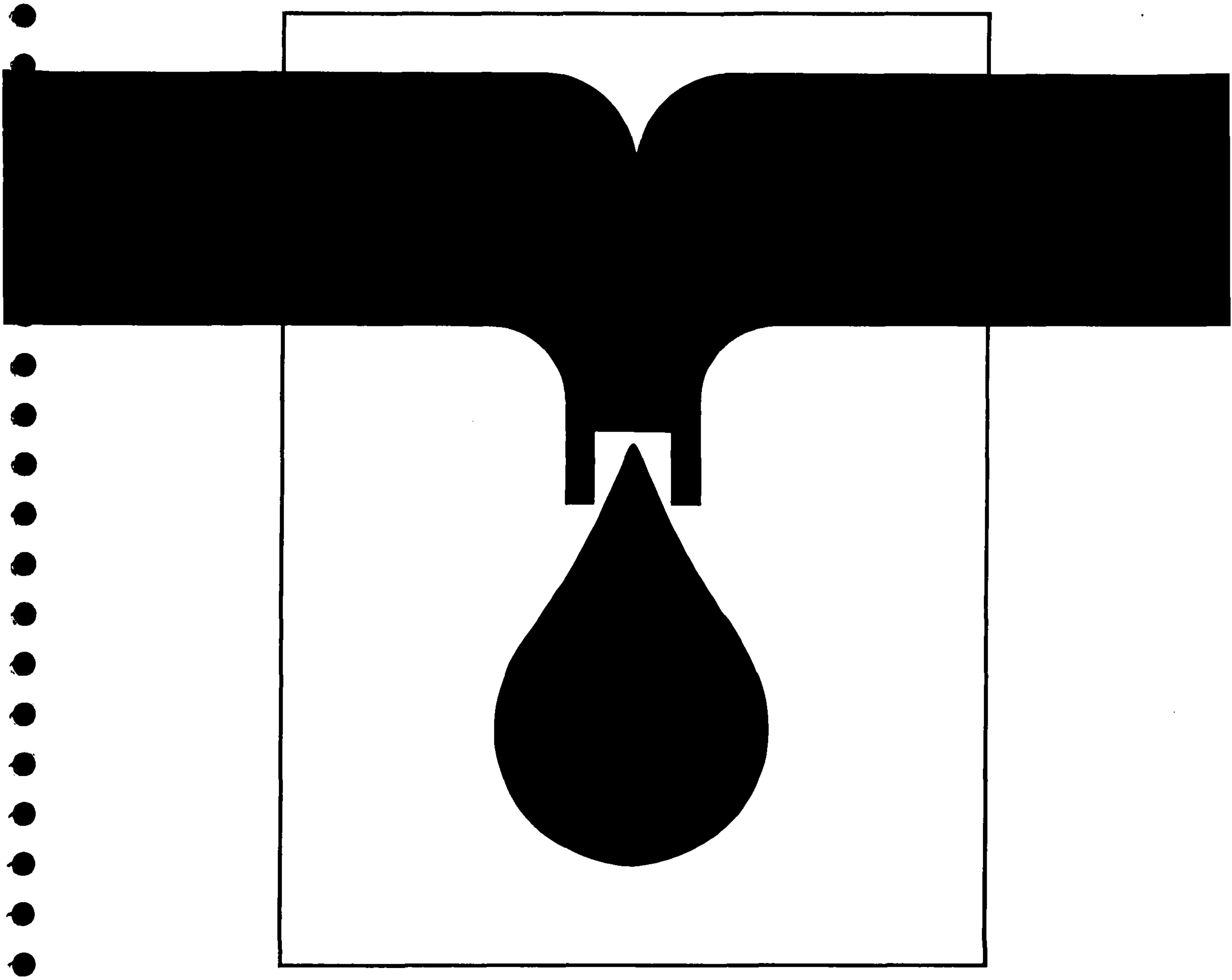
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Skills

3.5

Water-treatment systems:
construction and operation of principal components:
Part II

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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and
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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: Water-treatment systems: construction and operation of principal components

Table of contents: Part II

8 Flocculation

8.1 Methods of constructing simple versions

Flocculation tanks, basins or pools can be made from locally available materials such as stone or bricks, timber or concrete.

The construction work should be carried out by local craftsmen, but under qualified direction and with technical assistance where necessary. Ultra-simple versions without electrically-driven flocculation stirrers are recommended for relatively small installations, as temporary measures or in rural areas where proper maintenance and an adequate supply of spare parts may cause problems.

The exact design should always take the given situation into account, e.g.:

- is there an existing gradient which could be exploited,
- through what treatment stages has the water already passed - e.g. screening, cascade etc.,
- is adequate electricity available,
- what building materials are commonly used in the area and what qualified craftsmen are available,
- what further purification process is either already carried out or planned - e.g. sedimentation, filtration,
- what chemicals will be needed for flocculation and/or pH adjustment,
- what retention or reaction times will be necessary to allow readily-settling flocs to form,
- what advantage could be gained by a return of activated sludge to the flocculation tank (this can be determined by a jar test).

Flocculation begins as micro-flocculation in the flash-mixing tank. Here the flocculant is fed into the raw water under conditions of extreme turbulence and the mixture allowed to react for a short period (1 to 3 minutes). If the supply pressure is adequate to produce the required turbulence, the high-speed flash-mixing stirrer can be dispensed with.

The aim of the flocculation process is to induce suspended matter and colloids in the raw water, which settle only with difficulty, to form flocs which can then be separated more easily. This is why flocculation always precedes the sedimentation or filtration stages.

The flocculation tanks can be built to a simple design using concrete, bricks, steel, timber or plastics. The size of the tank depends on the retention time necessary to achieve flocculation - this is usually between 20 and 30 minutes. The mechanical equipment required - when local conditions allow it - comprises the stirrer and possibly baffle plates and overflow sills.

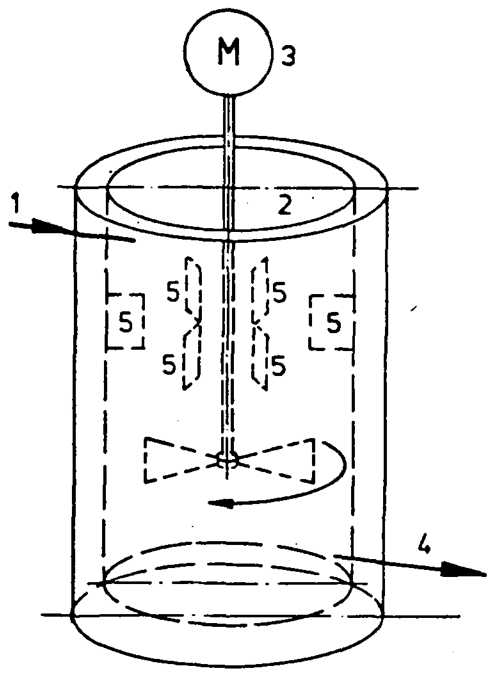
Circular flocculation tanks are better from a fluidic point of view and produce better process results overall. Square or rectangular tanks may also be used, however, where these are adapted to the shape of the following treatment installations. Whereas circular or square tanks generally need only one stirrer for gentle mixing and prevention of deposits on the floor of the tank, rectangular flocculation basins may require 2 or more stirrers (figs. 42 and 43).

When planning the arrangement of the raw water inlet and the outlet of the water/floc mixture, care must be taken to avoid "short-circuits" in the flow pattern. This means that the entire volume of raw water flowing into the tank must be brought thoroughly into contact with the flocculants, with any floc structures already formed (micro- and macro-flocs) and with the crystallization nuclei of the activated sludge. This is achieved by appropriate positioning of inlet and outlet conduits, e.g. inlet at the bottom, outlet at the top, plus a staggered arrangement on plan or the installation of baffle plates.

If, due to a misconceived design or mistakes in execution, this basic requirement is not met, a certain volume of non-flocculated raw water, containing non-settling or non-filtrable fine solids, will mix with the purified water and have a permanently detrimental effect on its quality, resulting in e.g. turbidity, taste, smell etc.

Just as important as gentle but thorough mixing is the correct arrangement of the chemical feeding points, with the possibility of adjusting these during the initial phase of putting the equipment into operation so as to optimize results.
It is therefore advisable to provide connections for at least 2 or 3 chemical feeding points, for both the flocculant (e.g. aluminium sulphate) and the auxiliary flocculant (polyelectrolyte).

As described above, a circular flash-mixing tank is often used for rapid, intensive mixing of the flocculant into the raw water (fig. 41). This may be made of concrete or brick (2). The tank is equipped with a high-speed stirrer (3) and inlet (1) and outlet (4) pipes. The flash-mixing tank immediately precedes the flocculation tank; the water flows through it without pressure. Baffles (5) may be installed to increase turbulence and thus the mixing effect.

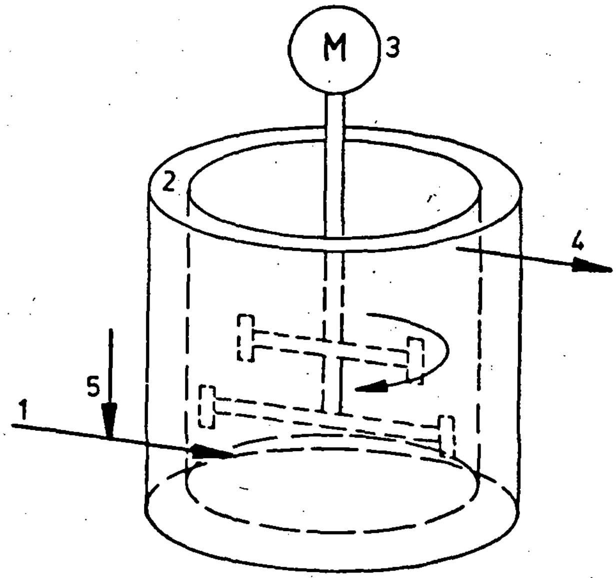


Flash-mixing tank

1 Raw water inlet
2 Tank
3 High-speed stirrer
4 Outlet to macro-flocculation
5 Baffle plate

Fig. 41

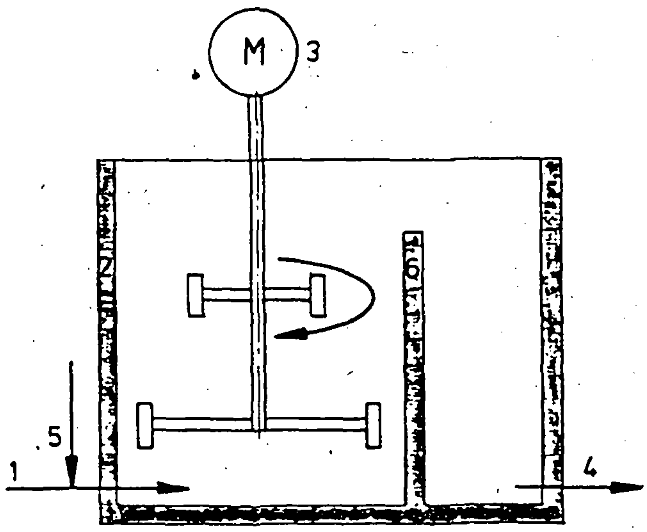
In the succeeding macro-flocculation stage (figs. 42 and 43), the actual flocculation process, in which fine solids stick together to form separable flocs, takes place.



Macro-flocculation tank

1 Inlet from flash-mixing
2 Tank
3 Low-speed stirrer
4 Outlet to sedimentation
5 Chemical feeding

Fig. 42

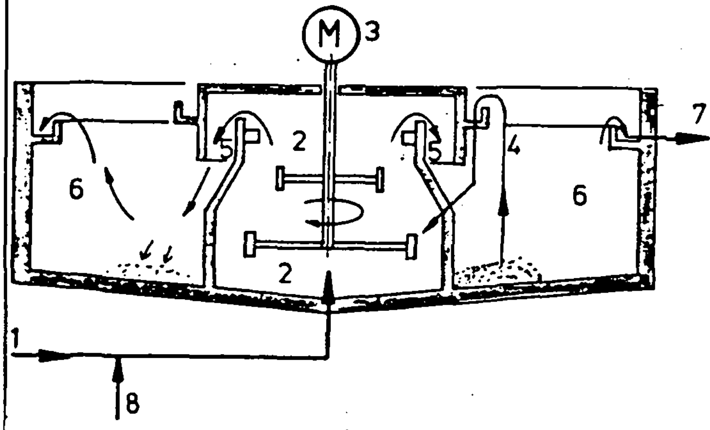


Macro-flocculation tank

1 Inlet
2 Tank
3 Low-speed stirrer
4 Outlet to sedimentation
5 Chemical feeding
6 Baffle plate

Fig. 43

Macro-flocculation chambers can also be integrated into the sedimentation tank. This improves the hydraulic design, makes transport of the water/floc mixture from flocculation to sedimentation smoother and reduces building costs (cf. figs. 44 and 45).



