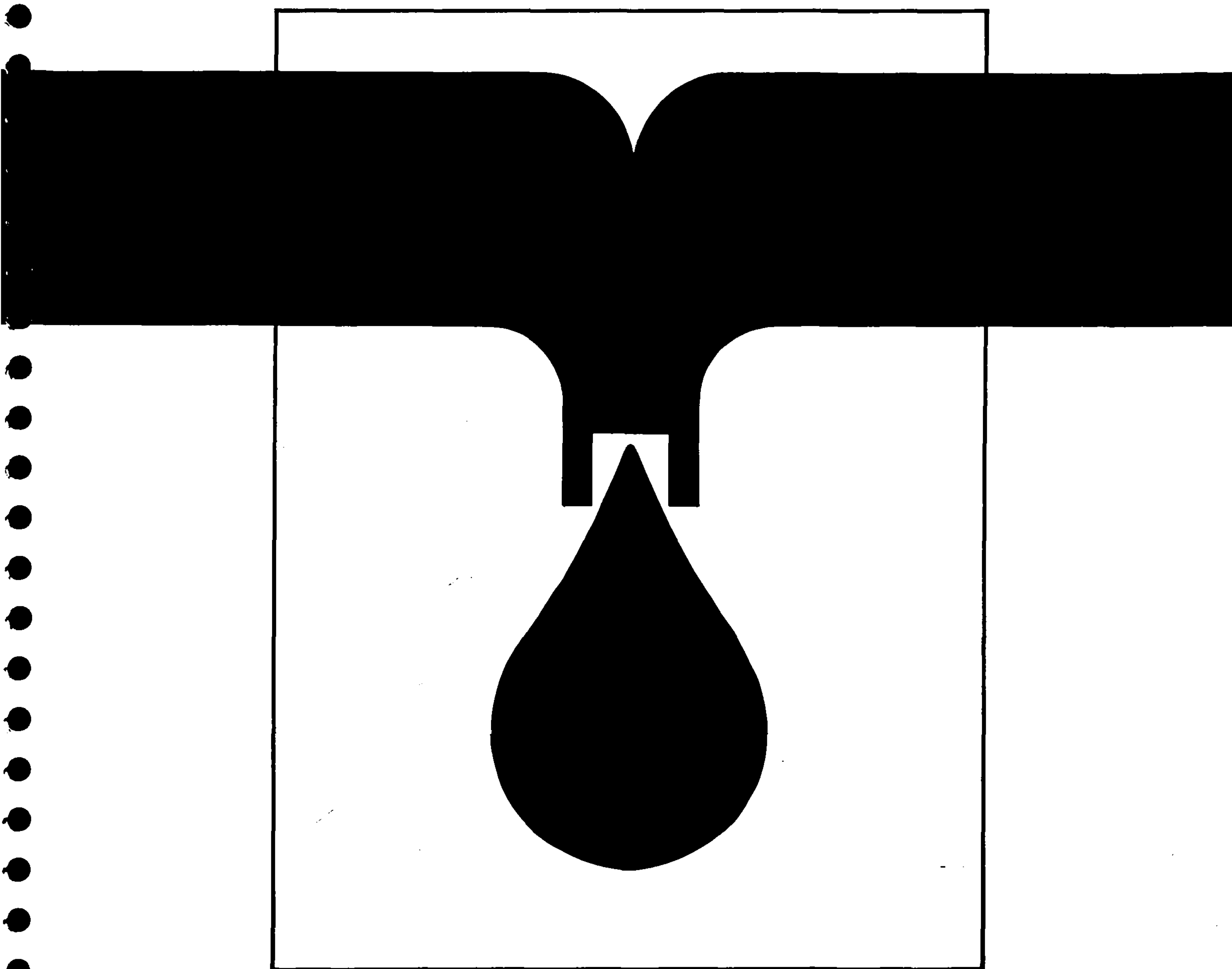
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Skills

3.5

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

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.

Our grateful thanks are due to

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and
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for their committed coordination work and also to the following co-authors for preparing the modules:

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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

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1 Drift barriers

1.1 Methods of constructing simple versions

Strong hardwood piles (4) are cut to the right length, sharpened at one end and coated all over with bitumen or some other suitable preservative material.

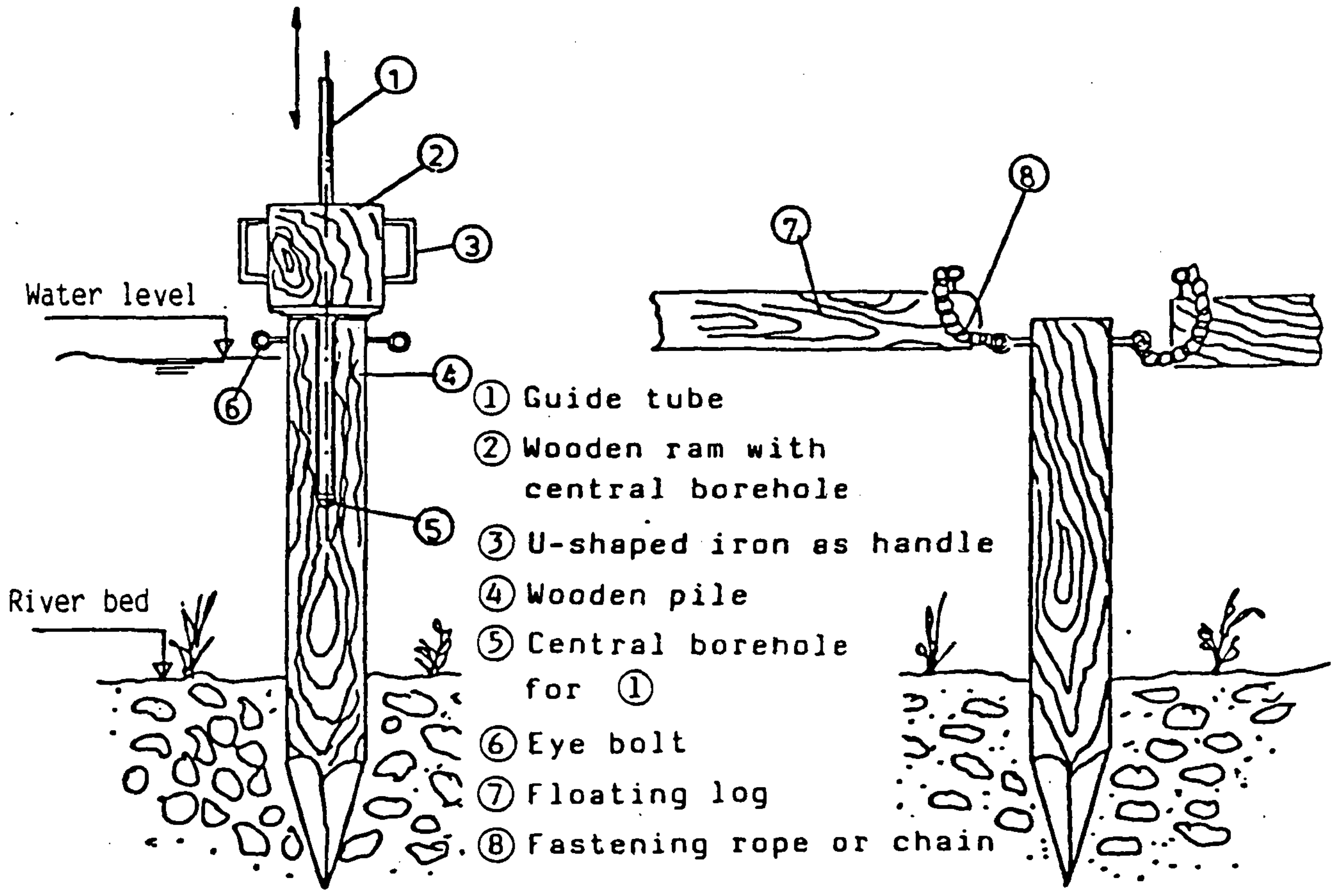


Fig. 1

A hole about 25 mm in diameter (5) and approx. 500 mm deep is bored into the middle of the pile. This is for the guide tube (1) of the ram. The ram (2) itself can be made from a thick log. It should not, however, be too heavy for 2 or at most 3 men to handle. The ram is worked with the aid of U-shaped irons (dogs) driven into its sides; 2 irons per man. A hole approx. 35 mm in diameter is drilled through the centre of the ram for the guide tube (1).

