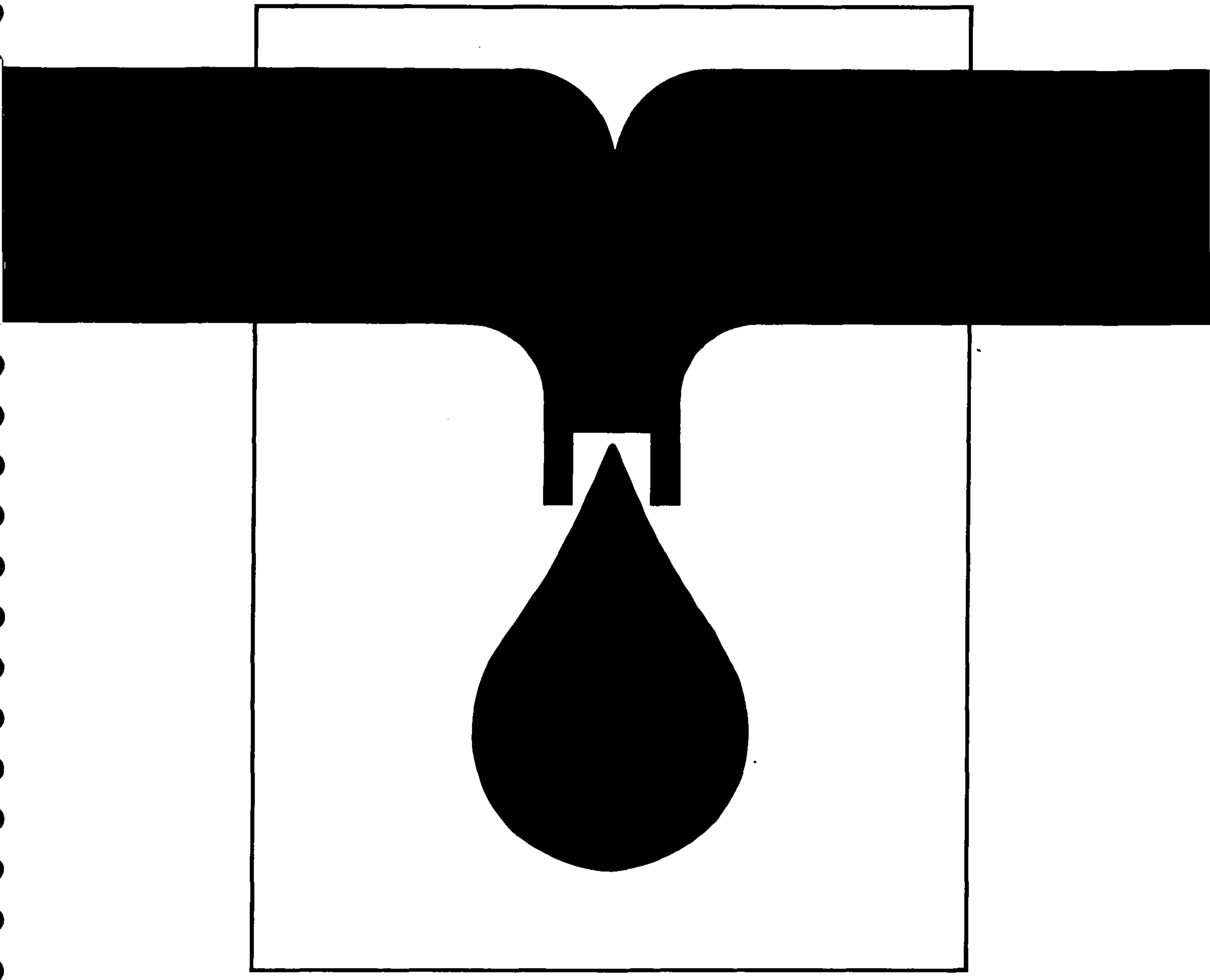
# TRAINING MODULES
# FOR
# WATERWORKS PERSONNEL



## Special Knowledge

## 2.5

### Principal components of water-treatment systems (definition and description)

## Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

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Eschborn, May 1987

Title: Principal components of water-treatment systems
(definition and description)

Table of contents:

## 1 Drift barriers

(for figures see Moduele 3.5, pages 1 to 6)

### 1.1 Definition

Drift barriers are structures which float on the surface of the water and, as their name suggests, repel floating matter such as driftwood, fragments of plants, dead animals, plastic or metal containers etc., but also oils and greases. Thus they shield and prevent possible damage to the water-treatment plant (racks, pumps, valves and fittings, pipes, sedimentation and filtration equipment etc.).