Macro-flocculation chamber
(integrated into OPUR sedimentation plant)

1 Raw water inlet
2 Flocculation chamber
3 Low-speed stirrer
4 Activated sludge return
5 Overflow of water/floc mixture to settling zone
6 Settling zone
7 Clarified water outlet
8 Chemical feed

Fig. 44

Combined flash-mixing and flocculation
(integrated into OPUR-S batter plate sedimentation plant)

1 Raw water inlet	7 Flash-mixing stirrer
2 Flash-mixing chamber	8 Flocculation stirrer
3 Flocculation chamber	9 Batter plates
4 OPUR-S sedimentation plant	10 Clarified water outlet
5 Flocculant feed	11 Sludge chamber
6 Auxiliary flocculant feed	12 Sludge removal

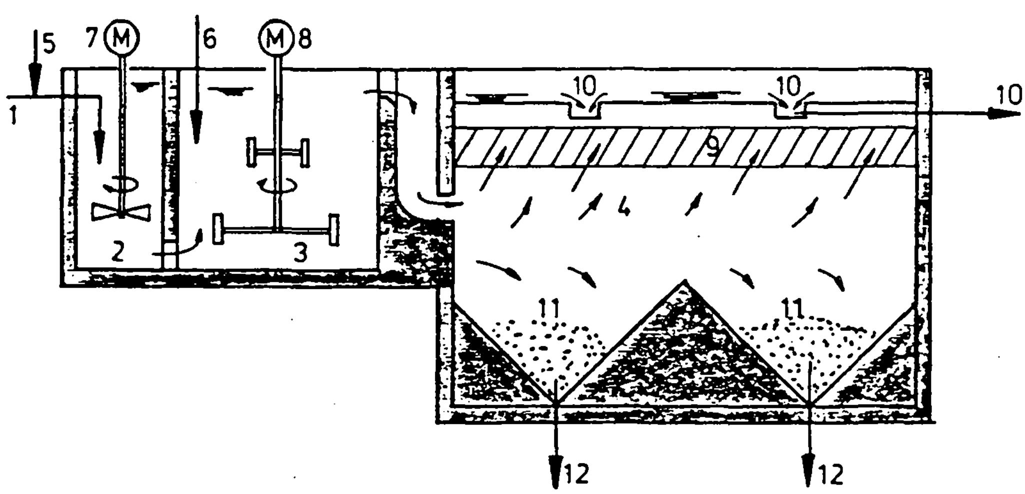
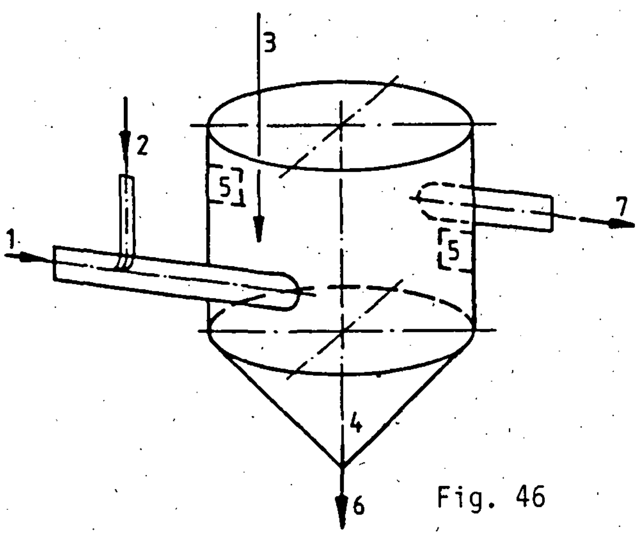


Fig. 45

Ultra-simple flocculation plants consist of a tank with the necessary volume, but without a mechanical stirrer, since in many cases an uninterrupted supply of electricity cannot be guaranteed.

Naturally, the efficiency of such extremely simple systems in terms of floc formation is not fully satisfactory. In such cases, the following stages in the water-treatment process - sedimentation and filtration - are often more generously dimensioned, so that a certain amount of post-flocculation can take place here.

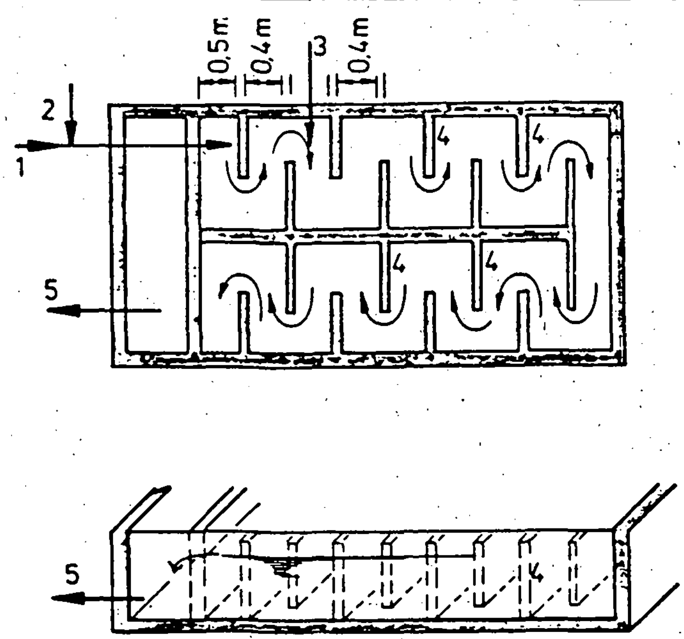
Circular flocculation tank with tangential inlet and outlet



1 Raw water inlet
2 Flocculant feed
3 Auxiliary flocculant feed
4 Tank
5 Baffles
6 Washout
7 Outlet

Fig. 46

Mixing and flocculation tank with baffles



1 Raw water inlet
2 Flocculant feed
3 Auxiliary flocculant feed
4 Baffles
5 Outlet
(Reaction time depending on throughput approx. 30 to 40 minutes)

Fig. 47

Mixing and flocculation cascade with flocculation tank

1 Raw water inlet
2 Flocculant feed
3 Auxiliary flocculant feed
4 Flocculation cascade
5 Flocculation tank
6 Outlet
7 Washout

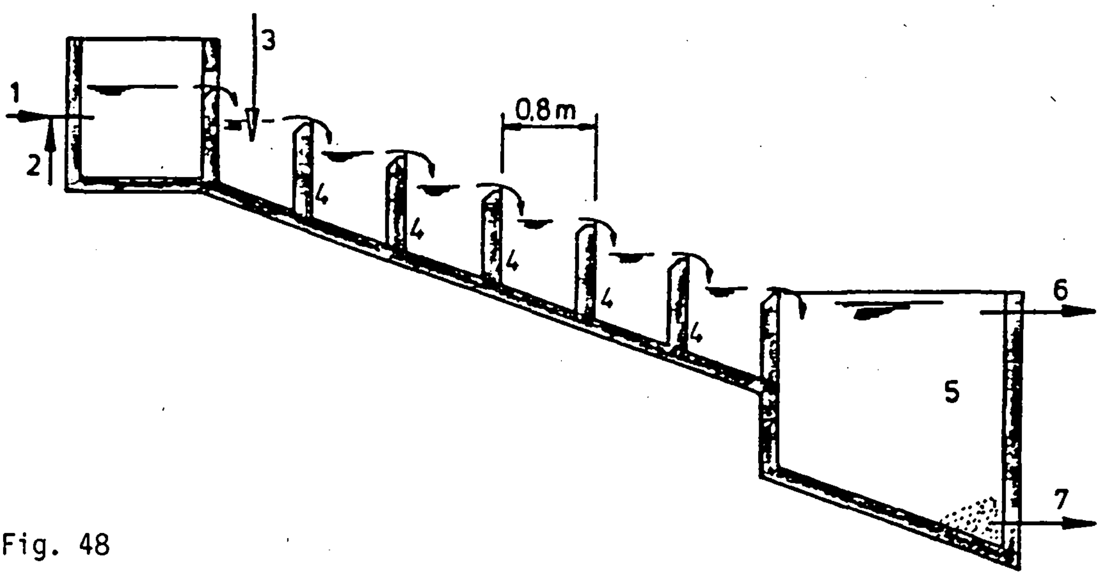


Fig. 48

8.2 Operation

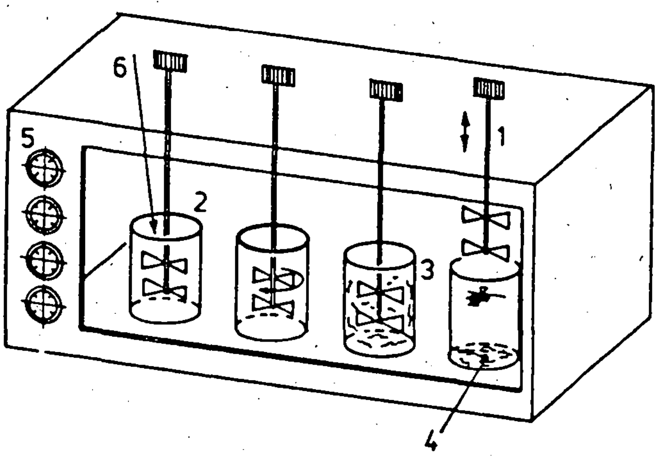
Assessment of flocculation

As already pointed out above, the effectiveness of water treatment as a whole depends very largely on the proper functioning of the flocculation process. For this reason, a number of simple, practical methods have been developed over the years by which the efficiency and economy of flocculation processes can be judged.

Simple tests (jar tests) can be carried out in the laboratory and give useful information on the interrelationships of the various factors involved: e.g. test series in which the flocculant and auxiliary flocculant, reaction time, stirring speed, sludge enrichment, pH range etc. are varied. Such tests should be performed not only in the planning phase of designing a new plant, but also, and especially, at regular intervals (e.g. weekly) during operation of existing equipment. This allows any changes in the composition of the raw water to be recognized immediately and appropriate alterations in the flocculation treatment to be made. Such changes in the raw water can be due e.g. to the effects of the rainy or dry season, the appearance of micro-organisms, etc.. With a thorough understanding of the interrelationships involved, control of the process can be maintained without the need for an excessive use of chemicals.

Jar Test

This is a method by which the results from a number of samples are compared with each other. A series stirring device (fig. 49) is used for the simultaneous mechanical flocculation of 5 to 6 samples, whereby the stirring speed and duration can be varied.



Series stirrer

1 Stirring vane (raisable)
2 1000 ml jar
3 Water/floc mixture
4 Settled flocs
5 Switches for speed adjustment
6 Addition of chemicals

Fig. 49

Simple driving methods

The energy required to drive the stirrer can be supplied, instead of by electricity, by a wind or water wheel or by muscle power. Wind or water driven wheels are simple and cheap to make and easy to repair using the materials and experience available. Muscle power can be provided by a donkey, ox or camel. As a comparison, it can be pointed out that water is raised by similar methods in many places all over the world.

Survey of some test parameters

1. Pre-treatment of the water (e.g. chlorination, ozonification in mg/l).
2. Type and amount of flocculant used (e.g. aluminium sulphate in mg/l).
3. Type and amount of auxiliary flocculant used (polyelectrolyte in mg/l).
4. Conditions of chemical feeding.
5. Stirring speed.
6. Stirring duration (reaction time).
7. Return of activated sludge.
8. pH.
9. Temperature.

Selection of criteria for flocculation assessment
(cf. test report on following page)

Flocs	Water
1. Formation rate	1. Turbidity
2. Size	2. Colour
3. Settling speed (sedimentation property)	3. Smell and taste
4. Filtrability	4. Organic substances CSB, BSB_5, $KMnO_4$ etc.
5. Sludge thickening	5. Bacterial content
6. Residual flocculant content in filtrate	

All the factors listed above are important for an accurate assessment of the efficiency of the flocculation process. In addition, the tests should reflect as accurately as possible the actual conditions in the existing or projected plant. Flocculation assessment covers the flocs themselves and the quality of the treated water. In nearly all cases both aspects have to be considered and the relevant data therefore recorded in every report giving the results of a jar test.

Test report (sample)

	1	2	3	4	5	6	7	8	9	10
1	Alu. sulphate mg/l	Poly-electrolyte mg/l	Ca $(OH)_2$ mg/l	Activated sludge enrichment times	Floc size mm	Settling rate of flocs Grade 0-5	Appearance Grade 5-0	pH	Sludge volume after 5'	Sludge volume after 60'
1	30	-	-	0	1	2	5	6.1	5	2
2	50	-	-	0	3	2	3	5.9	5	2
3	70	-	-	0	4	1	2	5.8	7	2
4	30	0.2	10	0	4	5	2	6.8	7	2
5	50	0.3	30	0	5	5	2	6.8	8	3
6	70	0.5	40	0	5	5	1-2	7.0	8	4
7	10	0.3	-	1	4	4	2	6.3	5	2
8	30	0.4	-	2	5	5	2	6.1	6	2
9	50	0.3	30	2	5	5	1	7.0	9	3

<u>Reaction/stirring times</u>

1 minute flash mixing - fast
12 minutes flocculation stirring - slow

The report shows that meaningful results can be obtained with a minimum amount of analytical equipment and only semi-skilled personnel.

In tests 1 to 3, aluminium sulphate only is added to the raw water. In tests 4 to 6, a polyelectrolyte is also added, for optimization of the flocculation effect, plus milk of lime to adjust the pH to a level inside the most favourable range for aluminium salt flocculation, i.e. between 6.8 and 7.0. The exact pH is measured in all cases (column 8). Floc size, settling rate and appearance (columns 5, 6 and 7) are judged on the basis of comparative observation and graded between 0 and 5.

The appearance of the water after settlement of the flocculated solids is also assessable on the basis of a measurement carried out with a turbidity measuring device (where available). Test no. 9 shows that the highest quality of the clarified water was obtained with the addition of 50 mg/l of aluminium sulphate, 0.3mg/l of polyelectrolyte, 30 mg/l of milk of lime for pH adjustment and double enrichment with activated sludge - i.e. with comparatively moderate consumption of chemicals.

The sludge volumes entered in columns 9 and 10 permit a conclusion to be reached on whether an adequate number of growth nuclei, i.e. enough activated sludge, is present in the flocculation zone, whether it would be better to operate without return of activated sludge, or if more should be returned.