Eye bolts (6) driven or screwed into the sides of the pile are used to fasten the floating logs which form the drift barriers (7). The fastening ropes or chains should be long enough to let the logs float on the surface of the water even when the water is at its highest level.

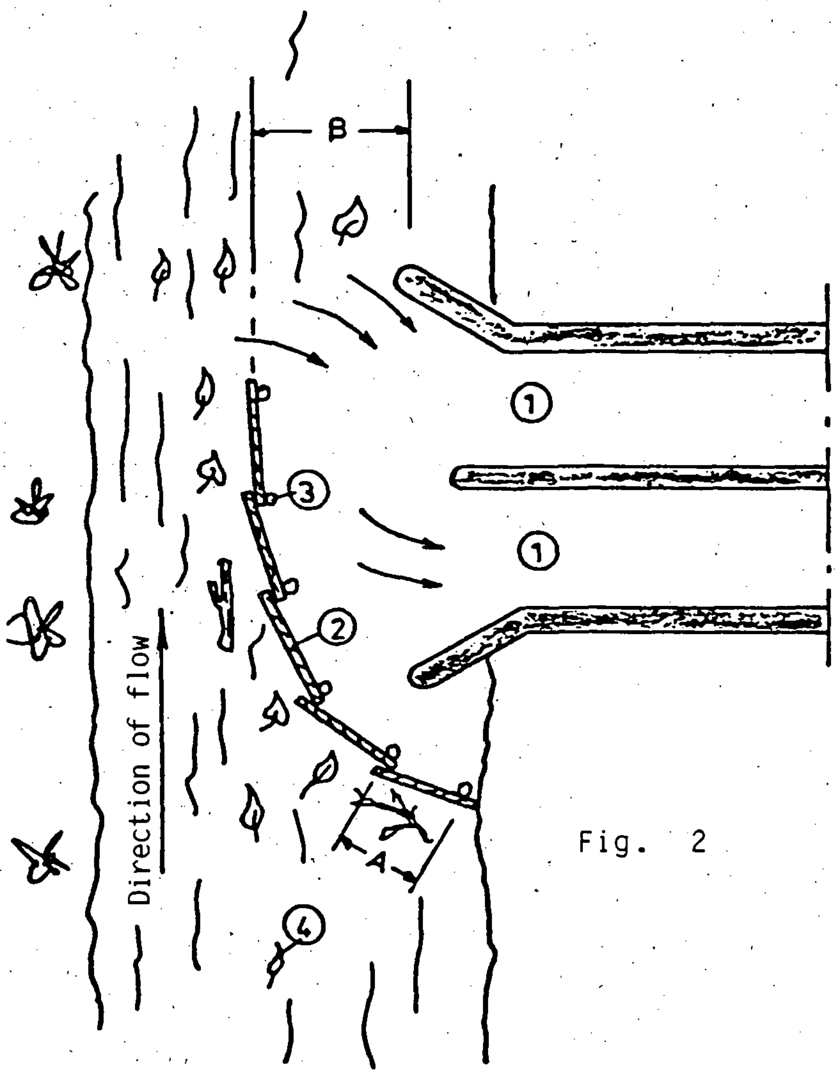


Fig. 2

The length of the floating wooden logs (2) depends only on the natural growth of the trees used (fig. 2). The distance between the vertical piles (A) should be roughly 2 m less than the length of the logs (2).

The length of the vertical piles (3) depends on the depth of the water in which the drift barrier is to be installed.

For instance: In a soft river bed (sand, clay, loam, laterite, gravel etc.)

- Depth of river	approx.	3.0 m
- Maximum increase at high water	+	1.5 m
- Depth to which pile is driven into river bed	approx.	1.5 m
- Remainder		0.5 m
Overall length roughly		6.5 m

When the pile has been driven in, any part of it which may project too far out of the water is sawn off. Distance (B) should be between 1 and 3 m, depending on the width of the river.

Where the water is deeper, a divided construction of the piles is practical and sometimes necessary. Here, the ends of the posts are joined by means of a tube coupling approx. 1,000 mm long, fixed by strong wood screws.

Piles made of steel or of reinforced concrete may also be used instead of wooden posts. Depending on their size and on the nature of the river bed, these piles usually have to be driven in mechanically.

Where rivers run through rock, the drift barriers are anchored to sunken concrete or stone weights, or are fastened to anchor rings concreted onto the river bed itself. Under favourable conditions, i.e. in small or slow-running rivers, the drift barriers can be anchored by ropes to the bank; or other floating bodies (e. g. pontoons, empty drums etc.) can be used as a practical alternative.

In order to design a structure which is easy to construct, cheap and yet still fully effective, the following basic investigations should first be made:

- An exact study of conditions at the site, including e.g. width and depth of the river, composition of the banks and river bed, amounts of drift occurring, maximum and minimum water levels.

- A thorough survey of what construction materials are available locally at a reasonable price, e.g.:
  - timber for the piles, impregnating materials, wire rope, chains, inflatable dinghies, canoes or rafts, tools etc.
- An enquiry into whether a similar structure already exists anywhere in the area. This could be visited and those who built it asked to share their experience in a discussion on methods of construction and operation.
- A search for a qualified carpenter and fitter, if possible one with some experience and who has already worked on similar structures.

Where water is drawn from small rivers or streams in rural areas, the drift barriers described above may be unnecessarily elaborate. In many such cases, it is sufficient to drive a vertical pile (4) into the middle of the river bed. One end of the horizontal floating log (3) is then fastened to the vertical pile (4) and the other to the bank (5) - cf. fig. 3.