### 1.2 Systems in common use

The main part of a drift barrier is always a repeuing body - usually a wooden log - floating on the surface of the water. This log is generally anchored in one of the following ways:

- to wooden piles rammed into the river bed,
- to steel or concrete piles driven into the river bed,
- to concrete or stone weights sunk to the river bed,
- to rings concreted directly to the river bed,
- or to ropes fastened to the bank of the river.

Basically, a drift barrier is a structure which, whilst being cheap and simple to make, gives valuable additional protection to water-treatment equipment of all kinds and thus reduces the risk of breakdowns.

In minor rivers or streams, very simple structures are usually quite adequate. Preference should be given to inexpensive, locally available materials, e.g.:
- wooden logs,
- steel or hemp ropes, chains,
- simple steel clamps and rings.

Depending on the size of the water source or water quantity a single repelling log fastened to a vertical pile or to a weight is often adequate (cf. fig. 3, Module 3.5, p. 4).

Other simple solutions are construction of the intake channel at an acute angle to the the river's direction of flow (cf. fig. 4, Module 3.5, p. 5), intake of water through a pipe from below the water surface (fig. 5, Module 3.5, p. 5), or use of a downflow baffle made, e.g. of timber (fig. 6, Module 3.5, p. 6).

## 2. Intake channels and pipes for relatively small amounts of water (for figures see Module 3.5, pages 9 to 11)

### 2.1 Definition

Intake channels or pipes are used to draw off and transport water from the intake point on the river or stream to the raw-water pumping station.

### 2.2 Systems in common use:

The following versions are in general use:

a) Open systems

- Reinforced concrete channel
- Channels made of brick or natural stone, sometimes plastered. Dry-stone masonry is also possible.
- Earth channel with sloping sides, reinforced with stone in the water-bearing zone. Turfed above the paved area.
- Earth channel with vertical sides. Reinforced with wooden piles driven in vertically and wattle work of branches or wooden laths.
- Where the amounts of water are very small, channels can also be made completely of wood, or of halved oil or creosote drums.

b) Closed systems

- Pipes made of earthenware, concrete, plastics, asbestos cement, steel, cast iron, etc..

Intake channels and pipes are necessary wherever the raw-water pumping station cannot be built directly next to the river. Where the draw-off pump can be installed immediately on the river, the raw water is pumped through a pressure pipe to the water-treatment plant. Open conduits are only used in this case if a convenient gradient is available.

## 3 Stop structures for closing up open water conduits

(for figures see Module 3.5, pages 13 to 15)

### 3.1 Definition

These structures are used to isolate raw-water intake channels, or sections of them, from other parts which contain water. This is necessary e.g. if maintenance or repair work has to be carried out on the channel itself, on racks or pumps, or whenever a channel has to be cleared of silt.

### 3.2 Systems in common use

The exact design of the structure (stop log, stop plank, flashboard, dam) depends on the size and shape of the intake channel, the maximum water pressure to be anticipated in front of or behind the structure and the exact object of the measure.

- In relatively large channels or canals, stop planks made of sheet steel or aluminium are used.
- In medium-sized channels, the stop structure will be made of steel, aluminium or timber.
- For small, shallow channels, simple flashboards generally made of wood, but also sometimes of sheet steel or aluminium, are used, or else several timber baulks fitted one above the other and fixed with wedges.
- Small and medium-sized units may also be permanently installed and raised and lowered by a threaded spindle operated by a hand-wheel.

Generally speaking, open water conduits are closed off at irregular and quite widely-spaced intervals. For this reason, it is usually considered adequate to provide vertical grooves or guide baulks in the sides of the channel. Logs or planks can then be fitted into these when the necessity arises, fixed in position with wedges and the gaps closed with hemp, rags, wood fragments or similar materials.

If more extensive repairs or alterations are necessary over a longer period, a dam made of stones or earth, reinforced with vertical wooden piles or baulks, may also be erected.

If the flow of water has to be diverted into several channels (e.g. for irrigation purposes), simple flashboards made of wood or metal are adequate. Wherever possible, they should be fastened by a small chain to a stake.

## 4 Racks (for figures see Module 3.5, pages 17 to 23)

### 4.1 Definition

Racks are used where water is drawn from rivers or lakes. Their task is to catch debris and any other large solids which may be floating either on top of or below the surface of the water (e.g. logs, branches, aquatic plants, dead animals etc.). Racks protect the mechanical equipment and other components of the water-treatment plant. Various types can be used, depending on the specific application and on local circumstances.