The correct performance of flocculation tests using the simple method described above, plus analysis of the results, is easy to learn. These tests have the advantage of being quick to perform, thus producing results within a short time and allowing prompt adjustment of the flocculation process to alterations in the compositjon of the raw water.

If an optical assessment of the quality of a flocculation process is to be accurate, practice and experience are necessary. This means that after some months of patient instruction, semi-skilled personnel can quite well be in a position to reach independent judgements on the main aspects of flocculation (cf. test report) and to initiate any measures which seem necessary.

Examples:

a) - The floc appears too big and too light. It is inclined to float on the surface, i.e. the sedimentation property is poor. Possible causes:
   - too much flocculant/auxiliary flocculant,
   - too little, too much or too old activated sludge,
   - wrong flocculants used.

b) - The floc appears too small; turbid water is still visible between the flocs. Possible causes:
   - pH too high/too low for the flocculant used,
   - wrong chemical feeding points (move forward, alter height),
   - reaction times too short,
   - not enough/too much energy input,
   - chemicals added in wrong sequence,
   - no activated sludge returned, or not enough,
   - activated sludge was too old (no longer fully active),
   - hydraulic design of tanks misconceived or wrongly executed ("short-circuit" current),
   - auxiliary flocculant too old, no longer active,
   - flocculant/auxiliary flocculant too highly concentrated when added, thus poor distribution,
   - composition of the raw water has altered.

If there is malfunctioning of the flocculation process, several of the above-named factors simultaneously can often be discovered to be the cause of the problem. Some patience is needed in systematically examining and eliminating possible sources of the fault one after the other.

8.3 Maintenance

As discussed above, the flocculation process is best kept under constant observation. Stirrers must be lubricated as specified by the manufacturer.

Silting up may occur in flocculation tanks, especially in the simpler types. The sludge should be removed frequently (approx. once a month). The amounts of sediment may vary - e.g. more in the rainy season or after the snow melt - so that the situation should be kept under observation and the sludge removed at more frequent intervals when necessary.

Dosing and feeding equipment should be checked frequently and cleaned whenever necessary. This applies in particular to milk of lime feed pipes, which should be flushed daily. Where hoses are used, these should be tapped or otherwise moved to dislodge any deposits.

8.4 Auxiliary materials

Normal hand tools are adequate for construction and maintenance work. Larger installations may require the use of ladders, scaffolding and lifting tackle.

8.5 Parts needing special attention

All stirrers must be mounted in such a way that they are exactly vertical, and screwed firmly to the base plate, to preclude unbalance. Any damage, distortion or removal of all or some of the stirrer blades also cause unbalance and result in a destruction of the shaft seal to the gearbox, possibly also of the gearbox itself.

Since the stirrers are partly supported by the upthrust of the water, it is not advisable to allow them to run when the tank is empty.

If the flocculation stirrers are not optimally designed or have been dispensed with and sludge accumulates in the macro-flocculation tank, this must be cleaned frequently to prevent the inception of biological decomposition - possibly with scum formation.

8.6 Safety measures

When inspecting or cleaning flocculation tanks, the inflow of water must be reliably stopped. The fuses of the flocculation stirrer should be removed.

9 Sedimentation

9.1 Methods of constructing simple versions

Smaller sedimentation tanks can be made of locally available materials, e.g. stone or brick, finished with plaster. Larger structures should be made of concrete.

The construction work can be carried out by local craftsmen under qualified direction. If sedimentation tanks are provided with mechanically operated scrapers, these should be made in appropriately equipped machine or steel workshops.

Simple sedimentation tanks without mechanically operated scrapers are suitable for small installations, in rural areas and as temporary measures, or in any other cases where proper maintenance and procurement of spare parts cannot be guaranteed.

A careful examination of the given situation should always be made, covering e.g. the following points:

- is there an existing gradient which could be exploited to allow the floc/water mixture to flow gently from the flocculation to the sedimentation stage,
- what cheap building materials are available locally,
- how qualified are the available craftsmen and/or the future operating personnel,
- what treatment is intended to follow sedimentation - e.g. filtration,
- what settling times are necessary, or with what inlet volume per unit of surface area is it feasible to operate the sedimentation stage.

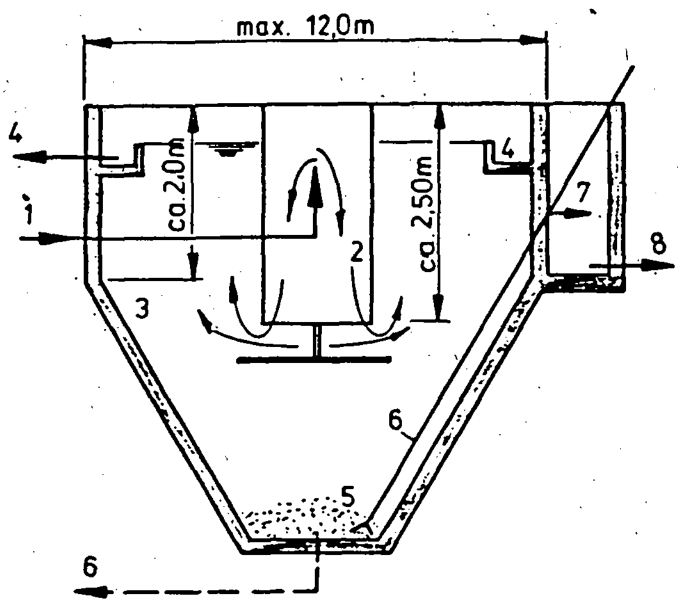
The sedimentation stage in water-treatment processes follows flocculation and precedes filtration. Both traditional systems and more sophisticated, high-efficiency designs are best dimensioned not too economically, thus gaining the following advantages:

- Good quality of the discharged clarified water and thus reduced loading of the succeeding filters.
- Lower consumption of chemicals.
- Improved basis for emergency operation. For instance, if the supply of flocculants is delayed or interrupted, operation can still be continued temporarily with reduced amounts of chemicals. Or if the supply fails completely, operation without flocculation and with static sedimentation only is feasible for a limited length of time. (In both cases a temporary deterioration of the quality of the water is accepted as unavoidable.)
- Easier to start up and shut down, better able to handle sudden high loads and alterations of raw water quality (storms, snow melt etc.), less susceptible to breakdowns, less sensitive to mistakes made by operating personnel in instruction phase, to power cuts etc..

In contrast, over-economical dimensioning of a plant can lead - sometimes already during commissioning - to a wide variety of problems and unintended extra costs. Alterations at this stage of a project often prove to be either impossible or highly inconvenient and generally very expensive. Where a plant is too small, the only solutions frequently prove to be an icreased use of chemicals, reduction of the volume of water or acceptance of lower standards.

The circular funnel-type settling tank with separate flocculation stage shown in fig. 50 is a simple structure with relatively little extra equipment.

The jacket of the tank may be made of concrete or steel with an appropriate protective finish against corrosion.



Circular settling tank with separate flocculation stage
(without mechanical scraper)

1 Water/floc mixture
2 Distributor pipe with spreader plate
3 Clarified water zone
4 Clarified water channel + outlet
5 Sludge chamber
6 Washout/sludge dredging
7 Sludge channel
8 Washout

Fig. 50

The interior components are usually made of steel and also given a thorough anti-corrosive finish. The raw water from the separate flocculation chamber enters through the inlet pipe (1) and is evenly distributed via the central distributor pipe (2) into the sedimentation chamber.

In the sedimentation chamber, the flocs separate from the water. The clarified water rises up to the clarified water zone and is drawn off via the channel provided (4) to the filters. The flocs settle in the sludge chamber (5). The sludge is expelled via a washout (6) or dredged up to the sludge channel (7).

The following details are important to ensure an optimum hydraulic design and to prevent breakdowns:

- The distributor pipe (2) should be in the exact centre of the tank and must be precisely vertical,
- the floor should slope at an angle of not less than 50°,
- the clarified water conduit (4) must be absolutely horizontal,

- the tank should be as exactly circular and its interior walls as smooth as possible.

As a preventive measure against blockages, the sludge dredging pipe (6) should have a diameter of approx. 150 mm. A second pipe is a useful standby.

Expelling of the sludge from the sludge chamber (5) can be continous, with relatively small amounts of sludge, or discontinuous, removing correspondingly larger amounts at once. A combination of the two methods is also possible. The sludge should not be left in the chamber for longer periods, especially in hot climates. The sludge dredging pipe (6) should be open at the top to allow cleaning.

If the raw water contains large amounts of heavy solids (e.g. sand, clay etc.), the sedimentation tank has to be taken out of commission from time to time and cleaned thoroughly by hand. In such cases, plants with 2 or more tanks clearly offer an advantage, since they allow operation to continue during cleaning of one of the tanks.

Longitudinal settling basins (fig. 51) are simple structures of conventional design operated with a relatively low inlet volume per unit of surface area. Usually these tanks are made of reinforced concrete. Where this is not possible e.g. because of the cost or because the necessary expertise is not available, plastered brickwork is used.

The raw water mixed with flocs flows in slowly through a channel or pipe (1), passes into the spreader channel (2) and from there flows through simple openings or stalk inlets into the actual settling basin. Heavy floc structures settle immediately in the sludge funnel (7), whereas the lighter flocs settle farther along the basin. A "settling line" develops, which gradually diminishes until at the far end of the tank, where the clarified water is drawn off, it reaches practically 0. The clarified water is drawn off via a sill (5) and a conduit (6) and transferred to the filters.

Longitudinal settling basin

1 Raw water with flocs
2 Distribution
3 Stalk inlets
4 Clarified water zone
5 Draw-off of clarified water
6 Clarifed water outlet
7 Sludge zone
8 Washout
9 Mechanical scraper

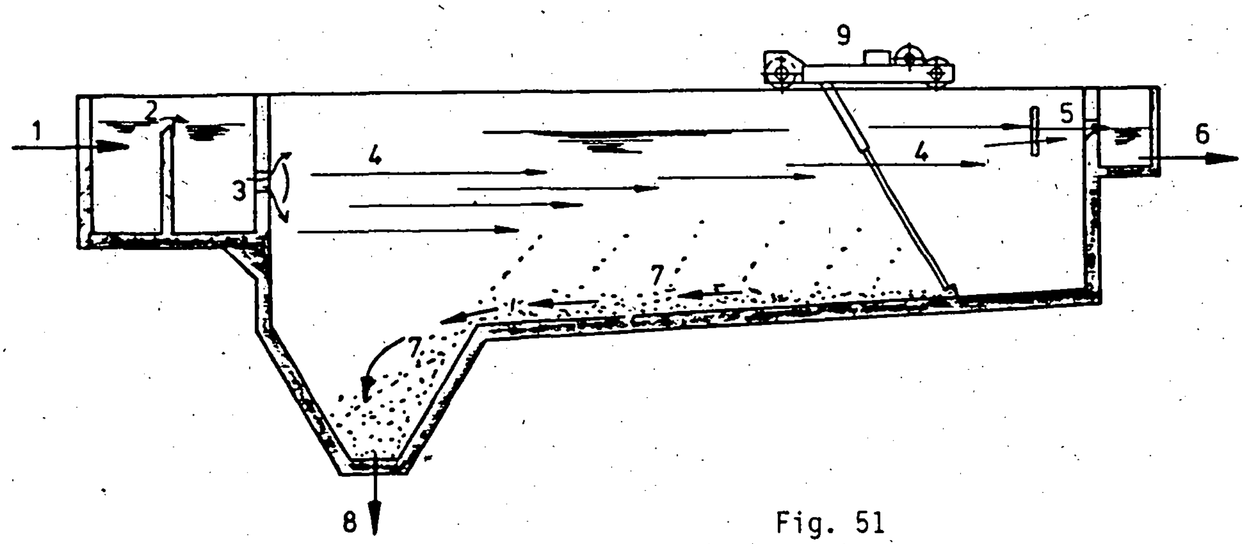
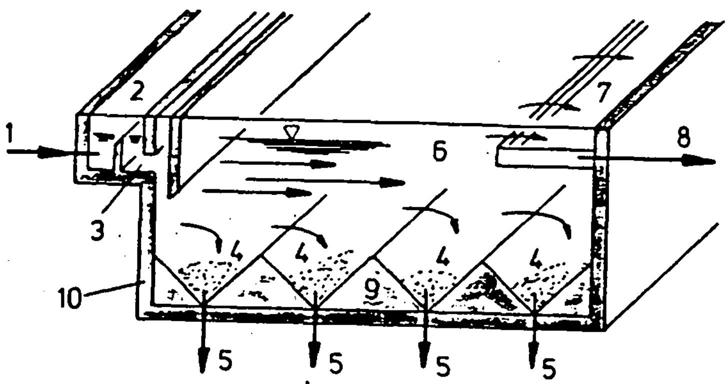


Fig. 51

It can often be observed that the water is clear after having passed about 2/3 of the length of the tank, i.e. the flocs have settled as expected on the floor. At the end of the tank, in the vicinity of the clarified water outlet, large amounts of flocs then suddenly appear, detracting considerably from the quality of the water being drawn off. This phenomenon points to an excessive volume of water per metre of sill length; in such cases the clarifed-water conduit running across the end of the basin should be continued a few metres round its sides. In this way the volume of water, or sill load, is reduced to approx. 15 to 20 m^3 per linear metre.

Simple longitudinal settling basins as shown in fig. 52, made from locally available or producible materials such as reinforced concrete, rubble or brick masonry (wherever possible plastered on the inside), logs or squared timbers, etc. should be designed for a maximum inlet volume of 1 m^3 per m^2 surface area/h. The depth of the water above the sludge bed should not be less than 2.5 m. Sills must be as horizontal as possible. Removal of sludge from relatively small basins can be facilitated by concreting or bricking funnels (9) in the floor of the tank, sloping at an angle of 45 to 60°. Sludge is expelled either continuously or discontinuously via washouts (5). With some types of sediment, the basin may have to be emptied and cleaned by hand twice a year.