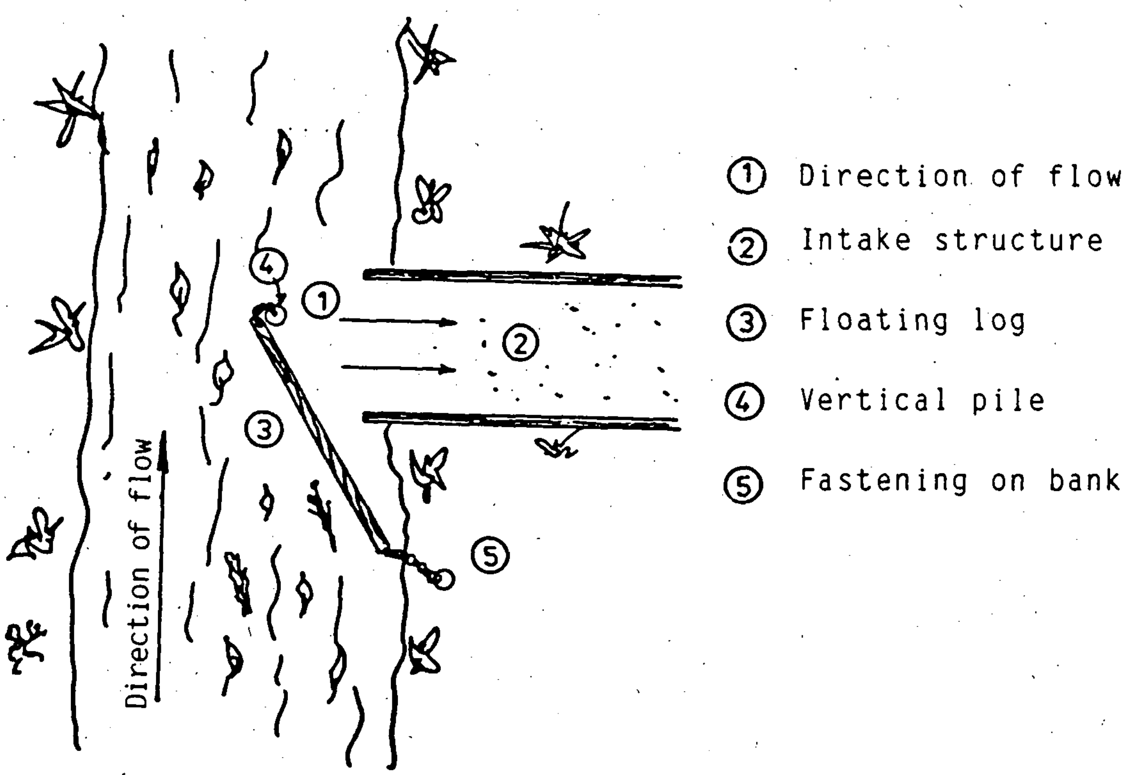


Fig. 3

Another possibility is to make the intake channel at an acute angle to the river's direction of flow and to dimension it so that the water flows through it slowly (at approx. 0.3 to 0.5 m/sec). Much of the debris is then carried past the intake point. In addition, if the intake is between 20 and 30 m long, if forms a natural sand trap. This must be cleared from time to time by hand.

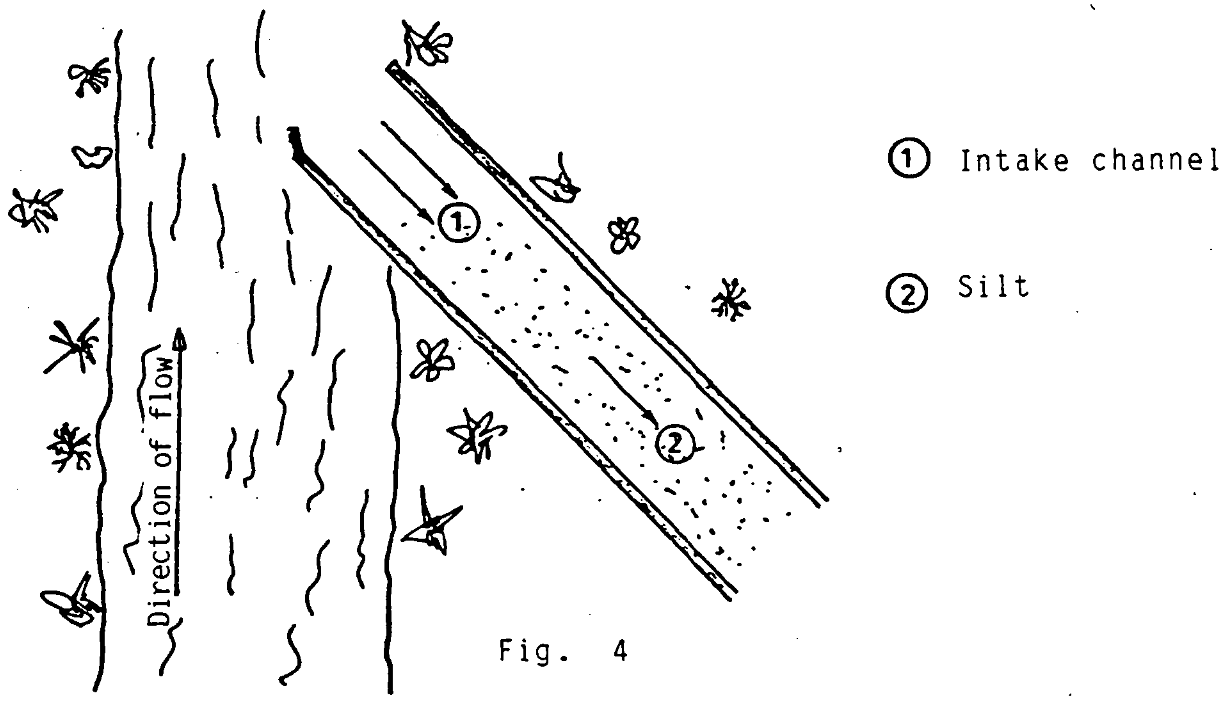


Fig. 4

If the water at the intake point is more than 2 m deep (A), it is often sufficient to draw the water off from below the surface to obtain water relatively free of debris (figs. 5 and 6).

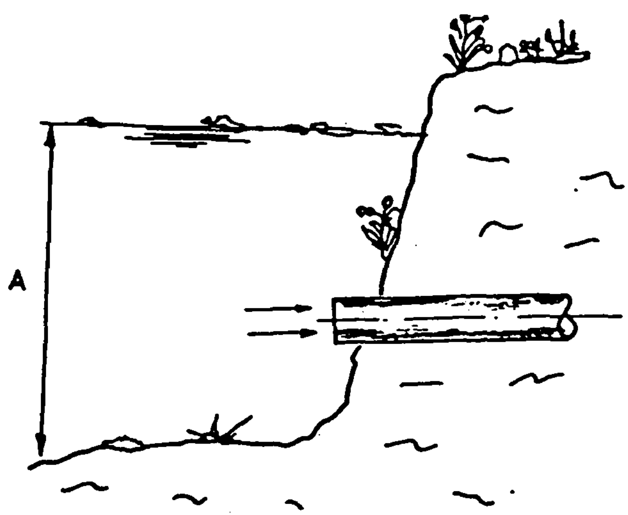


Fig. 5 Intake through a pipe

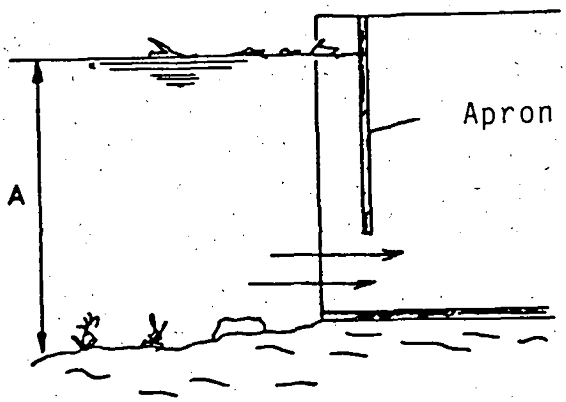


Fig. 6 Intake channel

1.2 Operation

Since drift barriers have practically no moveable parts or parts subject to abnormal wear and tear, they are very easy to operate. It may sometimes be advisable, at the beginning of high-water periods (rainy season, snow melt), to remove the logs of floating structures (figs. 1 to 3) temporarily and to store them safely above the flood line. This is normally only necessary where there are extreme fluctuations in water level.

1.3 Maintenance

Generally speaking, the drift barrier is positioned in such a way that the debris floats up to it and is then carried on downstream by the current.

Where a river has a very slow current, or the drift barrier is not optimally positioned, large amounts of debris may collect against it. This must either be removed and disposed of, or pushed off again into the current, at least once a week.

The structure must be inspected at least once a year, with particular attention paid to wooden or metal parts exposed to the interaction of water and air (floating logs, metal eyes, chains etc.). Any parts found to have deteriorated are either replaced or given a coating of bitumen. This also applies to piles driven into the river bed.

1.4 Auxiliary materials

Only simple tools, such as those described in Module 2.1, are needed, plus inexpensive materials wherever possible of local production or origin.

1.5 Parts needing special attention

Metal parts and hemp ropes may deteriorate quickly under certain conditions. In other respects the structure must be designed for strength and durability.

1.6 Safety measures

A simple raft or canoe is of great help in the construction of a drift barrier. Non-swimmers should not be assigned to this work.

2 Intake canals and pipes

2.1. Methods of constructing simple versions

In the building of intake conduits, cheap, wherever possible locally-available materials should be used; e.g. timber, wattlework, quarry stone, sand, concrete or earthenware pipes. Open channels can also be made of waste material, concrete or bricks.