### 4.2 Systems in common use

Generally speaking, racks are simple structures mostly designed to be cleaned by hand. Depending on the specific application, possible versions include the following:

- racks which can be pulled up vertically,
- racks which can be tilted at an angle of 15 to 45°,
- fixed (immobile) racks,
- fixed racks which are removable,
- removable suction strainers.

All racks and screens (for finer solids) can be made without difficulty from readily available materials and are easily installed and maintained. Particularly simple and inexpensive, and therefore widely used, are the racks shown in figs. 16 to 18, Module 3.5, pages 17 and 18. These require simple materials only, are effective and reliable.

## 5 Sand traps (for figures see Module 3.5, pages 25 to 28)

### 5.1 Definition

Sand traps are specially designed channels, funnels or tanks in which relatively heavy particles are allowed to settle out of the raw water - e.g. sand, gravel, ores, shells, snails.

Sand traps protect the components of the ensuing water-treatment plant e.g. racks, pumps, valves, pipes, flocculation, sedimentation and filtration equipment. If, for instance, water is continuously pumped from a river carrying large amounts of silt without a sand trap being provided before the draw-off pumps, the result is excessive wear on pump impellers, pump casings, valves, pipe elbows, etc.

### 5.2 Systems in common use

A number of different designs have proved effective. The best choice for a specific situation will depend on various factors, such as:

- the capacity of the projected plant,
- the required degree of separation,
- the amount of space available and general topography of the site,
- the availability of materials locally,
- the outlook as regards proper maintenance,
- construction costs.

After analysis of the relevant factors, one of the various possible designs will be chosen, e.g.:

- long sand trap
- cross-type sand trap
- deep sand trap
- circular sand trap
- short sand trap
- simple sand trap

Some types are comparatively sophisticated and technically complicated; often, however, very simply designed versions (cf. figs 26 to 29, Module 3.5, pages 25 to 27) are also effective and clearly much less expensive.

An effective sand trap also results if the raw-water channel is made relatively long and designed in such a way that the water flows through it slowly (at 0.2 to 0.5 m/sec), thus allowing larger suspended particles (sand, grit etc.) to settle.

## 6 Screens (for figure see Module 3.5, page 33)

### 6.1 Definition

Screens are installed after the rack and are responsible for straining out smaller solid particles floating on or under the surface of the water, e.g. pieces of wood or bark, fragments of plants, leaves, pieces of plastic, dead fish or animals.

Like the other structures already mentioned (drift barriers, sand traps, racks), screens also have the important function of protecting and preventing damage to the technical equipment of the water-treatment plant. Their main characteristic is the relatively small distance between bars or small mesh size (as compared e.g. with racks), resulting in rapid accumulation of impurities and consequent frequent need for cleaning.

### 6.2 Systems in common use

Quite a wide variety of different types are in widespread use. These differ both in their basic design and material and in other characteristics specific to their make. A principal distinction is made between:

- screens installed parallel to the flow line and
- screens installed perpendicular to the flow line.

Depending on the application,
- curved screens and
- screening mechanisms

can also be used.
If the aim is to separate extremely fine, i.e. microscopic solids (e.g. plankton), the installation of a micro-strainer to follow the screen and precede further treatment of the water may be expedient.

Screens generally catch large amounts of floating matter, because of the narrow space between the bars or wires (20 to 50 mm), and thus often become blocked very quickly. Frequent cleaning is therefore important. As a result, cleaning operations are often either wholly or partially automated.

Very simple versions such as those shown in figs. 21 to 25, Module 3.5, pages 21 to 23, are only adequate e.g. in relatively small water-treatment plants, as a temporary measure or where water is drawn from standing, comparatively clean sources.

## 7 Aerating systems

(for figures see Module 3.5, pages 36 to 42)

### 7.1 Definition

The function of aerating systems is essentially to drive out any volatile gases which may be contained in the water (e.g. aggressive carbonic acid, carbon bisulphide, chlorinated hydrocarbons etc.), at the same time introducing atmospheric oxygen into it. This has the important effects e.g. of oxidizing bivalent iron to the trivalent, separable form and of improving the taste of the water through a higher oxygen concentration.

## 7.2 Systems in common use

Various different systems are used, depending on specific conditions and special problems. Some operate with introduction of air by natural methods, some by forcing air into the water.

Main systems:
- atomization
- cascades
- trickling systems
- pressure systems in closed tanks
- aerating systems in open tanks
- simple systems

The use of cascades and trickling systems, taking maximum advantage of the natural slope of the ground, is recommended wherever possible. This allows the required aerating or degassing effect to be achieved with simple materials and without an additional input of electrical energy.