Simple settling basin
(without mechanical scraper)

1 Water/floc mixture
2 Distribution
3 Inlet structure
4 Sludge funnel
5 Washout
6 Clarified water zone
7 Clarifed water channel
8 Clarified water outlet
9 Lean concrete
10 Basin made from reinforced concrete or plastered masonry

Fig. 52

Simple settling basins can also be dug in earth (fig. 53), wherever possible with the floor and sloping sides reinforced with brick or rubble masonry and the inlet channel (2) bricked. The inlet slits (3) should be as horizontal and uniform as possible. Inlet volume should not exceed 1 m^3 per m^2 of surface area and hour, with the total depth at least 4 m and the settling time longer than 4 hours. The stone or timber side wall (6) should be vertical. The clarified water is drawn off via a pipe or open channel (9). The sludge must be removed by hand every 4 to 8 weeks, depending on the amount accumulated and on the size/depth of the basin.

The availability of water under pressure and of a washout (11) at the bottom of the basin are of advantage.

Simple settling basin
(dug in earth; reinforced or non-reinforced)

1 Water/floc mixture
2 Distribution
3 Inlet slits over full width
4 Sludge
5 Clarifed water zone
6 Stone or log wall
7 Clarified water sill
8 Clarifed water
9 Clarified water outlet
10 Reinforcement
11 Washout

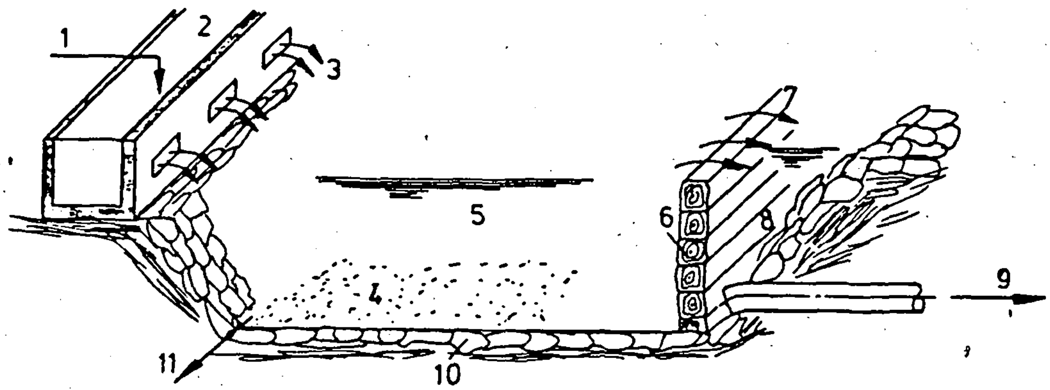
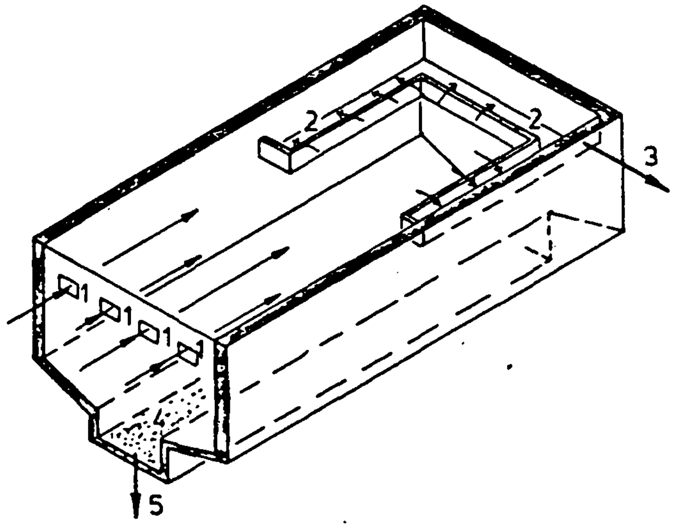


Fig. 53

Simple longitudinal settling basins of greater size (fig. 54), i.e. from an area of approx. 40 m^2 upwards, are built with a floor sloping slightly towards the middle (approx. 5 to 10°) and a central sludge channel (5) instead of a sludge funnel (cf. fig. 52). The inlet volume should not exceed 1 $m^3/m^2 \times h$, the total depth be at least 4 m and the sedimentation time longer than 4 hours. The clarified water conduit (2) must be horizontal and can be continued round the sides of the basin to limit the sill load to approx. 10 to 15 m^3/lin. m of sill.

The accumulated sludge is removed by hand approx. every 4 to 8 weeks, depending on the amount and the size/depth of the basin. The availability of water under pressure and of a washout (11) in the floor of the basin are of advantage.



Simple settling basin
(without mechanical scraper)

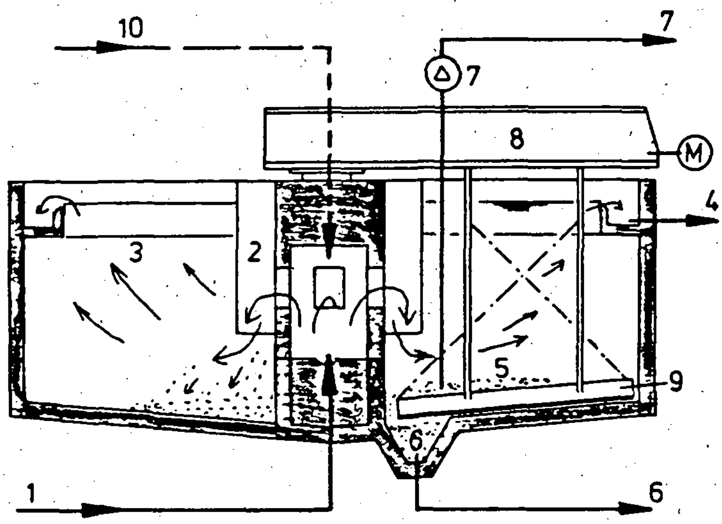
1 Inlet slits
2 Clarified water channel
3 Clarified water outlet
4 Sludge channel
5 Washout

Fig. 54

In some special cases, 2 earth basins operated alternately may achieve an adequate effect, with limitations. The inflow of water per m² of surface area should not exceed 0.5 m³/h, or the settling time should be longer than 10 hours. All simply designed settling basins function better, or in some cases can only function at all, if preceded by an efficiently funtioning flocculation stage.

Circular settling tanks with mechanical rotating scrapers and a central inlet of raw water (fig. 55) are technically more sophisticated systems. To keep costs down to a reasonable level, tanks with a diameter of up to 5.0 m are made of steel with an appropriate anti-corrosion finish. Structures with a diameter greater than 5.0 m are generally made of reinforced concrete.

The raw water (water/floc mixture) coming from the separate flocculation stage enters the centrally located distribution system (2) via the inlet pipe (1) from below or alternatively from above (10) and flows from here, spread as evenly as possible, into the ring-shaped sedimentation zone. Here the flocs are separated from the water. The clarified water rises to the clarified water zone (3), to be drawn off via a channel or pipe (4) and transferred to the filters.



Circular settling tank with separate flocculation stage (with mechanical scraper)

1 Water/floc mixture
2 Distributor system with baffle plate
3 Clarified water zone
4 Clarified water channel + outlet
5 Sludge chamber
6 Washout via funnel + pipe
7 Alternative sludge dredging via pump
8 Scraper bridge
9 Scraper blade
10 Mixed water/flocs - altern. inlet from above

Fig. 55

The flocs settle on the floor of the tank. The blades (9) of the rotating scraper (8) continuously clear the sludge into funnel-shaped pockets (6) or a channel which may run all the way round the tank. From here the sludge is expelled via a washout or is dredged by a pump located on the scraper bridge.

If failures occur in installed plants (figs. 55 and 56), the following points should be checked:

- the spreader system (2) with baffle plate should be in the exact centre of the tank and precisely vertical,
- the inclination of the floor should be between 6 and 10°,
- the floor must be smooth enough not to hinder scraping of the sludge,
- the sludge pockets (6) or channel should be generously dimensioned,
- the washout pipe (6) should be provided with a flushing facility,

- the clarified water channel (4) must be absolutely horizontal,
- the rotating scraper (8) and its blades (9) must be strongly made,
- the crown of the tank wall, i.e. the surface on which the scraper bridge runs, must be even and smooth,
- the inlet volume should be checked to ensure that the amount per m² of surface area is not more than 20 m³/h,
- proper chemical feeding and floc formation should be checked.

The sludge should not be left in the tank for long periods, especially in hot climates. The flocculation process can be optimized by providing 2 mechanical stirrers in the enlarged empty space between inlet system (2) and baffle plate. These stirrers are attached to the scraper bridge (8). The continuously operating scraper mechanism (8) and (9) results in a virtual elimination of the down-times otherwise necessary for manual removal of larger, heavier solids.

The settling basin with integrated flocculation zone described below and shown in fig. 56 is a representative example of many similar systems which are in widespread use under a variety of names. As precursors of more sophisticated, high-efficiency equipment, they still produce fully satisfactory results in many cases. Because of the cost aspect, tanks with a diameter of up to 5.0 m are made of steel, with an appropriate anti-corrosion finish. Tanks with a diameter greater than 5.0 m are normally made of reinforced concrete.

The raw water flowing out of a siphon (1) emerges from below into the centre of the flocculation chamber (2) into which flocculants - e.g. $Al_2(SO_4)_3$ or milk of lime for pH control - are also fed (12). In addition, the activated sludge (4) required to achieve optimum flocculation is also pumped into the flocculation chamber (2).

Mechanical flocculation is achieved as the low-speed stirrer (3) gently mixes the fluid in the flocculation chamber.

The mixture of water and flocculated impurities then flows, evenly distributed, into the ring-shaped sedimentation zone, where the flocs settle out of the water. The clarified water rises to the clarified water zone (10), flowing from here via the clarified-water channel (11) and pipe to the filters.

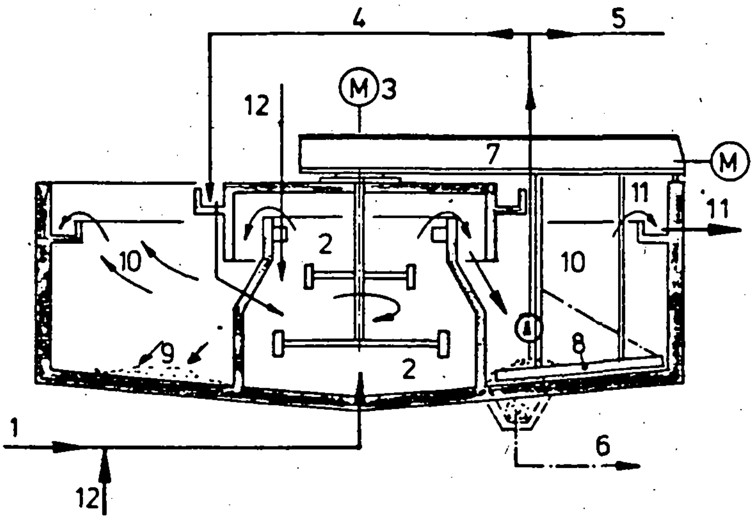


Fig. 56

High-efficiency clarifier with integrated flocculation (OPUR model)

1 Raw water inlet
2 Flocculation chamber
3 Stirrer
4 Activated sludge
5 Dredging
6 Washout
7 Scraper bridge
8 Scraper blade
9 Sludge zone
10 Clarified water zone
11 Clarified water channel + outlet
12 Flocculants

The flocs settle on the floor of the tank in the sludge zone (9). The mechanical scraper (7) with its blades (8) continuously scrapes the sludge into the sludge pockets (6), from where it is continuously or discontinuously expelled. If sludge removal via a washout in the tank floor is not possible, it can be dredged to the top by a pump (5).

In recent years, high-efficiency systems such as inclined-plate clarifiers and horizontal/radial through-flow systems have been developed; these will not be discussed here.

9.2 Operation

All sedimentation plants can be considered to be operating satisfactorily if, on a daily average, less than 15 mg/l of filtrable solids are found in the clarified water. A concentration lower than this is favourable for the following filtration system, since it means a longer service life between two filter backwashing operations, reduced consumption of cleaning water and a smaller volume of sludge liquor to be disposed of.

If the concentration of solids in the clarified water exceeds 15 mg/l, the service life of the filter may be considerably shorter. In extreme cases the filter can become so blocked that the necessary volume of cleaning water can no longer pass through it. The cause is often a malfunctioning of the chemical feeding and flocculation equipment, e.g.:

- dosage of chemicals too high/too low,
- poor-quality or wrong chemicals used,
- dosing and feeding equipment poorly serviced,
- wrong pH range,
- chemicals added at wrong point,
- wrong stirrer speed,
- stirrer not functioning,
- flocculation chambers too small or overloaded,
- no return of activated sludge,
- excessive turbulence after flocculation, leading to destruction of the flocs.

The results of the clarification process are also bound to be unsatisfactory if the sedimentation tanks, of whatever type, are not cleared of sludge often or thoroughly enough. Sediments left too long in the tank begin a natural process of decomposition. The gas which develops attaches itself in the form of small bubbles to particles of sludge, which then rise to the surface as scum and are carried into the filters. Further possible sources of problems in sedimentation are:

- under-dimensioned settling tanks,
- one-sided inlet of raw water (no spreading of the inflowing fluid),

- sill load too high,
- settling tank too shallow (especially in simple systems),
- strong fluctuations in loading (flotation of settled flocs),
- not enough time allowed for starting up,
- personnel not properly qualified to service the equipment,
- insufficient spare parts, tools, operating instructions, inadequate reporting procedures, supervision by inadequately qualified personnel.