Canals must always slope evenly. In pipe runs, continuous venting must be ensured. The routes of canals and pipes should be chosen wherever possible to avoid the risk of damage from landslides, rock falls etc.

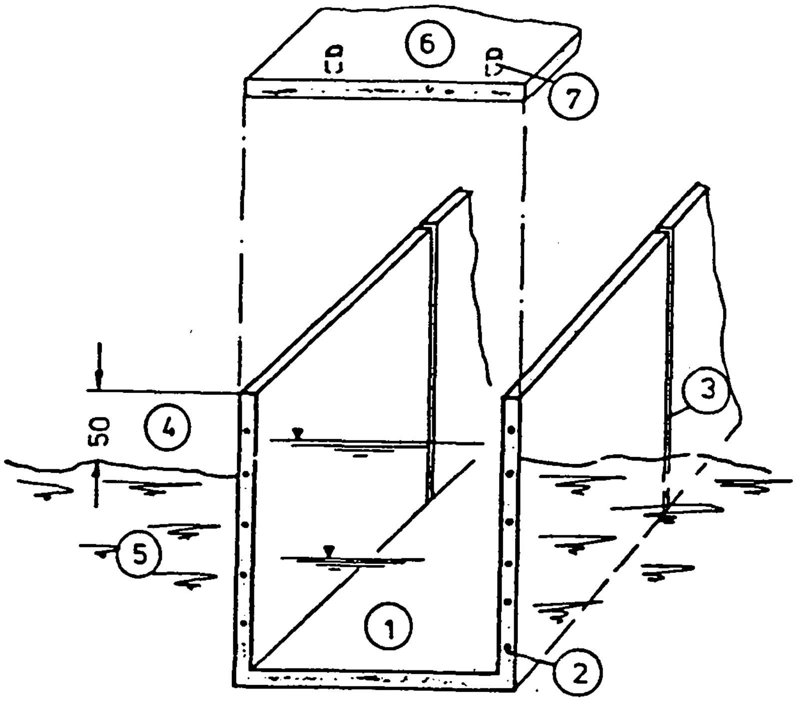
Deciduous trees in the direct vicinity of open channels may cause problems due to falling leaves. The building work can be carried out by locally-recruited workmen, although qualified guidance is necessary. Where structures are relatively simple, expensive tools are not necessary. Standard, sturdy tools such as picks, crowbars, spades, shovels, hammers, chisels, wheel-barrows, plumblines, straight edges, spirit levels, saws, axes, hatchets, plus an adequate number of (wherever possible) experienced workmen produce perfectly satisfactory results.

The interior surface of the concrete channel (1) shown in fig. 7 is made as smooth as possible using formwork. Formwork is not necessary on the outside, the concrete being continued here up to the earth walls. If there are no earth walls, formwork must be used on the outside too.

The concrete used for channels - even for relatively small ones - should have some reinforcing rods (2) embedded in it to prevent cracking. Expansion joints (3) should be provided at regular intervals.

Both side walls of the channel should be approx. 30 cm higher than the surrounding surface of the ground (4) to prevent dirty - especially faeces-containing - water or other contaminants from entering it. In wooded areas or districts where sand-storms etc. occur, it is advisable to cover the channel with concrete slabs. These slabs should not be too heavy for 2 men to lift, so that they can be removed for cleaning purposes. Each slab is provided with 2 holes into which a bent iron bar can be hooked and used as a handle. The floor of the channel must be smooth.

A channel of the same basic design can also be made of bricks. The brickwork may be plastered with cement mortar, but this is not absolutely necessary. Where natural stone is available, but cement on the other hand expensive and/or difficult to obtain, the sides of the channel can be made of dry-stone walling.



1 Reinforced concrete channel

2 Reinforcing rod

3 Expansion joint

4 Height of side above ground level

5 Ground

6 Covering slab

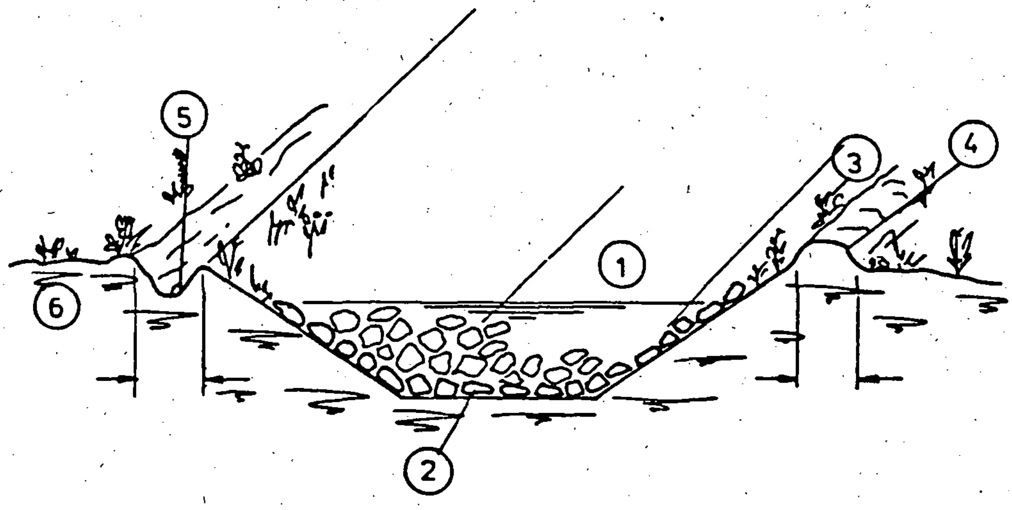
7 Holes for handle

Fig. 7

Earthen canals with sloping sides (fig. 8) are excavated cleanly to the required dimensions, the gradient of the sides being roughly between 1 in 2 and 1 in 3. The zone through which the water will flow is paved (2) with stones or bricks. The sloping sides may be surfaced with a layer of concrete instead, the remainder of the bank above the water line being grassed (3). To prevent any surface water, excreta or other contaminants from entering the canal, earth banks (4) or drainage ditches (5) at the side are a practical precaution.

The rate of flow in the canal should be between 0.3 and 0.5 m/sec.

Earthen canals with vertical sides (fig. 9) are excavated cleanly to the required dimensions. At intervals of approx. 0.5 to 0.8 m, lines of impregnated or tarred wooden posts, sharpened at one end (2) are driven vertically into the ground. Branches or laths (osiers) (3) are woven in and out of the posts, then earth (4) is piled in behind this structure and tamped.



(1) Earth channel

(2) Paving

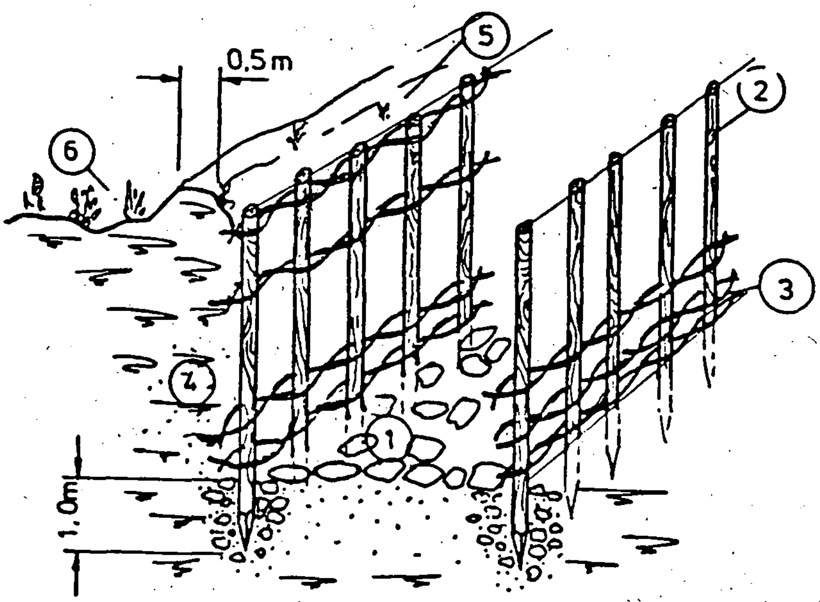
(3) Vegetation

(4) Low earth wall

(5) Drainage ditch

(G) Ground

Fig. 8



(1) Channel

(2) Wooden pile

(3) Hurdle-work

(4) Earth packing

(5) Low earth wall

(6) Ground

Fig. 9

This wattle-work (hurdle-work) fence is extended upwards on both sides and, with the addition of a low earth wall (5), prevents surface water, excreta etc. from entering the canal.