Aerating systems are best installed after intake of the raw water and before flocculation/sedimentation or filtration, so that any precipitated products can be flocculated and separated.

Selection of the most suitable system should follow consideration of relevant factors such as:

- the type of water-treatment plant,
- topography and other local features,
- operational reliability and extent of maintenance required,
- the purchase price and operating costs,
- the water source (analysis).

Ground waters, which as a general rule are comparatively clean, should be treated wherever possible in closed aerating systems (high-pressure oxidizers and mixed-element reactors etc.). If this is inexpedient, due e.g. to an excessive content of aggressive carbonic acid or iron, atomizing or trickling systems can also be used. Care must then be taken to isolate the system as far as possible from external influences (insects, air pollution etc.). Blockage-proof cascades or trickling systems have certain advantages in the aeration of surface waters drawn from lakes or rivers, especially if the treated water does not have to meet very high standards.

Simple systems, such as those shown in figs. 36 to 38, Module 3.5, pages 39 to 41, can be used where amounts of water are comparatively low and the required quality not very high.

## 8 Flocculation

(for figures see Module 3.5, pages 50 to 55)

### 8.1 Definition

Flocculation is extremely important for the proper functioning of the majority of the drinking-water treatment processes which follow it. Through the introduction of chemical flocculants, suspended matter and colloidal particles in the water, which settle only with difficulty, are induced to stick together to form flocs, which are then removed in a further process. Thus flocculation is the essential preparatory stage preceding a series of separation processes which remove virtually all impurities from the water. These are, for example:

- sedimentation
- flotation
- filtration.

Important is proper coordination of floc structure and method of separation. Thus, for instance, sedimentation requires flocs with maximum diameter and high density. Filtration, on the other hand, is more successful if the flocs are smaller, since these are still able to penetrate the filter media, thus allowing the full capacity of the filter to be exploited. Larger flocs would rapidly clog the filter material.

For flotation, voluminous, lighter structures are generally preferred. These attach themselves to air bubbles and rise quickly to the surface.

The object of all water treatment being to achieve an optimum purification effect, attention must be paid not only to good separability of the flocs, but also to optimum bonding of the impurities in the floc structure. In practice, this problem, which is governed by a number of different factors (chemical reactions, electro-kinetic effects etc.), is approached by carrying out flocculation test series, as far as possible using fresh water from the original source. These tests cover determination of:

- the best flocculants,
- optimum dosages,
- correct dosage concentration,
- reaction times,
- stirring speed,
- the best feeding point, etc.

Parallel to these investigations, tests are also performed to establish peripheral factors such as water temperature, pH etc.. Finally an overall assessment of the floc structure is made and the process specified.

## 8.2 Systems in common use

A number of proven methods are in use which, either singly or in combination, allow an optimum floc structure to be attained, or else the correct measure to be identified, e.g:

- dosage of flocculants
- adjustment of pH
- dosage of auxiliary flocculants
- return of activated sludge
- design of flocculation tanks
- energy input (destabilization).

### 8.3 Calculation

Survey of the most widely used flocculants

| Flocculant | Formula | pH range for optimum flocculation | Practical dosage minnmax (mg/1) | Applications |
|---|---|---|---|---|
| Aluminium sulphate | $Al_2(SO_4)_3 . 18 H_2O$ | 6 - 7 | 10 - 100 | For all waters the pH of which is within the given limits |
| Ferric chloride | $FeCl_3$ | 5.5 - 6.0 and 8 - 9 | 10 - 60 | As above |
| Ferrous sulphate | $FeSO_4 \cdot 7 H_2O$ | 5.5 - 6.5 | 20 - 100 | As above. The iron II ions must be oxidized e.g. by chlorine to iron III ions |
| Sodium aluminate | $Na_3ALO_3$ | 5.5 - 8 | 10 - 60 | In charbonate-rich waters with high magnesia hardness |
| Sodium aluminate and aluminium sulphate | $2 Na_3ALO_3 + AL_2(SO_4)_3 \cdot 18 H_2O$ | | | In low-carbonate waters |

## 9. Sedimentation

(for figures see Module 3.5, pages 63 to 71)

### 9.1 Definition

Sedimentation (settlement) is the sinking of impurities to the bottom of the water which contains them. The particles sink as a result of gravity as soon as they have a density higher than that of the surrounding liquid. For this reason, particular attention must be given to flocculation (cf. Section 8 of this module and Module 3.5, Section 8) as a preliminary to the sedimentation process.