These and other possible sources of problems in operation of the plant should be investigated and eliminated one after the other. Often only minor corrections are needed in order to achieve the proper balance between dosing of chemicals, flocculation and sedimentation. Patience is an important factor. The basins often have very large capacities, so that several hours may pass before any reaction to alterations - e.g. of the amounts of chemicals used - can be determined.

A frequently-observed phenomenon is the sudden appearance on the surface of large clouds of sludge. As an immediate measure, the sediment on the floor of the tank should be expelled. Then the possible causes listed above should be examined conscientiously one by one until the process is again under control.

9.3 Maintenance

The mechanical equipment, e.g. electrical drives, stirrers, scrapers, pumps, valves, switch cabinets etc. should be serviced as specified in the operating manual supplied by the manufacturer.

Special attention should be paid to removing the sludge from the settling tank at regular intervals. Equally important is regular lubrication of the installed machines.

It is useful, if not essential, to keep an exact record of maintenance work performed, oil changes, sludge removal etc. in a log specially kept for the purpose.

A stockkeeping system, in which the amounts of spare parts needed are properly calculated and replacements ordered in good time, is of great benefit. Even installations of the simplest type need some spare parts, plus paint for protective finishes. A stock of spare parts and paint sufficient for 5 years should be kept to prevent early deterioration of the equipment.

Regular sweeping and cleaning of the surfaces of the equipment should not be neglected - this allows personnel to become familiar with the details of the plant and to recognize any changes or defects as, or soon after, they occur. General cleanliness is an important aspect in the operation of any water-treatment plant.

9.4 Auxiliary materials

Normal hand tools are adequate for erection and maintenance of the structures described. Large plants (i.e. with heavy mechanical scrapers) will need lifting tackle and scaffolding.

The best possible "material" in the long-term proper maintenance and operation of the equipment is well-trained and positively motivated personnel. This applies equally to fitters, mechanics, electricians, shift workers and casual labour. An adequate stock of spare parts, operating manuals and maintenance regulations and the keeping of accurate records are also important.

9.5 Parts needing special attention

All the machinery is subject to a certain amount of unavoidable wear and tear, especially pipes and sheet-metal or timber structures which are exposed to the interaction of air and water. Sludge pipes must be flushable or else easily accessible for cleaning purposes.

9.6 Safety measures

Before settling tanks are cleaned, they must be drained, either fully or sufficiently to allow the work to be carried out without hindrance. Often the bed of sludge at the bottom is very thick, making special safety measures necessary. When heavy machines or other parts are installed or dismantled, enough ropes and hoists should be available. During repairs to machines the power supply must be cut off (fuses removed).

10 Dosing equipment

10.1 Methods of constructing simple versions

Only the very simplest types of dosing installations can be made of locally available materials such a timber, stone, bricks or possibly plastics. The choice of material is much restricted due to the aggressivity of many of the chemicals used.

Whereas storage facilities for the chemicals can be built easily by semi-skilled personnel, the actual dosing equipment (e.g. proportional or pH-based system) is much more difficult to design and build correctly. Personnel entrusted with this task must be appropriately trained or adequately assisted.

High-precision dosing systems requiring dosing apparatus for dry chemicals, metering pumps, electrical control mechanisms etc. must be obtained from specialist companies and installed under qualified supervision. If the dosing system is to be kept as simple as possible, a number of important points must first be considered, such as:

- What chemicals are to be used (e.g. aluminium sulphate, lime, chlorine etc.)?
- In what physical states are the substances to be dosed
  - e.g. liquid - what concentration;
    solid - what grain size;

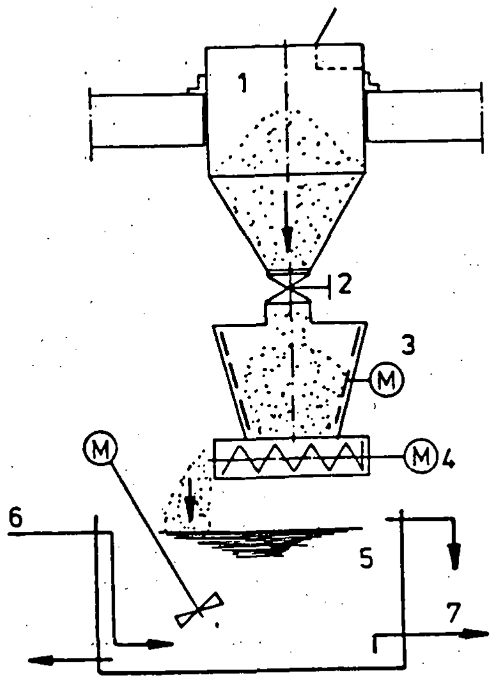
and what impurities or foreign matter might be found in them?

- Unit weight, percentage of effective substance, storage properties, solubility etc. of the chemicals.
- Intended concentration of solution or suspension:
  e.g. milk of lime - 5%;
  aluminium sulphate - 10 to 15%;
  polyelectrolyte - 0.05 to 0.1%.
- Method of storage, preparation and dosing; e.g. dry storage in a hopper, wet storage in a concrete, timber or plastic tank, dilution before dosing and dosing via metering pumps; or dosing as dry substance followed by solution.
- Can the supply of chemicals be relied on?
  E.g. larger storage facilities may have to be provided if difficulties are anticipated.
- Are the chemicals aggressive?
- If so, what materials are resistant to this aggressivity and can they be obtained locally?
- What are the minimum and maximum dosages? (Can be determined by jar test - cf. Section 8).
- Calculation/confirmation of the dosing concentration and marking of the required amount - e.g. of aluminium sulphate - and quantity of dilutant.
- How are the chemicals to be dissolved/diluted? E.g. addition of water manually, mixing by hand or by simple mechanically-driven apparatus (energy from wind or water powered wheel).
- What dosing method is to be used?
  E.g. proportional (i.e. to the volume of raw water); pH-related, or depending on optical assessment of the floc structure? (Cf. Section 8).
- Is there a utilizable gradient leading up to the feeding point, or what are the pressure conditions there and how can the chemicals be fed into the water at the correct point and with a minimum of mechanical equipment?
- How, and how often, are feed pipes, hoses, channels and chutes cleaned/kept clean?

Dry chemicals are dosed by devices designed to handle dry substances (cf. figs. 57, 58, 59, 60). Dosing may be proportional to the volume of raw water or to some other given quantity, e.g. pH, chlorine residue etc..

Volumetric dosing devices

The screw-type dosing apparatus shown in fig. 57 operates on a volumetric basis. The chemical is kept in a large-capacity or day-supply hopper (1). A quantity of the chemical is released by a valve (4) into a funnel, which is equipped with a vibrating mechanism (3) to ensure smooth transport of the substance.



Screw-type dosing apparatus

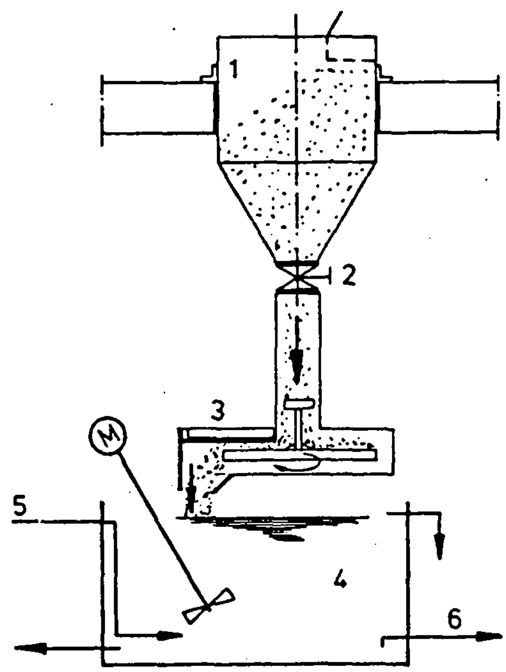
1 Hopper
2 Valve
3 Intermediate transport
4 Single or double screw dosing apparatus
5 Suspension/solution tank
6 Water inlet
7 Discharge of liquid

Fig. 57

The screw (4) - single or double - conveys the chemical in correct proportion to the inflow of raw water into the suspension/solution tank (5). Setting of the basic quantity (e.g. 100 m^3/h of raw water x 50 g/m^3 of aluminium sulphate = 100 x 50 = 5 kg/h) takes place on the dosing apparatus. Heating of the delivery equipment is useful; also an appropriate design to prevent spray or moisture entering the mechanism.

The chemical is dissolved or diluted by the addition of water (6), which should be as clean as possible. A mixing device of robust construction stirs the mixture. The tank (5) containing the suspension or solution must be provided with an overflow and a drain. The fluid leaves the tank via the outlet (7).

The rotary-disc dosing device shown in fig. 58 also operates on a volumetric basis. Storage and solution/suspension of the chemical are as in the screw-type device (fig. 57). Dosing here is carried out by a flat, centrally mounted rotary disc (3). The chemical falls onto the centre of this disc, thus forming a cone which is adjustable in height and width. A stripper mounted at the side removes some of the chemical into the suspension/solution tank (4).



Rotary-disc dosing apparatus

1 Hopper
2 Valve
3 Rotary disc
4 Suspension/solution tank
5 Water inlet
6 Discharge of liquid

Fig. 58

The rotary vane dosing apparatus (fig. 59) also operates volumetrically. The chemical is stored and dissolved or suspended as above (fig. 57). Dosing is carried out by a centrally mounted rotating wheel (3) comprising several chambers. As an empty chamber arrives at the funnel underneath the valve (2) it is filled with the dry chemical. This then leaves the wheel via a discharge branch into the suspension/ solution tank.

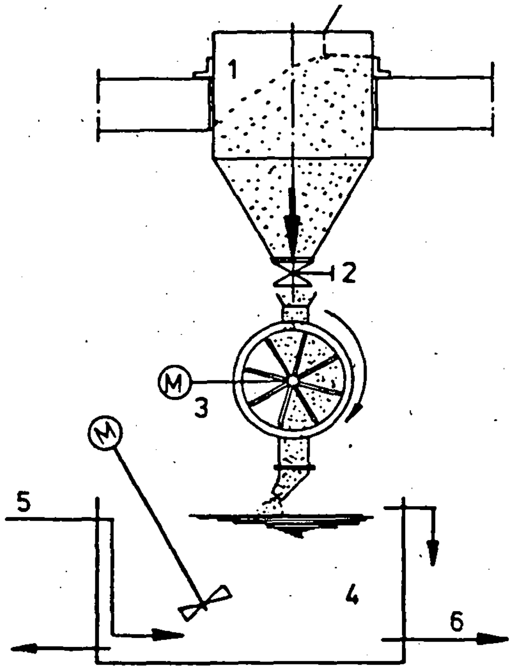


Fig. 59

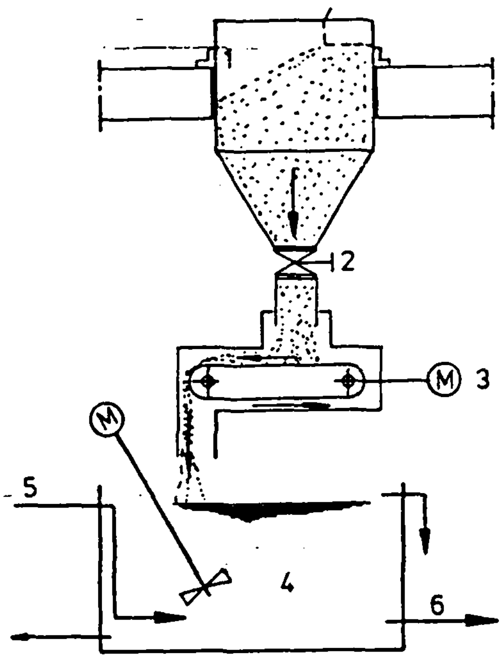
Rotary-vane dosing apparatus

1 Hopper
2 Valve
3 Vaned wheel
4 Suspension/solution tank
5 Water inlet
6 Discharge of liquid

The basic quantity in proportion to the volume of raw water is set by altering the speed of drive for the vaned wheel.

The volumetric dosing devices shown in figs. 57, 58 and 59 require particularly careful and thorough maintenance, especially if the chemical is damp and/or contains impurities (cf. 3. below: Maintenance). It is important for the chambers of the rotary vane dosing device to be completely emptied. Encrustations in the screw-type and rotary disc dosing devices can lead to serious disruptions of operation, inaccuracies in dosage and additional down-times due to the need for cleaning and servicing.

The belt-weigher dosing device shown in fig. 60 operates with considerably greater precision and reliability. The method of storage and of dissolving/diluting the chemical can be seen from the diagram. Dosing on a proportional basis is carried out by the belt-weigher (3). This consists of a weighing apparatus with a rotating conveyor belt. In contrast with volumetric metering devices for dry chemicals, the substance is here dosed continuously, controlled by the weighing system. The dosage is adjusted by altering the speed of the conveyor belt and the height of the layer of material on it. The belt-weigher dosing device is relatively unaffected by impurities up to 10 mm.



Belt-weigher dosing apparatus

1 Hopper
2 Valve
3 Belt-weigher
4 Suspension/solution tank
5 Water inlet
6 Discharge of liquid

Fig. 60

Aluminium sulphate and lime are normally supplied in sacks. If larger consignments have to be stored, a shed or hangar must be built for the purpose. This can be of locally available materials, e.g. timber, reeds, bamboo, stone, loam, adobe etc.. Important is a watertight roof, so that the material is kept dry and not spoilt.