If the volume of water drawn off is relatively low, or the measure only temporary, inexpensive, extremely simple solutions may be quite adequate (fig. 10). Small channels made of wood (1), earthenware troughs (2), halved oil drums (2), PVC pipes, bamboo, corrugated iron or similar materials are all quite viable.

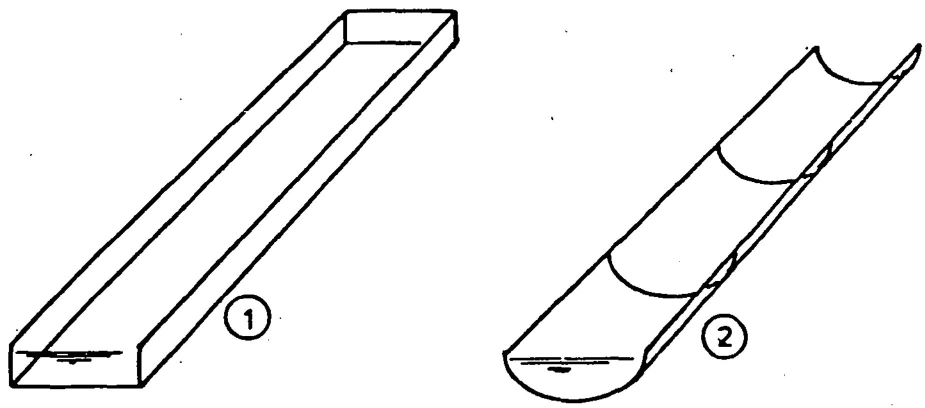


Fig. 10

2.2 Operation

If intake canals have been properly constructed, or pipes properly laid, they normally function, with appropriate maintenance, without problems for many years. Longer canals or pipe runs should be cleaned out or thoroughly flushed at least once a year. During this operation, the flow of water to the water-treatment plant must be temporarily stopped, so that large amounts of sand or sludge are not carried into it.

It is advisable to inspect the canal or pipe run carefully once a month, paying particular attention to:

- accumulations of impurities
- leakages/rupture
- damage to the banks, caused e.g. by rain or animals

blockages caused by branches, dead leaves, plants, roots, dead animals, air bubbles etc.

2.3 Maintenance

Accumulations of dirt and rubbish and blockages must be cleared immediately. Any damage to pipe walls, canal banks, hurdle work or posts should be repaired without delay. If even quite minor damage is not attended to promptly, it may lead in the course of days or weeks to serious deterioration which can only be remedied at considerable cost in terms of both time and money.

Major and minor repair work should be carefully prepared, to reduce the time the conduit will be out of commission to a minimum. If major measures lasting for a relatively long time are necessary, a bypass may have to be provided. Sometimes algae develop in large numbers in open channels. These must be removed approx. once a month. Covers, e.g. of wood, asbestos cement or stone, considerably retard the growth of algae.

2.4. Auxiliary materials

Simple tools, such as those described in Module 2.1, are adequate, plus the use of cheap materials, wherever possible of local production or origin.

2.5 Parts needing special attention

None: the structures must be designed for hardiness, reliability and durability.

2.6 Safety measures

When excavating canals, preventive measures agains earth- or stone-slips must be taken. Also it must be ensured that large amounts of water cannot enter the canal before it is completed.

3 Stop structures for closing up canals or smaller channels

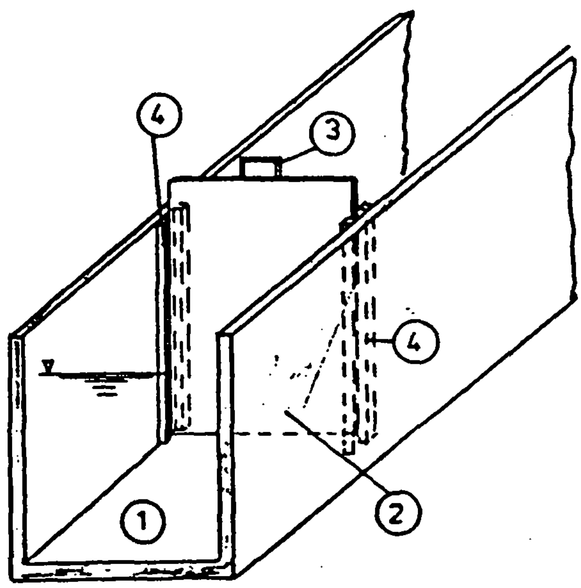
3.1 Methods of constructing simple versions

Structures for closing up canals or smaller channels (stop logs, stop planks, flashboards, dams) can be made of cheap materials which are often available locally: e.g. timber, scrap metal, or for dams stones, earth, boughs, sand etc.

As the water level behind the closed stop structure rises, a high water-pressure builds up. These structures must therefore have adequate strength: if they break, not only is any work already completed then destroyed, but injury or loss of life is also not unlikely, especially in large works.

The construction work can be carried out by local workmen under qualified guidance. Expensive tools are not necessary. Simple fitter's tools and the tools and devices mentioned above (2/1.) are quite adequate.

In small channels, simple vertical-lift gates made of strong wooden boards, or plain metal sheets can be used. Baulks laid horizontally on top of each other, fitting between grooves in the sides of the channel, nailed together with vertical battens and sealed with hemp or rags are also quite viable if the measure is only temporary. Depending on local conditions and the means available, a temporary dam can also be made of stone or wood sealed with sandbags, faggots or similar materials.



(1) Channel

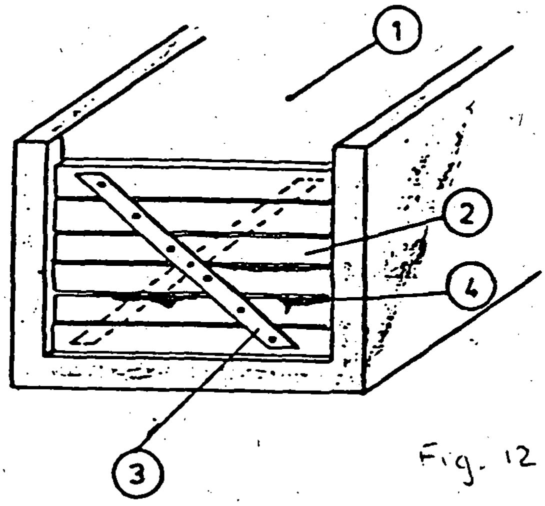
(2) Stop slab

(3) Handle

(4) Guide grooves

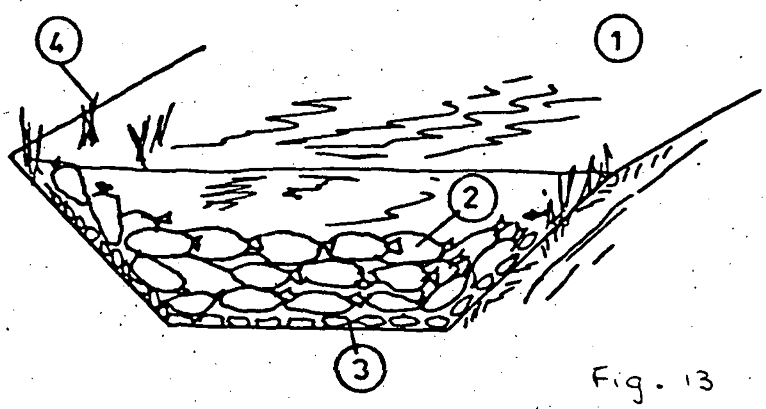
Fig. 11

Sandbags and anything else used for sealing must be removed in full after completion of the maintenance work (figs. 11 to 14).