The flocculated water is fed into tanks of widely varying size, shape and equipment. Important is a properly thought-out co-ordination of the shape of the tank, the hydraulic system, reaction times, sludge extraction etc. with the specific application for floc structure.

### 9.2 Systems in common use

The most widely used types of sedimentation tanks or basins fall into the following main categories:

- circular basins with external flocculation zone
- circular basins with integrated flocculation zone
- rectangular basins
- basins with installed equipment
- ultra-simple systems.

In addition, a number of specialized companies offer systems combining aspects of various different types.

The floc/water mixture must be transported with minimum turbulence from the flocculation basin (cf. figs. 42 and 43, Module 3.5, page 51) to the settling basins, otherwise the macroflocs which have already formed could be destroyed. Intermediate pumping stations, even operating at relatively low speeds, damage the floc structure and thus hinder settlement. Transfer of the water by free (gravity) flow through an open channel or pipe should be preferred wherever feasible. The flow speed should not exceed 0.5 m/sec.

Funnel-type basins without continuous sludge clearance (cf. fig. 50, Module 3.5, page 63) need a floor sloping at an angle of 50 to 60°, so that the sediment (sludge) can slip down into the lower part of the funnel, from where it is expelled. If the slope of the funnel is less steep, the sediment, or some of it, remains where it settles and biological decomposition, with scum formation, can take place.

The steep sides of the funnel mean that the structure must have a considerable depth, increasing proportionately with the diameter of the basin. Sedimentation basins of this type are therefore usually not built with diameters greater than about 12.0 m.

The inlet volume per m² of surface area can be between 1 and 2 m³/h, depending on the preceding flocculation process and the settling rate of the flocs, e.g. with/without return of activated sludge. The lower figure applies to the less stable floc structures. The centrally installed distributor pipe begins above the water surface and continues for approx. 2.5 m below it. To direct the flow of water, a deflecting plate is attached to the mouth of the distributor pipe.
In circular basins with mechanical rotating scrapers and central inlet of raw water (cf. fig. 55, Module 3.5, page 69), the floor slopes at an angle of 6 to 10°. The sediment is scraped continuously towards the centre of the basin. The mechanical scraper moves very slowly, to avoid churning up the sludge.

Practical experience has shown that the diameter of the basin is best kept below approx. 50.0 m. In some areas, several smaller basins may represent a better solution than a single large basin with a diameter of 50 m, since these are easier to build and usually cheaper and simpler to run. As pointed out above, the possible inlet per unit of surface area depends on the quality of the flocs. In sedimentation basins of this type, the volume is limited to between 1 and 2 m³ per m² and hour.

The circular clarification basin with integrated flocculation zone shown in fig. 56, Module 3.5, page 71 is a practice-proven compact flocculation and sedimentation system. The raw water flows centrally from below into the flocculation zone, where a mixture of raw water, chemicals and activated sludge in precisely defined amounts permits adjustable or controllable flocculation to take place. The floc/water mixture enters the annular settlement zone evenly distributed and with minimum turbulence. Here the flocs settle on the floor, whilst the water is extracted via the clarified water channel at the top. The sludge is either expelled downwards, exploiting the geodetic head, or upwards, using a dredging pump.

Depending on the application, an inlet volume of between 2 and 4 $m^3$ per $m^2$ and h can be planned; in special cases, e.g decarbonization, up to 6 $m^3$ per $m^2$ and h.

Rectangular settling basin with scraper mechanism and inlet along the front (fig. 51, Module 3.5, page 65)

The use of rectangular settling basins has the advantage that several basins can be positioned one next to the other, with optimum utilization of the available space. The water flows horizontally through the basin from inlet to outlet. The ratio of length to width is usually between 1:3 and 1:5 and the average depth between 2 and 4 m. The inlet volume per unit of surface area can be between 1 and 2 $m^3/m^2 \times h$, although the total retention time of the water in the basin should not be under 1.5 h. Sludge clearance is continuous, carried out by longitudinal mechanical scrapers against the direction of flow into the sludge sump at the inlet end. The scraper must move very slowly. The sludge is then expelled either downwards, utilizing the available pressure of the water, or upwards using a sludge pump.

Settling tank with inbuilt baffles

The inlet volume per unit of surface area of existing and new settling tanks can be increased by installing inclined baffle plates. Depending on the situation, inlet volumes of up to 10 to 15 $m^3$ per $m^2$ and hour are possible.