The roof should have deep eaves or be provided with a gutter (bamboo, wood), otherwise the rainwater running off the roof could splash up onto the chemicals. A light roof (without side walls) continued up to the feeding point protects the chemicals during transport in tropical rain or heat. The shed should be large enough to allow an adequate supply of material to be stored and to give personnel sufficient freedom of movement. Transport of the chemicals to the dosing equipment can be manual, using normal wheelbarrows.

Figs. 61 and 62 show hoppers for storage of chemicals. These can be made of steel, concrete or timber, depending on size.

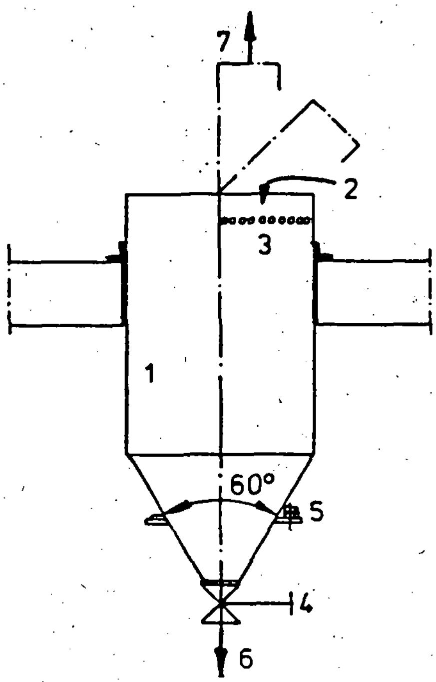


Fig. 61

Day-supply hopper

(calcium hydroxide or aluminium sulphate)

1 Hopper
2 Opening for filling
3 Screen
4 Valve
5 Vibration motor (when required)
6 To dosing apparatus
7 Sack-slitting device with dust extractor

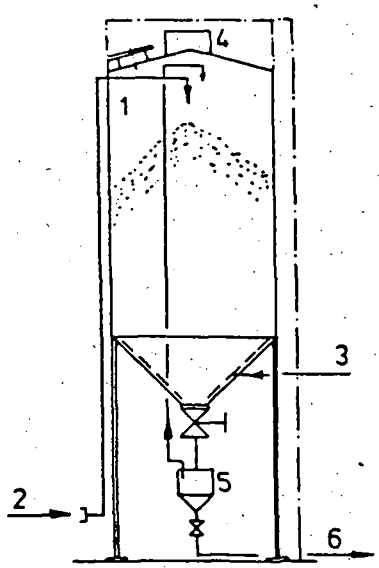


Fig. 62

Large-capacity hopper

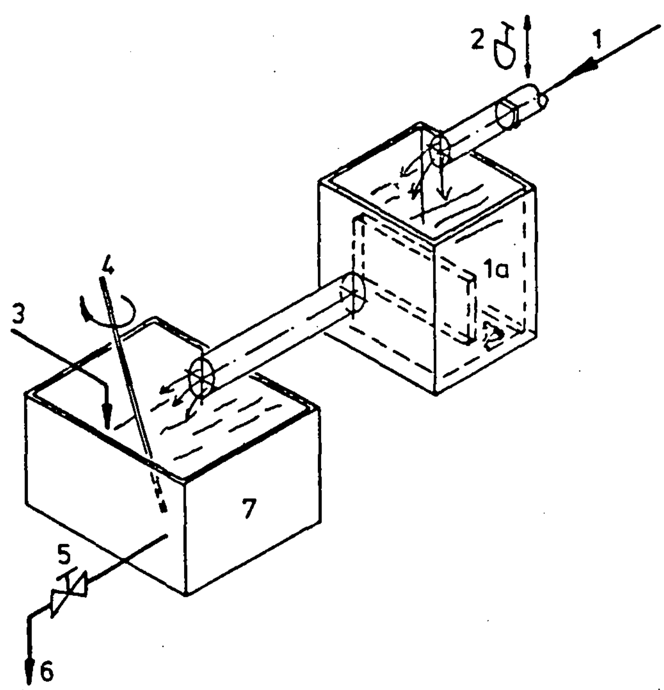
(calcium hydroxide or aluminium sulphate)

1 Hopper
2 Filling pipe
3 Loosening
4 Dust extraction
5 Day-supply hopper
6 To dosing apparatus

Sometimes circumstances are such that a system of water treatment can only be maintained with ultra-simple, cheap methods.

Fig. 63 shows a simple tank for chemical preparation. The diluting water (1) is fed into a tank made of concrete, wood, stone or plastics, or an ordinary drum, via a channel made out of wood, bamboo, earthenware etc. or a pipe, following the removal of coarse impurities in a simple settling tank or pit (1a).

Once the tank (7) is full up to the mark, the inflow of water is cut off by a stop plank (2) and the calculated amount of chemical - e.g. aluminium sulphate - added manually. Mixing can be by hand (4) or else mechanical, powered by wind, water or animals.



Chemical preparation tank

1 Water
1a Settling tank
2 Stop plank
3 Chemical
4 Stirring rod or hand-operated mixer
5 Dosing valve
6 Gravity pipe to flocculation chamber
7 Tank, drum

Fig. 63

The fluid is stirred with a rod (4) until the aluminium sulphate is dissolved. If milk of lime is being used, stirring must be repeated at fairly short intervals to prevent the substance from settling. When the solution or suspension is ready, the dosage is approximately adjusted by means of a valve (5) or a necked hose and transferred via a gravity pipe to the flocculation chamber (figs. 42 and 43). The inaccuracies inherent in this system have to be accepted as unavoidable.

Even simpler, but at the same time considerably more inaccurate, is addition of the dry chemical (lime or aluminium sulphate), measured in a flask or bucket, directly into the flocculation chamber (figs. 42 and 43). This very rough dosing method often means that results of the flocculation process are unsatisfactory - an effect which can be partially equalized by generously dimensioning the settling basins (cf. figs. 50 to 56).

In relatively small plants, "drop by drop" dosing using a "Mariotte bottle" (fig. 64) may be possible.

Mariotte bottle

1 Bottle containing chemical
2 Immersion tube - depth adjustable
3 Stopper
4 Level indicator
5 Adjustable valve

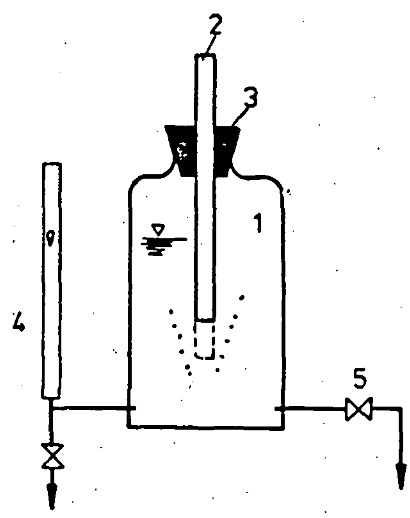
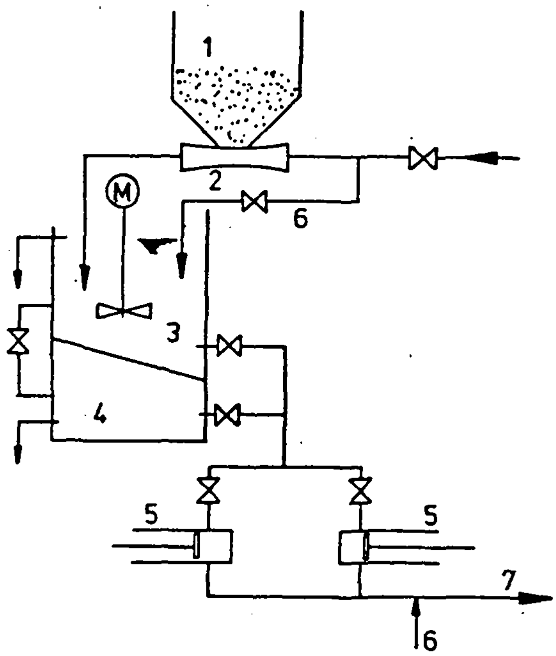


Fig. 64

The apparatus shown in fig. 65 is especially suitable for the preparation and feeding of polyelectrolytes in solid form as auxiliary flocculants. Auxiliary flocculants are relatively expensive and their use therefore not very widespread.



Dosing apparatus for solid chemicals
(e.g. polyelectrolyte)

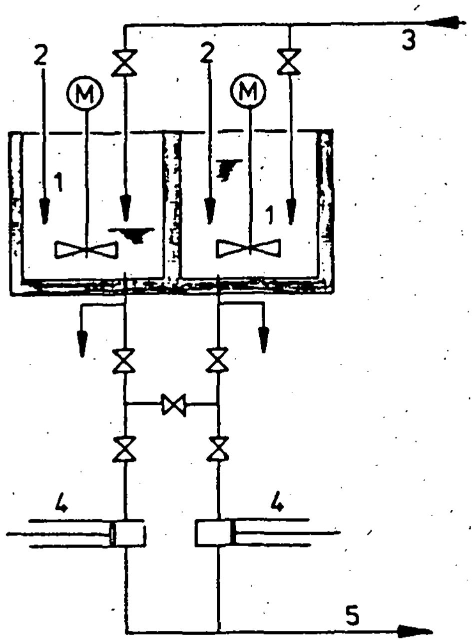
1 Feed hopper (polyelectrolyte)
2 Mixing and diluting
3 Maturing tank
4 Standby tank
5 Metering pumps
6 Further dilution (if necessary)
7 Transport to feeding point

Fig. 65

One day's supply of auxiliary flocculant is kept in the hopper (1). Using clean water, the chemical is dissolved and diluted by the mixing and diluting apparatus (2). The maturing tank (3) holds one batch, and here the necessary final concentration is adjusted by the addition of more water if necessary. A low-speed stirrer provides the necessary mixing turbulence. A metering pump (5) is provided for proportionate dosage of the chemical. It is advisable to provide a standby pump. The metering pump (5) normally takes the dissolved electrolyte from the tank (3). If this is empty, the standby tank (4) is brought into operation manually and a new batch prepared in the main tank (3).

The auxiliary flocculant solution can also be prepared manually. In this case, the chemical is scattered by hand slowly, in very small amounts so as to prevent the formation of lumps, directly into the maturing tank (3). The solution is transported through plastics pipes or hoses. Connections for flushing water are recommended.

Fig. 66 shows a dosing installation with wet storage of chemicals. Two concrete tanks (1), if necessary lined or painted with a corrosion-proof material, are filled up to a certain level with a previously calculated volume of water (3).



Dosing installation for solid chemicals
(wet storage)
- e.g. aluminium sulphate

1 Wet storage and dilution (alternate operation)
2 Chemicals filled in by hand
3 Diluting water
4 Metering pumps
5 Transport pipe

Fig. 66

The two agitators are switched on and the correct amount of chemical for the volume of water scattered in sack by sack (2). When the chemical is properly dissolved or suspended, dosing via the metering pumps (4) can begin. The liquid is drawn off and a new batch prepared in such a way that a full tank is always waiting in reserve. When dissolving aluminium sulphate, the fluid can be circulated by pumping or moved by passing air through it until the process is completed; in this case an agitator is not required. The dissolved or diluted chemicals are transported through plastic pipes or hoses or channels made e.g. of plastics, wood or bamboo. Long distances up to the feeding point should be avoided. This applies especially to suspensions of substances such as milk of lime which have a pronounced tendency to separate. An inspection or flushing operation carried out once in every 8-hour shift is advisable (especially when using lime).

Fig. 67 shows a plant with a storage tank (1) for liquid chemicals. Tanks in which highly aggressive chemicals are stored must be installed inside a safety vat (7).

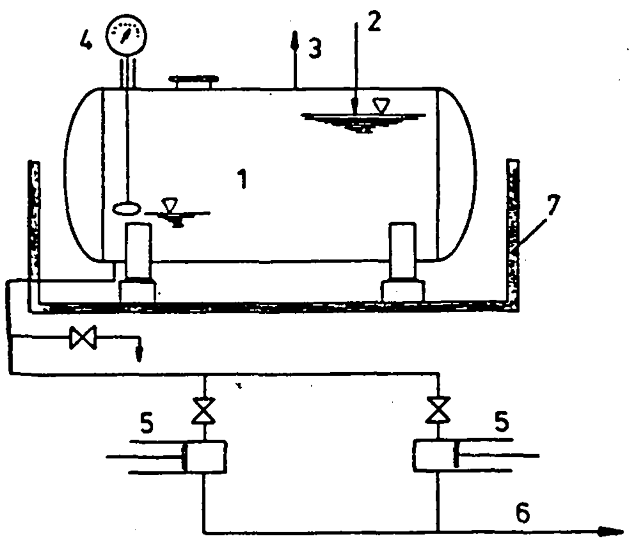


Fig. 67

Dosing installation for liquid chemicals - e.g. iron III chloride or NaOH

1 Storage tank
2 Filling of chemical
3 Ventilation
4 Level control
5 Metering pumps
6 Transport pipe
7 Safety vat

The tank is filled via a nozzle (2). Nozzle (3) is used for ventilation. A float (4) allows the level of liquid in the tank to be monitored. The metering pump (5) transfers the medium via the transport pipe (6) to the feeding point.

Fig. 68 represents a chlorine gas dosing plant.