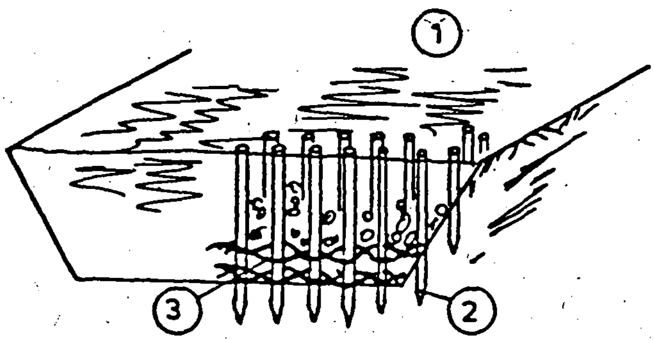
(1) Channel
(2) Wooden baulk
(3) Batten
(4) Hamp, rags etc. for sealing

Fig. 12



(1) Channel
(2) Sandbags
(3) Paving
(4) Turf

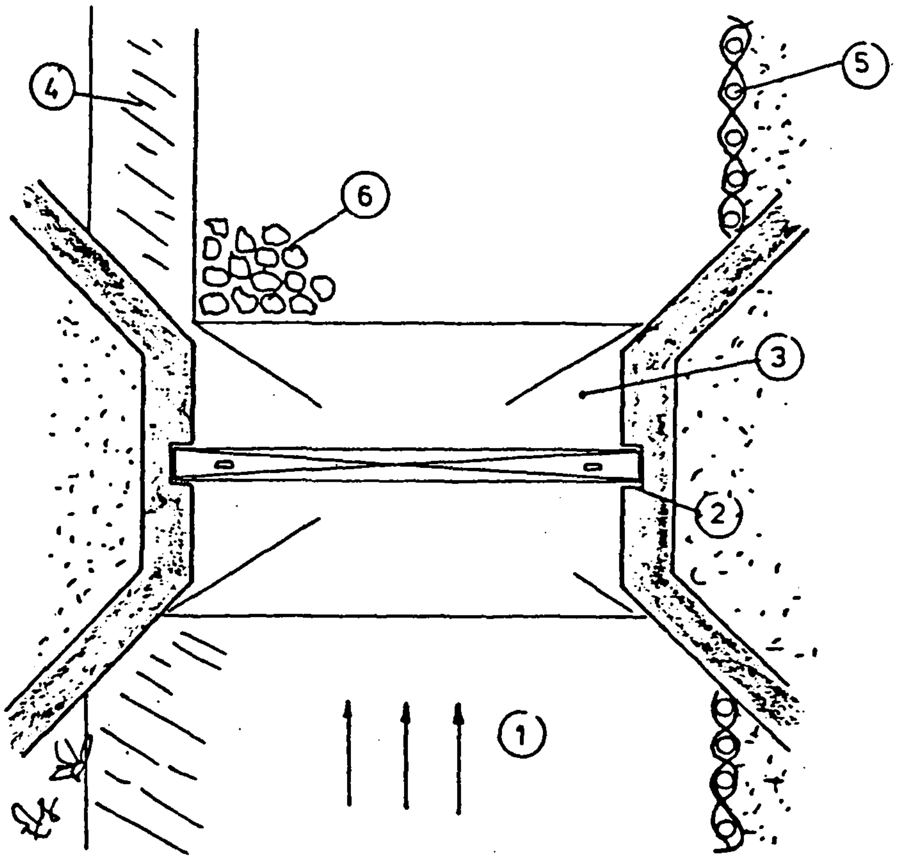
Fig. 13



(1) Channel
(2) Wooden pile
(3) Branches, grass etc.

Fig. 14

If a stop structure is to be installed in an earthen canal, the lateral grooves in which it runs and the floor of the canal in the vicinity of the stop slab must be made of concrete or brickwork.



(1) Earth channel

(2) Lateral grooves

(3) Bedplate

(4) Sloping side

(5) Vertical bank reinforcement

(6) Paving

Fig. 15

3.2. Operation

All stop structures must be sealed carefully. Small leaks can lead very quickly - especially in the case of dams made of earth or sand - to large breaches, resulting in the flooding and destruction of canal or pipe sections under construction or already completed.

If the dam is no longer required when the work has been finished, it must be removed carefully and in full. Care must be taken to prevent any large amounts of contaminants or rubbish (earth, pieces of wood, stones etc.) from being carried into the water-treatment plant.

If a stop slab (fig. 15) or vertical lift gate (figs. 11 and 12) is used, this should first be raised slightly on one side, using a wedge or lever, so that the water can flow through to the dry side and equalize the pressure. The slab or gate can then be pulled up quite easily.

3.3 Maintenance

Stop structures which are periodically not required should be cleaned and stored in a dry place. Wooden structures should be laid flat or else leaned up at a slight angle against a wall to prevent warping.

3.4 Auxiliary materials

Only simple tools and materials are required.

3.5 Parts needing special attention

None: these structures must be hardy and durable.

3.6 Safety measures

When closing up or re-opening larger canals, workmen in the water zone should be roped up. During building of the dam or installation of stop slabs, it is advisable to erect a temporary bridge across the canal.

4 Racks

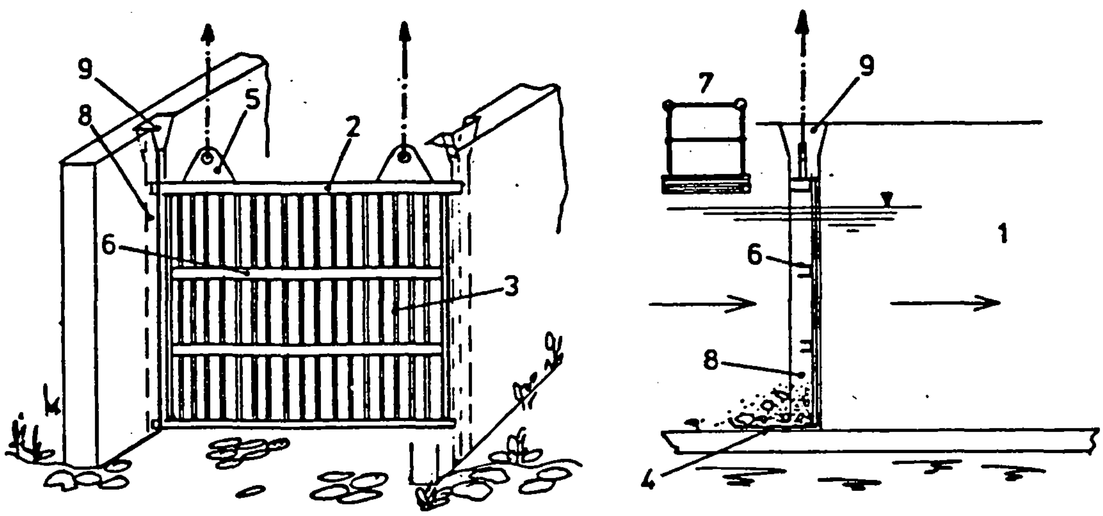
4.1 Methods of constructing simple versions

Racks can be made of inexpensive materials, wherever possible procured locally: such as sheet metal, sectional steel, construction steel (including scrap metal).

The construction work can be carried out by local workers and craftsmen, with some technical advice and assistance (e.g. provision of simple dimensioned drawings).