## 10 Dosing equipment

(for figures see Module 3.5, pages 77 to 86)

### 10.1 Definition

Dosing devices are appliances which feed the chemicals required in water treatment into the water at a suitable point and in the correct amounts.

In an extended context, dosing equipment can include facilities for the storage, preparation and transport of the chemicals up to the dosing point.

## 10.2 Systems in common use

A basic distinction must be made between the storage, preparation and dosing of

a) Solid chemicals,
   such as e.g. aluminium sulphate, $Al_2(SO_4)_3$, as flocculant,
   polyelectrolyte as auxiliary flocculant,
   calcium hydroxide, $Ca\ (OH)_2$ for pH control;

b) Liquid chemicals,
   such as e.g. ferric chloride, $FeCl_3$, as flocculant,
   polyelectrolyte as auxiliary flocculant,
   sodium hydroxide, NaOH, for pH control;

and

c) Gaseous chemicals,
   such as e.g. chlorine, $Cl_2$, for sterilization.

e) Solid chemicals:

dry storage (fig. 61 and 62, Module 3.5, page 81),
dosing of dry chemicals by gravimetric/volumetric method,
solution/dilution of dry substances,
transport of the chemical solution to feeding point, possibly further dilution,
controlled feeding of solution into water;
or
wet storage (fig. 66, Module 3.5, page 85),
dosing of dissolved or diluted substances,
transport of chemical solution to feeding point, possibly further dilution,
control of metering pumps.

b) Liquid chemicals (fig. 67, Module 3.5, page 86):
wet storage,
metering of liquid chemicals,
transport of liquid to feeding point,
possibly further dilution,
control of metering pumps;

c) Gaseous chemicals (chlorine) - (fig. 68, Module 3.5, page 86):
storage in liquid state,
drawn off as gas,
dosing as gas or solution,
transport of liquid to feeding point,
controlled feeding.

## 11 Filtration

(for figures see Module 3.5, pages 93 to 98)

### 11.1. Definition

Next to flocculation and sedimentation, filtration is one of the principal components of water treatment. It follows the sedimentation stage and has the function of separating any remaining fine solids not removed by sedimentation.

In some cases, filters may also have the task e.g. of removing iron or manganese, of clarifying water with activated carbon, de-acidifying it with dolomite filter material or increasing its hardness with granulated marble.

### 11.2. Systems in common use

Filters used in water treatment can be classifed roughly as follows:

- open steel cylinder filter units (slow filters)
- closed steel cylinder filter units (pressure filters)
- open concrete filter units (slow filters)
- closed concrete filter units (pressure filters).

Alternatively, they may be designated according to special features, such as:

- single-medium filters
- multi-media filters
- trough-type filters
- filters without troughs
- nozzle-plate filters
- filters without nozzle plate
- filters with water head
- filters with increased water head;

or according to a specific function to be performed by the filter, such as:

- manganese-removing filters
- iron-removing filters
- de-acidifying filters;

or, finally, to the filtration rate:

- ultra-slow filters
- slow filters
- rapid filters.

Open steel cylinder filter (fig. 69, Module 3.5, page 93)

For ease of transport and to limit costs, these are made in diameters of up to approx. 5.0m, effective filtration area A = 19.6 m².

Filtration rate (V) is normally 4 to 6 m/h. If quartz sand and pumice or hydro-anthracite are used, the filtration rate can be considerably increased by exploiting the large-capacity filtration effect. Underneath the layers of filter media is a nozzle plate or special drainage system.

Filtration generally takes place from the top downwards and back-washing from the bottom upwards. As soon as the filter has accumulated the maximum amount of sludge (maximum water level), it is cleaned by scouring with air, air and water and water for final rinsing. Clean, filtered water should always be used for back-washing.

Closed steel cylinder filter (pressure filter) - (fig. 70, Module 3.5, page 94)

For ease of transport and cost limitation, these are generally made in diameters of not more than 5.0 m, effective filtration area A = 19.6 m².

The filtration rate is normally between 10 and 15m/h. Higher filtration rates are possible, depending on the general application and composition of the filter.

The maximum permissible degree of contamination is determined on the basis of differential pressure. This is the difference in pressure between the raw water above the filter medium and the pressure of the filtered water underneath the nozzle plate (fig. 70). This pressure difference must not be greater than 10 m $H_2O$, since the nozzle plates are not usually designed to support more than this. If the differential pressure rises to this level, the maximum possible degree of contamination has been reached, the filter is taken temporarily ouf of service and throughly cleaned. As an additional measure, the through-flow through the filter can also be measured. If the volume of filtered water drops below a certain minimum level, this also indicates that maximum contamination of the filter has been reached. The differential pressure should then also be checked by means of a pressure gauge.

