of energy required can be minimised by, e. g.,

- exploiting the initial geodetic pressure,
- using energy-efficient pumps (with a high efficiency at the bias point),
- adequately dimensioning pipelines, valves and fittings (e. g. reducing friction losses, trace of the pipeline, pipeline diameter), and
- if necessary, using ELCB control in pumping operation.

The recommendations and possible savings potentials described in DVGW Water Information No. 77 shall be considered.

The post-treatment of sludge-containing water that has accumulated during the filter backwashing and the disposal of sludge require additional energy input (see also DVGW W 221-4 (A)).

6.11 Demand of treatment chemicals and other chemicals

Treatment chemicals and other substances that are required for e. g. disinfecting and cleaning the filter systems (see also DVGW W 291 (A)) shall be taken into account including, in particular, the required effort associated with the storage of water-hazardous substances and occupational safety and health measures. The guidelines on the selection, procurement and quality assurance of treatment stages outlined in DVGW Standard W 204 shall be considered.

The requirements set forth in the list of approved treatment substances and disinfection methods published by the Umweltbundesamt (German Environment Agency) in accordance with the Drinking Water Ordinance shall be observed.

6.12 Preliminary studies

Selecting the right method requires the carrying out of preliminary studies, which are mandatory in any case prior to designing the treatment method. Pilot runs are especially recommended for plants with a high throughput rate if no experience is available with systems operating under similar general conditions.

6.13 Environmental compatibility

The LCA (Life Cycle Assessment) method should be applied to assess and compare the ecological impact of the various treatment methods. The LCA method permits the systematic and comprehensive quantification of all relevant emissions and consumed resources as well as an assessment of the impact of the different treatment chemicals, materials and energy sources on health and the environment.

7 Operation and monitoring – fundamentals

7.1 Continuous operation

The optimal mode of operation is continuous operation with regular intermittent filter cleaning phases, but without any other interruptions or downtimes. This also encompasses the most homogeneous flow rate possible and the lowest possible degree of fluctuation in raw water quality. Where water demand fluctuates greatly, however, it is frequently impossible to provide constant, homogeneous flow rates.

Filters can be adapted to fluctuations in water demand by changing flow rates or stopping the operation of individual filters, in addition to using storage capacities.

7.2 Constant filtration rate

The optimal mode of operation is continuous operation with regular intermittent filter cleaning phases, but without any other interruptions or downtimes. This also encompasses the most homogeneous flow rate possible and the lowest possible degree of fluctuation in raw water quality. Where water demand fluctuates greatly, however, it is frequently impossible to provide constant, homogeneous flow rates. Filters can be adapted to fluctuations in water demand by changing flow rates or stopping the operation of individual filters, in addition to using storage capacities.

7.3 Particle breakthrough

The breakthrough of particles shall be prevented. The operation of the filter and, if necessary, the pretreatment steps (e. g. flocculation and separation of coagulates) shall be adjusted accordingly. Measures shall be taken to ensure the early detection of a deterioration of the filtrate quality. This requires monitoring the filtrate quality, e. g. by continuous turbidity measurements (see also sub-Clause 7.10.1 and DVGW W 213-6 (A)).

7.4 Filter cleaning

The criteria that trigger a filter cleaning operation depend on the filtration method. They include, among others, loss of head, particle breakthrough, filtration runtime or filtration runtime volume. Filters shall be cleaned in due time before a relevant particle breakthrough. The cleaning procedure shall aim to restore the efficiency of the filter so that it will approximately correspond to that of the original condition of the filter prior to the filter run and with clean filter media. The filtrate that accumulates during the cleaning process shall be discharged (see also sub-Clause 7.5) unless it meets the requirements set forth in Clause 4 (first filtrate). The first filtrate may be fed back into the treatment process, provided that it does not compromise the hygienic integrity of the water to be treated (see also DVGW W 221-4 (A)).

7.5 Recirculation of backwash water

When treating microbiologically pure raw water, hygienically safe sludge-containing water that accumulated during the backwashing of the filter may be fed back into the treatment process after the solids have been removed.