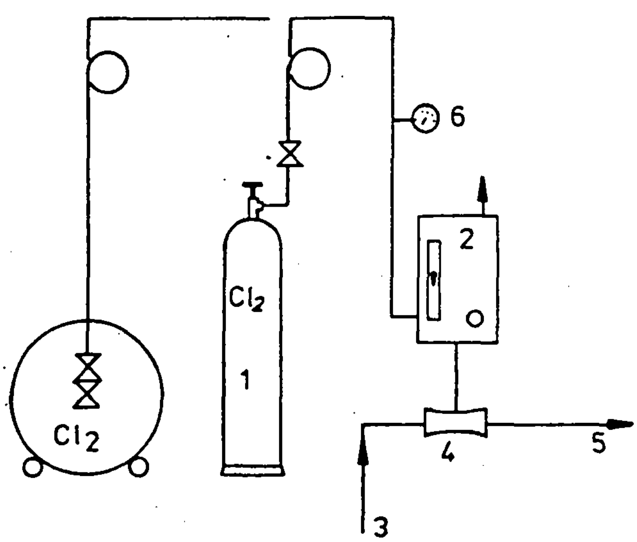


Fig. 68

Dosing plant for gaseous chemicals (e.g. chlorine)

1 Bottle/drum containing chlorine
2 Dosing device for gas
3 Connection for expanding water
4 Injector
5 Transport pipe
6 Chlorine pressure gauge

The liquid chlorine (amount according to consumption) is kept in drums or bottles (1). Chlorine gas is taken from this container and transferred via a connecting pipe to the dosing device (2). Here the necessary amount of chlorine gas is metered and the chlorine solution produced using clean pressurized water (3) in the injector. Most chlorine dosing plants operate at negative pressures as a safety measure. It is very important to observe the relevant safety regulations when handling chlorine. A new bottle is connected up when the chlorine pressure gauge (6) shows "empty".

If chlorine is used in powder or tablet form, the solution is prepared as shown in fig. 33 or 66 and fed via a metering pump or valve.

10.2 Operation

Dosing installations, whether of simple or of more sophisticated type, have a relatively high fault incidence and therefore need to be carefully monitored.

- Storage
  The storage system must allow the need for a fresh supply to be recognized without delay, so that appropriate action can be taken.
- Solution/suspension tanks
  These should be inspected hourly, to enable a new batch to be prepared well in advance (aluminium sulphate content should be measured out after each batch).
- Dosing apparatus, transport pipes and pumps
  These must be checked several times a day.
- The structure of the flocs should be examined once every hour and the dosages of chemicals altered if necessary (i.e. more/less). As parallel measures, activated sludge return, pH, sludge removal and the sedimentation process should also be observed.

- When dosing milk of lime, caustic soda solution or acid, the pH should be checked and recorded hourly. PH measuring devices should be recalibrated once a week. The use of pH-indicating paper is only permissible in some cases. Cheap and relatively reliable is the titration and colour screen comparison method.
- The turbidity of the water after sedimentation and after filtration must be measured every hour with the aid of a simple device. If the turbidity figures after sedimentation are good, the amounts of chemicals used can be gradually reduced. If, on the other hand, turbidity is too high, the chemical dosage should be slowly increased.
- The residual chlorine content should be measured hourly via titration and colour screen comparison and recorded. What residual chlorine content is permitted or required depends on the extent of the supply system following the treatment plant. Ideally, a slight amount of residual chlorine should still be detectable at every point in the water mains. The chlorine pressure gauge should be read once in every 8-hour shift and chlorine cylinders/drums replaced promptly when necessary.
- If delays in the supply of chemicals are foreseen (possible causes: weather, strikes, hostilities, lack of foreign currency etc.), the amounts of chemicals consumed must be reduced well before the supply runs out completely, any deterioration of the quality of the treated water which may result then having to be accepted as unavoidable.

10.3 Maintenance

All dosing equipment must be serviced and maintained as carefully and thoroughly as possible under consultation of the manufacturer's instructions. In addition to this, the following measures are also recommended:

- Storage container (wet and dry storage) should be inspected and cleaned at least once every 6 months.
- Tanks in which the chemical solution or suspension is prepared should be emptied and cleaned once a month.
- Metering pumps should be checked over daily and recalibrated once every 6 months.
- Feed pipes, especially those used for milk of lime, should be flushed once in every 8-hour shift. Hoses are often used, since these are easier to keep clean by kneading, followed by flushing with clean water. Hardened calcium carbonate deposits are virtually impossible to remove from feed pipes.
- Any aggressive chemicals leaked or spilled must be hosed off the floor immediately.
- Dust on dosing equipment and floors should be removed once a week.
- When emptying chemicals into tanks out of sacks (lime or aluminium sulphate), care must be taken not to allow scraps of paper or plastic to fall into the tank. The installation of simple wire-mesh or steel-bar screens can be of considerable benefit here.

10.4 Auxiliary materials

The auxiliary materials required in maintenance and repair work do not go beyond normal hand tools plus the maintenance instruction sheets. Wherever chlorine is used, it is essential to ensure that gas masks and protective clothing are available. Men working near acid or caustic dosing and feeding installations need protective goggles, rubber gloves, rubber boots and rubber aprons.

A stock of spare parts should be kept wherever at all possible.

10.5. Parts needing special attention

Dosing equipment is, generally speaking, relatively fault-prone. This tendency increases the more sophisticated the technology used. In addition, many of the chemicals used are highly aggressive - e.g. chlorine, iron III chloride, aluminium sulphate, acids, etc. - leading to an increased need for materials with special properties and/or corrosion-resistant finishes. Some abrasive chemicals, such as calcium hydroxide, alumina products etc., which have a tendency to separate and form encrustations, can eventually block the system and cause considerable problems.

10.6. Safety measures

Personnel should always be informed of the dangers inherent in the chemicals they have to handle. The training programme carried out should include instruction on preventive measures and elementary first-aid procedures - e.g. how to prevent and what to do in the case of accidents with

- chlorine
- acids
- caustic soda solutions
- aluminium sulphate
- iron III chloride
- lime, etc.

II Filtration

11.1. Methodes of constructing simple versions

Next to flocculation, sedimentation and dosing of chemicals, filtration is one of the main components of water treatment. Some aspects of filtration are also covered in Module 2.5, Section 11. The examination of existing filtration systems or design of new installations should only be undertaken by qualified personnel. Locally recruited craftsmen can then perform the work under qualified supervision. Materials such as stone, bricks, timber, asbestos cement or plastics pipes for floor drainage, filter gravel and sand, possibly pipes and hand-operated valves which are locally available should be given preference.

If an existing filter is to be overhauled to improve performance or repaired, or a new unit - even of ultra-simple type - constructed, a careful survey should first be made of the following points:

- What filtration system is currently being used?
- Is the water source a river or lake, or a well?
- Have analyses already been carried out, or if not who could perform and/or evaluate these?
- Is any primary treatment (flocculation/sedimentation) carried out?
- How efficient is this primary treatment? (Optical assessment of flocculation results, determination of residual solid content and turbidity - cf. Module 2.5 and this module, Sections 8 and 9.)
- What are the hydraulic conditions?
- In what general condition is the existing plant?

  Mechanical aspects

  Filter gravel: insufficient
  too much
  too coarse
  too fine
  clogged

Nozzle plate or floor drainage in working order or:
broken
leaking
blocked
uneven

Pipes in working order or:
leaking
corroded
blocked

Valves in working order or:
leaking
seized
corroded

Back-washing mechanism in order or defective; check:

bearings
impellers
seals
motors
shafts
casing
couplings
lubrication, etc.

Electrical aspects

Motors functioning or defective:

- switching cabinets in working order or faulty; check:

  fuses
  contactors
  relays
  switches
  indicator lamps etc.

- cabling and earthing in working order or faulty.

Structure

Intact or leaking, eroded, surface damaged, reinforcement visible, etc..

- How can the faults discovered be put right both inexpensively and durably?
- When designing a new installation, thought should be given to which technology can be expected to give good long-term results at what cost.

Open steel cylinder filter units (fig. 69)

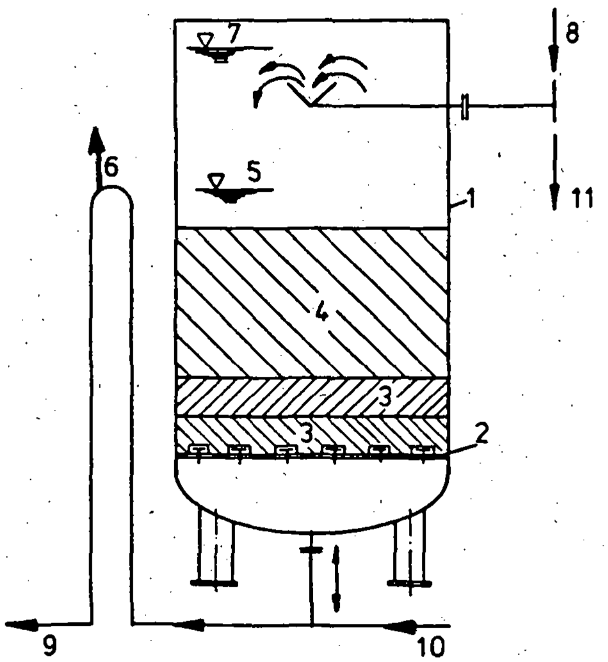
These consist essentially of a steel cylinder (1) open at the top and with a perforated plate at the bottom. The perforated or nozzle plate (2) supports the layers of gravel and sand (3) and (4). The filter must be erected in such a way that the nozzle plate is absolutely horizontal.

The raw water enters via an inlet pipe (8). The filtered water is drawn off through an outlet pipe (9).

In a freshly cleaned or new filter, the water stands at a certain initial level (5). With increasing contamination of the filter, the water rises to its maximum level (7). The filter must then be back-washed with water from the backwash pipe (10). The sludge water leaves the filter via the washout (11). Good results are obtained by first loosening with air, then scouring with air and water. The cleaning process is completed when clean water emerges from the washout (11).

Thorough cleaning of the filter media is essential for proper functioning of the filter unit.

If the back-washing process is too short or not thorough enough, the filter material may clog together to such an extent that in extreme cases water can no longer pass through is. As a result, the gravel layers may have to be removed and cleaned or replaced with fresh material.



Open steel cylinder filter unit

1 Steel cylinder
2 Nozzle plate
3 Distribution layer (quartz gravel)
4 Filtration layer (quartz sand)
5 Min. water level
6 Min. head of water
7 Max. water level
8 Raw water inlet
9 Filtered water outlet
10 Flushing water/scouring air
11 Washout

Fig. 69

Closed steel cylinder filter units (fig. 70)

These consist of a welded steel cylinder (1), closed at top and bottom. Their use is economical if operation is at higher pressures or if a filtration area of at most 20 m²/filter is adequate. Design and operation of the pressure filter are similar to those of the open filter unit shown in fig. 69.

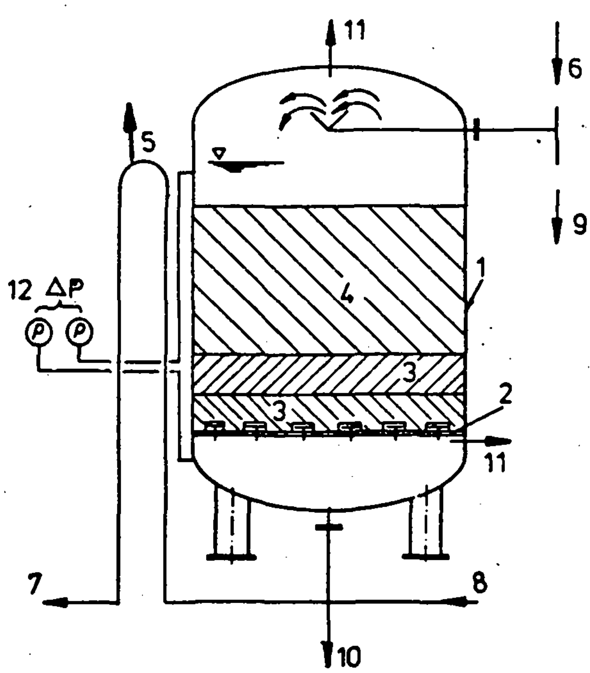


Fig. 70

Closed steel cylinder filter unit

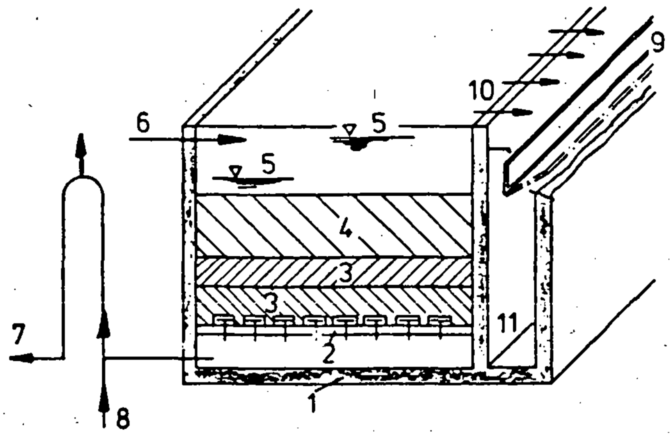
1 Steel cylinder
2 Nozzle plate
3 Distribution layer (quartz gravel)
4 Filtration layer (quartz sand)
5 Head of water
6 Raw water inlet
7 Filtered water outlet
8 Flushing water/scouring air
9 Washout
10 Drain
11 Air valve
12 Differential pressure gauge

As mentioned above, the principle of operation is the same as that of the open gravitational filter, the difference resulting from the fact that the water enters under pressure, making the filtering process much quicker. The pressure filter is completely full during operation. The degree of contamination, or the rise in differential pressure, is indicated by pressure gauges (12). When the maximum permissible differential pressure (degree of contamination) has been reached, the raw water inlet (6) and filtered water outlet (7) are closed and the filter cleaned by back-washing as described above. Here too it is essential for the filter to be precisely vertical and the nozzle plate exactly horizontal.