The filter media rest on a nozzle plate or other surface without nozzles.

Open concrete filters (figs. 71 to 73, Module 3.5, pages 95 and 96).

These are built with effective filtration areas between approx. 25 m² and 100 m².

The filtration rate is normally about 6 m/h. Depending on the exact application of the filter, its composition and the maximum possible water level, higher filtration rates are also attainable.

To prevent the freshly cleaned filter from running empty, either a filtered-water inlet pipe (figs. 71 to 73, Module 3.5, pages 95 and 96) or an "outlet control" is provided.

As figs. 71 to 73 in Module 3.5 show, open filters can be built either with or without troughs and with either a nozzle plate or floor drainage system.

The filter type without trough and with nozzle plate shown in fig. 71, Module 3.5, offers a fully satisfactory technical solution. Here the raw water is distributed onto and flows through the filter media extremely evenly. Back-washing is also highly efficient, with no loss of filter medium during the cleaning process, since the sludge water trap remains closed during this operation.

Filters without troughs also have the advantage of requiring only very low amounts of back-washing water, i.e. 2 $m^3$ per $m^2$ of filtration area for single processes and up to $4^3$ per $m^2$ of filtration area for double operations.

If the system is then designed as a large-capacity filter, this gives in addition a reaction volume adequate for a filter flocculation process to take place under good conditions.

If the filter media rest on a nozzle plate approx. 70 cm above the floor, this permits the process to be monitored from below, with very useful results. Floor drainage systems do not allow this (cf. fig. 71, Module 3.5).

Single-medium and multi-media filter

A single-medium filter has only one active filtration layer (fig. 71, Module 3.5, page 95). This usually consists of quartz sand. The granular size is chosen to fit the specific application. The quartz sand layer is generally between 800 and 1,000 mm thick.

Since filtration takes place principally in the top layer of sand, the capacity to absorb filtrable substances, and thus also the service life of the filter, are limited.

The capacity of the filter to absorb solids and with it its useful life can be increased by covering the layer of fine sand with a layer of coarser material, the structure and composition of which are such that the filtrable solids can penetrate the filter medium. The denser layer of fine sand underneath the coarse material then screens out the remaining particles not removed by the top layer.

Since a combination of two different materials is used, these filters are called "multi-media" filters, as are those in which three media of varying density are layered one above the other. Suitable material for multi-media filters are pumice, hydro-anthracite and activated carbon. Filters with a sand layer between 400 and 800 mm thick and a pumice layer from 400 to 600 mm thick are a widely used type.

Trough-type filter (figs. 72 and 73, Module 3.5, page 96).

Trough-type filters are open or closed concrete structures prvided with one or more interior troughs for distribution of the raw water and removal of the sludge water. In sand filters, the upper edge of the trough must be at least 500 to 600 mm higher than the surface of the filter material, to preclude loss of this material during the back-washing operation. Although in widespread use, this type of filter presents a number of technical problems, e.g:

- Depressions in the active filter material scoured out by the inflowing raw water underneath the trough, possibly leading to a deterioration of the quality of the filtrate.
- In back-washing there is a risk of filter material being removed, especially in multi-media filters where the material is relatively light. Loss of material is also observable during the process of media separation (multi-media filters).

- Relatively high consumption of back-washing water, since the water is used to lift the contaminants into the trough.
- Problems in constructing troughs which are uniformly high and completely horizontal.

Filter without trough (fig. 71, Module 3.5, page 95)

These are open or closed concrete or steel cylinder filter units without a trough, either for inlet of the raw water or for removal of the sludge water. The complete space above the filter media is empty. Raw water is let in either at one end (in slow filters) or via a central spreader pipe (in pressure filters). The back-washing water is discharged at the opposite end from the inlet via a wide sludge water trap. The advantages of this design have already been pointed out.

Filter with nozzle plate (figs. 71 and 72, Module 3.5, pages 95 and 96)

These filters have a nozzle plate at the bottom which supports the filter media, drains off the filtrate and evenly distributes the back-washing water and scouring air. The nozzle floor should be high enough to allow a man to crawl underneath it to carry out maintenance work. It should be horizontal and, except for the nozzles, watertight. Between 60 and 80 nozzles per m² of floor have proved practical, also the provision of two gravel distributor layers each 100 mm thick.