When treating microbiologically contaminated raw water, water may be fed back into the treatment process only after further treatment and if the water is demonstrably hygienically safe (see DVGW W 221-4 (A)).

7.6 Commissioning

Filters shall be thoroughly cleaned and, if necessary, disinfected prior to commissioning. The filtrate produced immediately after commissioning shall be discarded or, alternatively, specially conditioned. Studies shall be performed on a case-by-case basis to determine the time required for discharging the filtrate.

7.7 Technical acceptance

The technical acceptance of filters shall take place after first commissioning, in the presence of the plant owner, plant designer, plant engineer and, if necessary, the plant operator. Proof shall be provided that the specified treatment goal can be reached (see also VOB). The result shall be documented. Efficiency checks shall be repeated at regular intervals, in particular if unfavourable raw water quality is given. Where plant operators cannot provide properly qualified personnel, external staff shall be contracted who demonstrably have the expertise to accomplish their tasks.

7.8 Decommissioning

Rapid sand and membrane filters shall be cleaned prior to decommissioning. Decommissioned filters shall be put in a condition that permits their quick recommissioning when necessary. All measures shall depend on the envisaged length of the downtime. Membrane systems shall be disinfected or preserved, if necessary.

7.9 Recommissioning

The measures required for recommissioning shall depend on the length of the downtime prior to recommissioning. Filters that were decommissioned for a short period of time generally only require a simple cleaning routine prior to recommissioning.

7.10 Monitoring

7.10.1 Turbidity monitoring

The turbidity of the filtrate on the discharge side shall be continuously monitored. If such monitoring fails to detect particle breakthrough in individual filters, it shall be extended to cover individual filters (see also DVGW W 213-6 (A)).

7.10.2 Particle concentration monitoring

Particle concentrations in the filtrate should be monitored either continuously or quasi-continuously if turbidity monitoring does not provide sufficient information about the quality of the filtrate (see also DVGW W 213-6 (A)).

7.10.3 Microbiological parameter monitoring

Regular microbiological analyses of the filter outlet water shall be performed prior to disinfecting the water in order to identify microbiological faecal indicators, in particular *Escherichia coli* and coliform bacteria as well as enterococci, if applicable. Upstream conditioning using ozone as part of the treatment impairs the meaningfulness of the information provided by the usual microbiological faecal indicators.

7.10.4 Chemical parameter monitoring

The necessity for chemical parameter monitoring of the filter outlet water shall be checked on a case-by-case basis. Pre-treatment involving flocculation requires performing an analysis in any case to detect residual concentrations of flocculants and, if applicable, flocculation aids.

7.10.5 Operating parameter monitoring

The loss of head in rapid sand and membrane filters shall be continuously measured, if necessary, and documented.

It may be necessary to monitor the filter pressure in individual cases.

The parameters listed below shall be monitored to ensure proper operation:

- Filtration runtime,
- volume flow rate,
- filtration runvolume,
- Filter resistance and filter pressure (back up levels, if applicable), and
- in membrane filter systems, additionally: Transmembrane pressure and temperature.

7.10.6 Raw water quality monitoring

Raw water quality monitoring on the basis of hygiene and processing parameters is necessary, in particular where these may change rapidly. The selected monitoring points and parameters shall offer the possibility to react in due time to an unacceptable change in filtrate quality (see also DVGW W 254 (A)).

7.11 Record keeping and documentation

As a general rule, the parameters outlined in sub-Clause 7.10 shall be entered in a process control system and kept on file. The temporal resolution of the data archiving is crucial with regard to traceability; data storage shall be adequately large for that reason. If digital recording is not an option, all operating parameters shall be recorded in an operating log.

7.12 IT and data security; risk management

Filtration methods for particle removal are generally a central element of the water treatment process and, therefore, shall fully comply with all IT and data security requirements.

DVGW Guideline W 1060 provides information on IT security. For information on risk management, see DVGW Guideline W 1001 as well as DIN EN 15975-1 and DIN EN 15975-2.