Vertical, removable racks (fig. 16) consist of a strong frame made of sectional steel (2) to which bars (3) are welded at top and bottom. Depending on the size of the rack, transverse reinforcing struts (6) may be necessary in order to give it the necessary rigidity. A sludge-collecting plate (4) approx. 30 to 50 cm wide is welded horizontally to the bottom edge of the rack.

Experience has shown that a footbridge (7) erected in front of the rack is very useful: the necessary cleaning of the rack can be carried out from here quite easily.



1 Intake channel
2 Rack frame
3 Rack bars
4 Sludge-collecting plate
5 Eyes
6 Horizontal reinforcement
7 Footbrige
8 Guide grooves
9 V-shaped widening

Fig. 16

The tiltable rack shown in figs. 17 and 18 should also be sturdily built, with strong transverse or oblique reinforcing bars. The rack is fastened by strong hinges (4) either to a side wall of the canal or to the service footbridge at the top. Normally the rack is cleaned manually, using a rake. If the rack becomes blocked with wedged or twisted matter, it is swung to the side or upwards with the aid of a hook inserted in the eye (3) and cleaned.

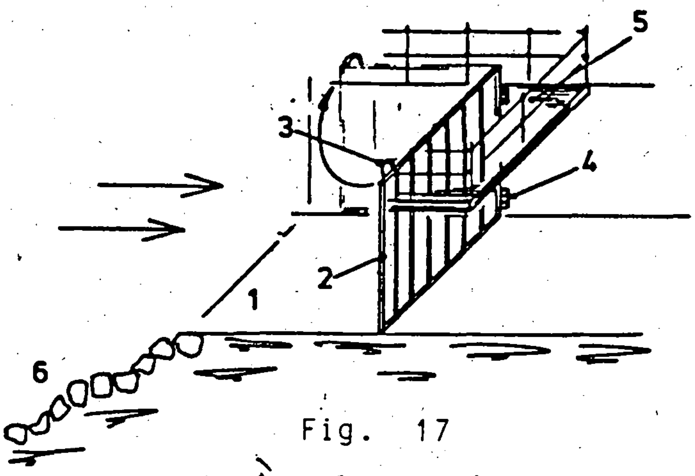


Fig. 17

1 Channel

2 Tiltable rack

3 Eye

4 Hinge

5 Footbridge

6 River or stream bed

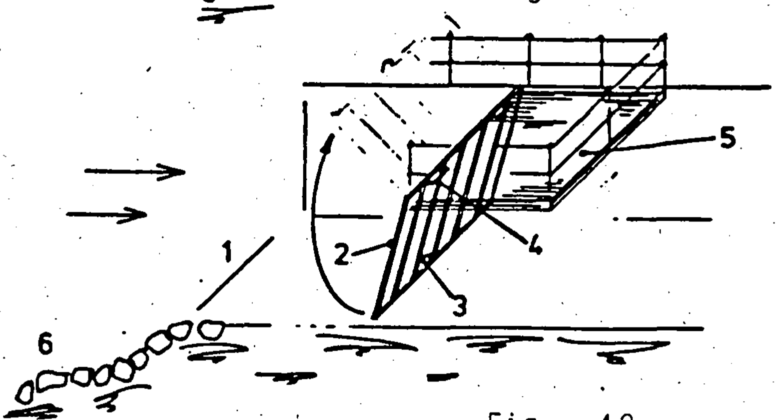


Fig. 18

The permanently concreted-in rack as shown in fig. 19 is suitable for use in intakes from standing water (lakes) or flowing water containing relatively small amounts of debris, or in locations where the rack is not in the direct current and the river carries most of the debris past the intake point. Such structures should not be used where large amounts of floating debris and other solids are likely to occur.

This type of rack is not removable. Cleaning can only be carried out using a rake from a boat, raft or footbridge (5). Where this is not possible, divers have to carry out the work.

In lakes and rivers where the level of the water fluctuates widely, structures with 2, 3 or more permanently installed racks at different depths are often used. Sometimes the intakes at the current water level are closed off with stop slabs (4) or sluices, so that water relatively free from solids can always be drawn off from below the surface. To reduce costs, the screens which should follow the coarse racks are sometimes dispensed with. This is justifiable only in special cases, however, since it may easily result in damage to the water-treatment equipment. The bars of

1 Structure
2 Racks in concrete fixture
3 Suction pipe
4 Stop plank
5 Footbridge

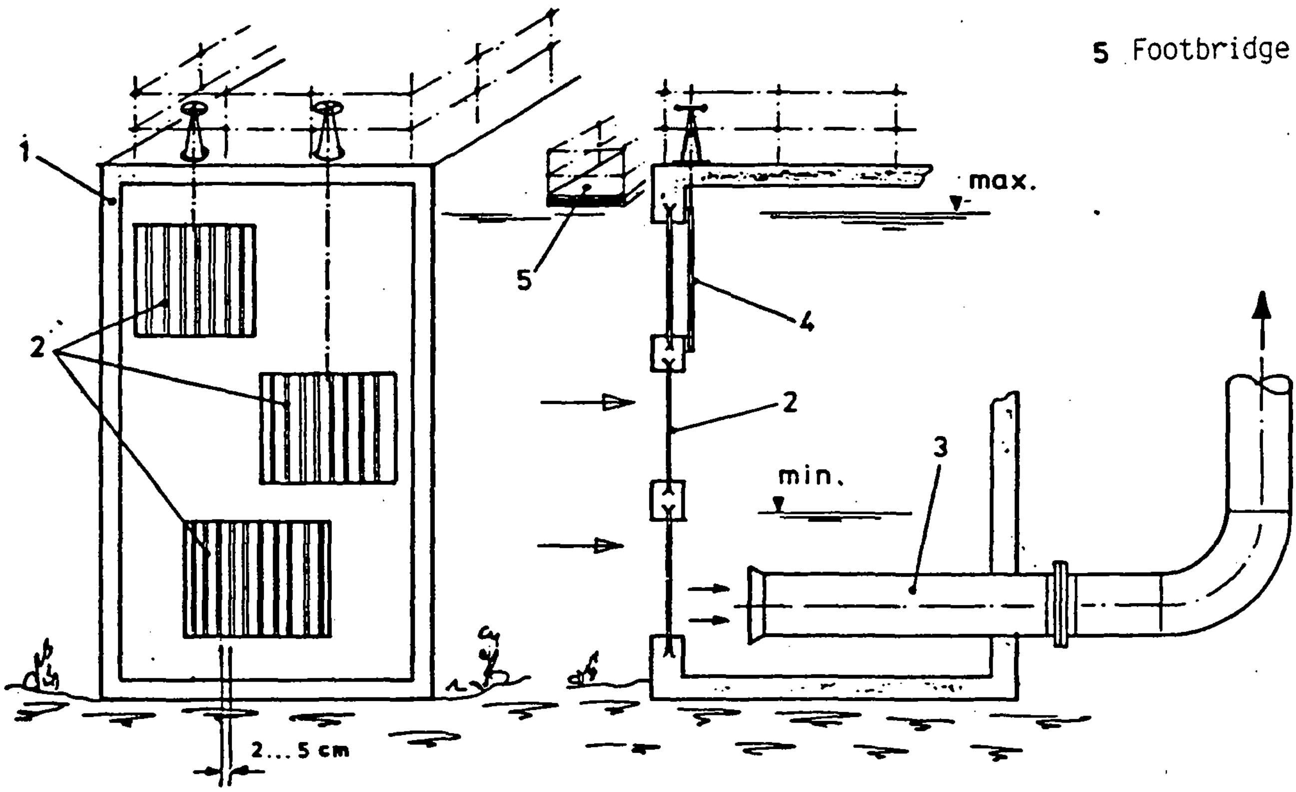


Fig. 19

Bodies of water which contain relatively little solid matter allow the direct use of suction strainers (fig. 20) without concrete structures. A necessary condition is that it must be possible to install the complete suction strainer far enough below the minimum water level to ensure that the amounts of solid matter are not excessive. The suction strainer (1) itself can be a perforated sheet-metal structure or basket made of iron rods. A flushing device (3), although not always fully effective, is nevertheless useful. A lifting device (5) should be provided to enable the strainer to be raised and lowered quickly and reliably.