Filter without nozzle plate (fig. 73, Module 3.5, page 96)

Instead of the nozzle plate described above, a special drainage construction can be used to drain off the filtered water and to distribute the back-washing water and scouring air. This must be covered by especially thick layers of gravel, however, to prevent the fine sand from getting into the drainage system, e.g:

| | |
|---|---|
| 150 mm | 15 to 35 mm |
| 150 mm | 7 to 15 mm |
| 150 mm | 5 to 7 mm |
| 150 mm | 3 to 5 mm |
| 100 mm | 2 to 3 mm |

Filter with water head (fig. 74, Module 3.5, page 97)

These filters are designed in such a way that the surface of the water is approx. 100 mm above the freshly cleaned filter media. As the coating of slime thickens (i.e. the resistance of the filter increases), the water level rises (see figs. 74 and 75 in Module 3.5, pages 97 and 98) up to a maximum level and the filter must then be cleaned.

Filter with increased water head

Here the water is at a level of approx. 2000 mm above the freshly cleaned filter media. With increasing clogging/filter resistance, there is initially no further rise in the head, until the resistance which has to be overcome exceeds the head. This then results in a rise of the water level and the filter has to be cleaned.

Nomenclature of filters according to application

Iron-removing, manganese-removing, de-acidifying filters etc. may be built either as open or as closed structures.

Filtration rates

| | V (m/h) |
|---|---|
| Ultra-slow sand filter | 0.1 to 0.5 (see note) |
| Slow sand filter | up to 3.0 |
| Rapid filter | up to 8.0 |
| Pressure filter (concrete) | up to 15.0 |
| Pressure filter (steel) | up to 30.0 |

Note on ultra-slow sand filters:
Due to the extremely low filtration speed, these require a very large active filtration area and are, for this reason, only seldom used nowadays. Ultra-slow sand filters cannot be cleaned by back-washing. The filtration layer has to be carefully removed. The intervals between cleaning operations can be as long as several months. This type of filtration results in a filtrate of a high standard, due to its biological efficiency of more than 90%.

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# TRAINING MODULES FOR WATERWORKS PERSONNEL

## List of training modules:

### Basic Knowledge

**0.1** Basic and applied arithmetic
**0.2** Basic concepts of physics
**0.3** Basic concepts of water chemistry
**0.4** Basic principles of water transport
**1.1** The function and technical composition of a watersupply system
**1.2** Organisation and administration of waterworks

### Special Knowledge

**2.1** Engineering, building and auxiliary materials
**2.2** Hygienic standards of drinking water
**2.3 a** Maintenance and repair of diesel engines and petrol engines
**2.3 b** Maintenance and repair of electric motors
**2.3 c** Maintenance and repair of simple driven systems
**2.3 d** Design, functioning, operation, maintenance and repair of power transmission mechanisms
**2.3 e** Maintenance and repair of pumps
**2.3 f** Maintenance and repair of blowers and compressors
**2.3 g** Design, functioning, operation, maintenance and repair of pipe fittings
**2.3 h** Design, functioning, operation, maintenance and repair of hoisting gear
**2.3 i** Maintenance and repair of electrical motor controls and protective equipment
**2.4** Process control and instrumentation
**2.5** Principal components of water-treatment systems (definition and description)
**2.6** Pipe laying procedures and testing of water mains
**2.7** General operation of water main systems
**2.8** Construction of water supply units
**2.9** Maintenance of water supply units Principles and general procedures
**2.10** Industrial safety and accident prevention
**2.11** Simple surveying and technical drawing

### Special Skills

**3.1** Basic skills in workshop technology
**3.2** Performance of simple water analysis
**3.3 a** Design and working principles of diesel engines and petrol engines
**3.3 b** Design and working principles of electric motors
**3.3 c** –
**3.3 d** Design and working principle of power transmission mechanisms
**3.3 e** Installation, operation, maintenance and repair of pumps
**3.3 f** Handling, maintenance and repair of blowers and compressors
**3.3 g** Handling, maintenance and repair of pipe fittings
**3.3 h** Handling, maintenance and repair of hoisting gear
**3.3 i** Servicing and maintaining electrical equipment
**3.4** Servicing and maintaining process controls and instrumentation
**3.5** Water-treatment systems: construction and operation of principal components: Part I - Part II
**3.6** Pipe-laying procedures and testing of water mains
**3.7** Inspection, maintenance and repair of water mains
**3.8 a** Construction in concrete and masonry
**3.8 b** Installation of appurtenances
**3.9** Maintenance of water supply units Inspection and action guide
**3.10** –
**3.11** Simple surveying and drawing work

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