Open concrete filter units (figs. 71 to 73)

Open filter installations made of concrete are used when relatively large volumes of water have to be filtered. They may be built with a trough (figs. 72 and 73) or without (fig. 71) and with either a perforated plate at the bottom or a floor drainage system. Filters of this type without troughs are of a high technical standard, guaranteeing operational reliability and a good filtrate quality with low consumption of back-washing water and long intervals between cleaning operations.

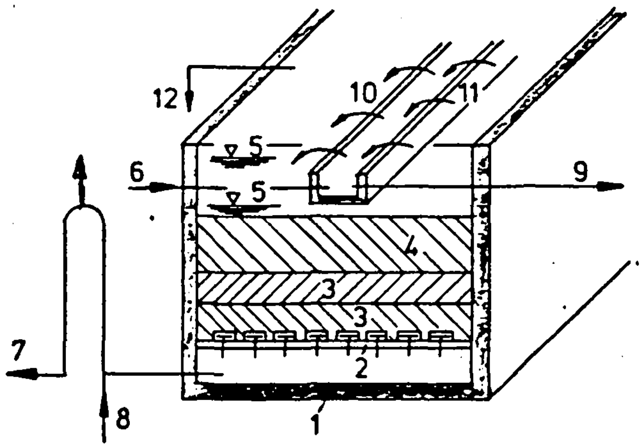
Normal operation and back-washing of these filter units are the same as for the steel cylinder type (see above). It is especially important for the concrete nozzle plate (2) to be absolutely horizontal. Of advantage is the use of plates which are smooth on the underside, giving a level surface both on the top and the underside of the filter floor, thus ensuring even back-washing of the filter and also preventing bacteria from developing in "dead" zones.



Open concrete filter unit
(without trough, with nozzle plate, gravitational operation)

1 Concrete structure
2 Nozzle plate
3 Distribution layers
4 Filter media
5 Water level min/max
6 Raw water inlet
7 Filtrate
8 Back-washing water
9 Sludge water trap
10 Overflow
11 Drain

Fig. 71

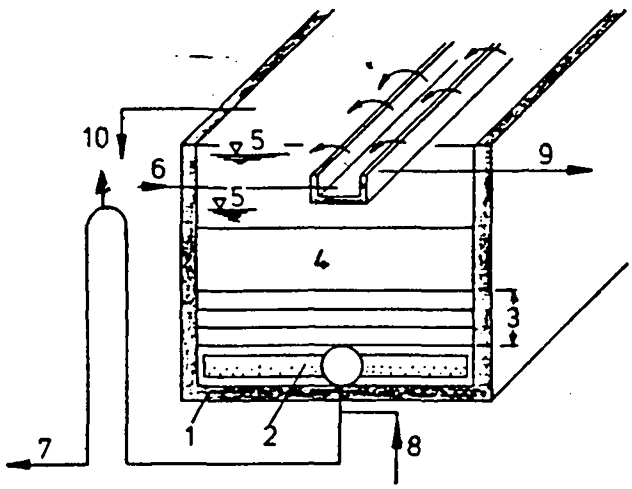


Open concrete filter unit

(with trough and nozzle plate)

1 Concrete structure
2 Nozzle plate
3 Distribution layers
4 Filter media
5 Water level min/max
6 Raw water (trough)
7 Filtrate
8 Back-washing water
9 Sludge water (trough)
10 Direction of filtration
11 Direction of back-washing
12 Overflow

Fig. 72



Open concrete filter unit

(with trough and floor drainage system)

1 Concrete structure
2 Perforated drainage pipe
3 Distribution layers
4 Filter media
5 Water level min/max
6 Raw water (trough)
7 Filtrate
8 Back-washing water
9 Sludge water (trough)
10 Overflow

Fig. 73

Simple versions

Ultra-simple versions such as those shown in figs. 74 to 76 should only be used under special circumstances. The quality of the filtrate is only moderately satisfactory.

The filter structures shown in figs. 74 and 76 cannot be cleaned by back-washing. As the layers of filter sand become choked by impurities, they are removed manually and washed or replaced.

The filtration rate should not be greater than 0.5 to 1.0 m/h. From the bottom upwards, the filter media consist of the following: first at least 5 layers of coarse gravel (2). Directly above these a 2.0 m thick layer of sand (3), with a grain size of between 1.2 and 1.6 mm. The raw water enters at the top and the filtrate is drawn from the layer of coarse gravel (2) at the bottom (fig. 74), or collects in perforated (also non-perforated) concrete or earthenware pipes (figs. 75, 76) laid a few millimetres apart (fig. 76).

Simple slow sand filter

1 Reinforced pit
2 Coarse gravel
3 Fine sand
4 Raw water inlet
5 Draw-off of filtrate
6 Filtrate chamber
7 Filtrate outlet
8 Water level min.
9 Water level max.

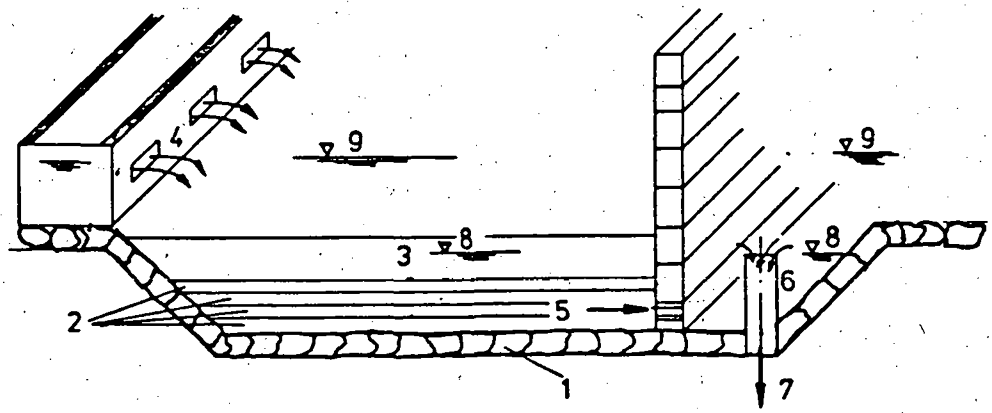
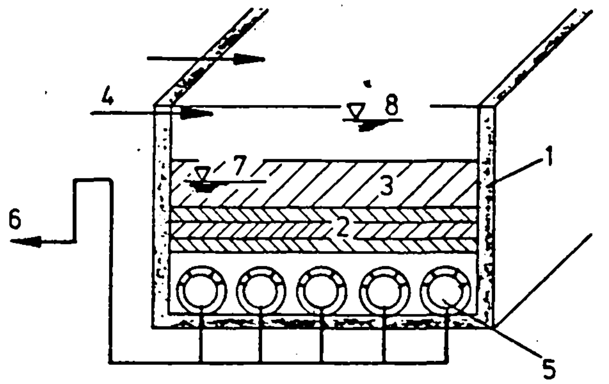


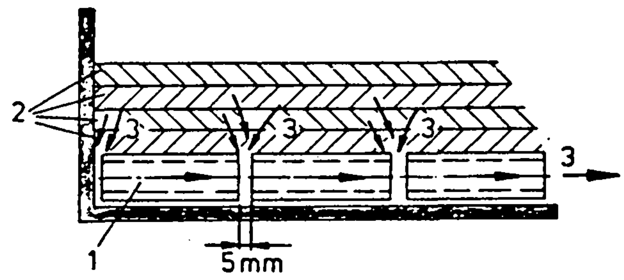
Fig. 74



Simple slow sand filter

1 Concrete or brick tank
2 Coarse gravel
3 Fine sand
4 Raw water inlet
5 Draw-off of filtrate (perforated concrete or earthenware pipes)
6 Filtrate outlet
7 Water level min.
8 Water level max.

Fig. 75



Floor drainage system of a simple slow sand filter

1 Drainage pipes
2 Coarse gravel
3 Filtrate outlet .

Fig. 76

Special points

- Filter gravel

Best is quartz gravel, wherever possible round in shape and having a non-solubility in acid higher than 90%.

Under special circumstances, broken quartz can also be used. Careful attention should always be paid to the quality of the filter media (including limitation of the percentage of undersize), since this largely determines the efficiency and the useful life of the filter.

If quartz sand with a high percentage of undersize has to be used, this must be thoroughly washed when in position in the filter and the fine material on the surface removed with a board.

Revised:

- Nozzles

The use of louvred nozzles has proved particularly advantageous. The effect of the mobility of the louvre rings and the wider distribution of the back-washing water is to hinder growth of algae and the formation of dirt pockets between the nozzles.

11.2. Operation

If properly designed and operated with care, filters of all types normally function well and reliably.

It is important for the design of the perforated floor or drainage at the filter bottom to be properly conceived and executed. Equally important are high-quality filter media, good primary treatment of the raw water and, especially, careful cleaning of the filter through back-washing.

Back-washing

Careful cleaning of the filter is of paramount importance for the efficient functioning of filtration systems. It prevents the formation and solidification of dirt pockets in nozzles and filter material - these prevent the filter from operating efficiently and have a detrimental effect on the quality of the filtrate.

Leaving the filter cleaning systems of the various manufacturers on one side, the following general recommendations can be made:

Sand filters	1. Air scouring:	V = 60 to 80 m/h	
		t = 3 to 6 minutes	
	2. Scouring with air and water:		
	- air	V = 60 to 80 m/h	
	- water	V = 10 to 15 m/h	
		t = 2 to 6 minutes	

3. Back-washing with water: V = 20 to 30 m/h
(trough-type filters) t = 15 to 30 min
(filters without trough) - water banked up to maximum level once or twice

Multi-media filters

1. Scouring with air: V = 60 to 80 m/h
t = 3 to 6 minutes
2. Scouring with air and water:
- air V = 60 to 80 m/h
- water V = 10 to 15 m/h
t = 2 to 6 min
3. Back-washing with water: V = 20 to 30 m/h
Water banked up to max. level twice
4. Separating back-wash with water:
V = 50 to 60 m/h
t = 10 to 30 seconds

In spite of the need for optimum cleaning of the filter, systems with the lowest possible consumption of back-washing water should be given preference.

The interval between cleaning operations in gravel filters (figs. 69 to 73) should be at least 18 to 24 hours. If these operational times - or else the required filtrate quality - are not being achieved, the following points should be checked and measures taken where necessary:

- primary treatment of the raw water
  - dosing of chemicals
  - flocculation
  - sedimentation,
- the volume of water/filtration rate,
- the grain size of the filter sand,
- the nozzle plate or drainage system,
- the intensity and duration of each cleaning operation,
- the possibility of calcium carbonate deposits in the sand,

- apparent resistances in the sand bed or below the nozzle plate, due to poor ventilation,
- even spreading of the raw water onto the filter,
- the outlet of filtered water.

If the quality of the filtrate is still unsatisfactory after these points have been checked, it is possible to convert sand filters into multi-media systems by covering the sand with a layer of pumice or hydro-anthracite, approx. 30 to 50 cm thick. The pumice or hydro-anthracite layer functions as a high-volume filter with an increased filtration capacity. It is also possible, by adding small quantities of a flocculant or auxiliary flocculant directly before the filter, to operate the system as a flocculation filter. This has proved to be very successful in separating ultra-fine dirt particles.

If the amounts of impurities in the raw water are so low that a filter remains operative for longer than 1 week without a noticeable differential pressure or rise in the water level, it should nevertheless be cleaned at intervals of 5 to 7 days to maintain a hygienic standard.

11.3 Maintenance

All machines must be serviced carefully and regularly as specified by the manufacturer.

The following additional measures are also recommended:

- Operating personnel should keep a log, recording details of e.g. the operational times of filters, duration of cleaning operations, method of cleaning, rise of differential pressure, maintenance and repair work performed, any special circumstances or events.
- At the end of each cleaning operation, a check should be carried out to ensure that the filter material is smoothly and evenly distributed. If pronounced depressions or elevations can be observed, the nozzle plate or section of the drainage system below that point must be uncovered and examined.

- Every cleaning operation should be watched to see if the back-washing pattern (i.e. turbulence of the cleaning water or of the gravel layer) is regular. If larger fountains of water can be observed at any points, the nozzles or drainage system below them should be examined as above.
- Should large amounts of algaé develop, these must be removed manually. The growth of algae can be reduced by preventing light from reaching inlet channels and filters. If necessary, filters can be sterilized by impulsive chlorination, using approx. 10 to 20 g per m^3 of filter volume with a reaction time of 1 to 2 hours.
- A check should be carried out to ascertain whether there is a loss of filter material; if necessary the intensity of the cleaning operation must be altered.
- Wherever possible, the quality of the filtrate should be checked every hour and recorded on a log sheet together with any measures taken to improve results, e.g. increase of chemical dosages, etc..
- The area round the filter should be swept and surface areas cleaned once a week.

11.4 Auxiliary material

Apart from the maintenance instruction sheets, no auxiliary materials are needed in addition to normal hand tools. A stock of spare parts, however limited, is always very useful.

11.5 Parts needing special attention

Properly dimensioned filters are, on the whole, robust and reliable. Components such as valves, pipes, control devices, motors, are subject to normal wear and tear. Carefully executed anti-corrosion finishes can considerably reduce wear in many instances. Generally speaking, nozzle plates, floor drainage systems and filter media function reliably as long as the equipment is properly dimensioned, good-quality materials and proven components used and the cleaning operations carried out correctly and with clean water.

11.6. Safety measures

As described in Section 9.6.

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0.1 Basic and applied arithmetic
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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
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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 –
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