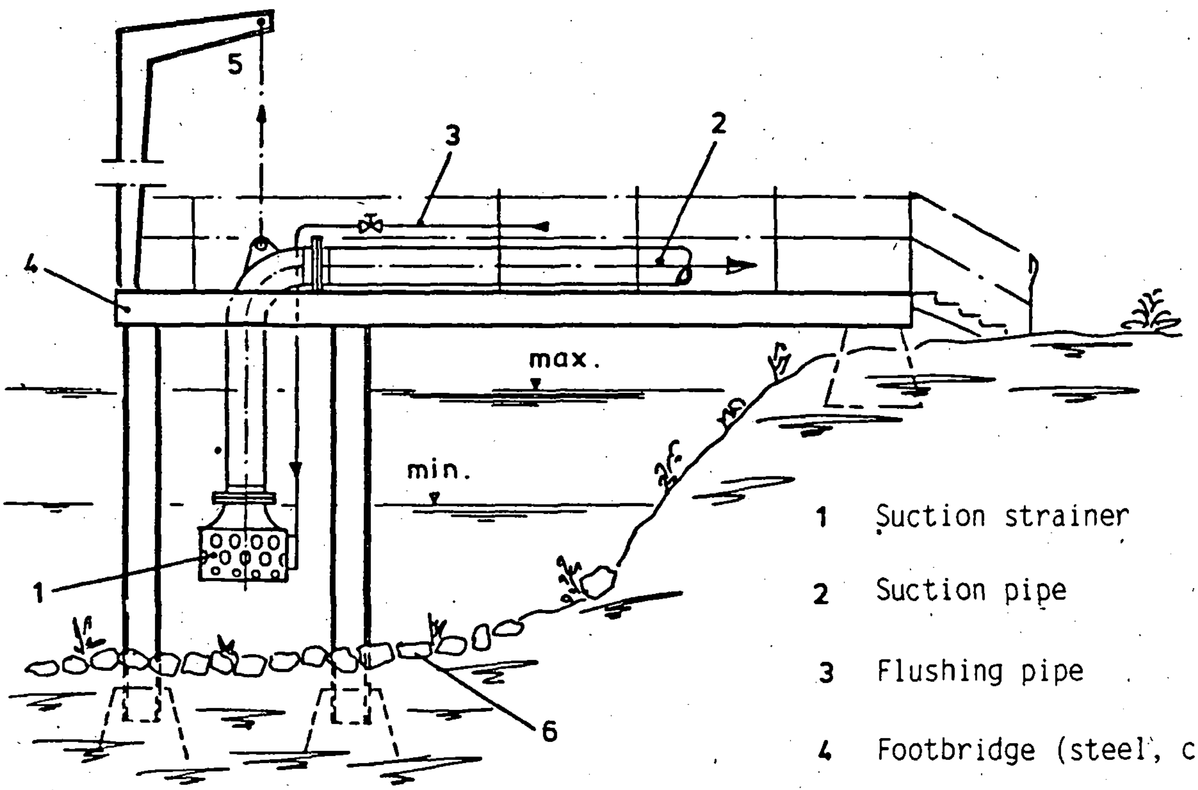


Fig. 20

1 Suction strainer

2 Suction pipe

3 Flushing pipe

4 Footbridge (steel, concrete)

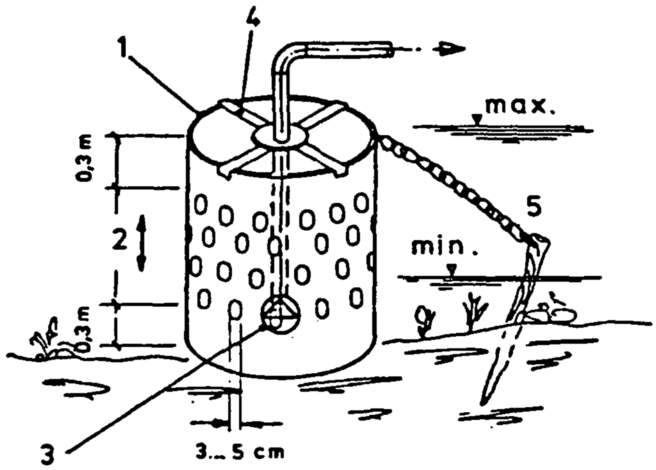
5 Lifting device

6 Reinforcement of river bed

Instead of the permanent jetty (4) as shown above, a structure floating on pontoons or drums can be of advantage, especially where the water level fluctuates widely. Care must be taken to anchor the floating structure firmly, and the connection to the suction pipe on the bank of the lake or river must be flexible and durable.

In special circumstances (emergency water supplies in disaster areas, limited-duration measures etc.), a vertical submersible pump can be installed directly in the lake, etc. These pumps are already fitted with a strainer by the manufacturer. It must be realized, however, that these pumps are under considerable strain from the sometimes large amounts of solids in the water, with the result that in many cases they are unusable after only a few weeks. The following simple but effective measures can in some cases substantially relieve the strain on pumps and water-treatment equipment (figs. 21 to 25).

-Pump suspended inside perforated oil drum (fig. 21)



1 Drum

2 Perforated zone

3 Pump

4 Holding strips

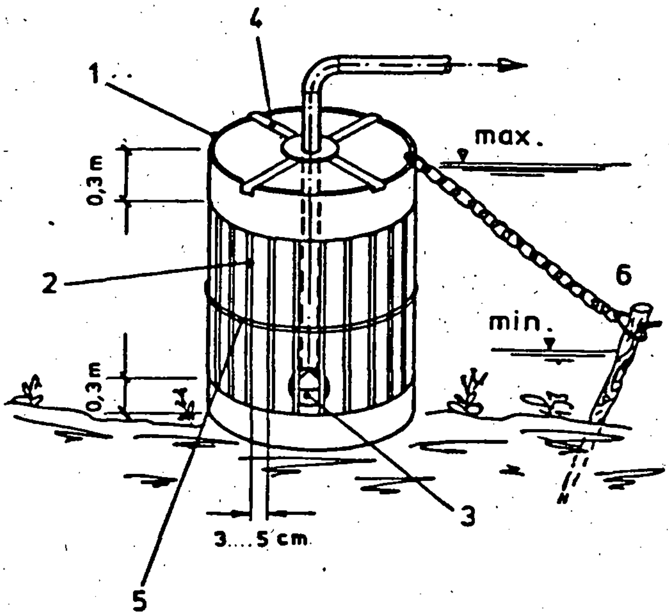
5 Anchor

Fig. 21

The holes or slits should not be more than 3 to 5 cm in diameter. A zone about 0.3 m high is left without perforation at the bottom, to prevent large amounts of sand from entering. Equally, a strip about 0.3 m wide should be left closed at the top, so that no coarse floating matter or oil can enter the drum. The drum should be firmly anchored (5)

- Vertical-bar drum (fig. 22)

The bars should be approx. 3 to 5 cm apart. In other respects construction is as above.



1 Drum

2 Strainer rods

3 Pump

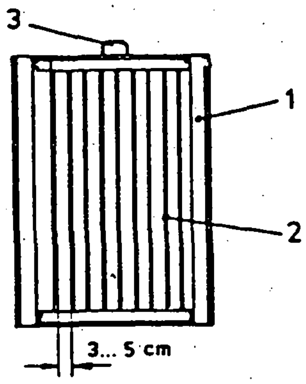
4 Holding strips

5 Reinforcing ring

6 Anchor

Fig. 22

-Simple screen made from scrap material (fig. 23)

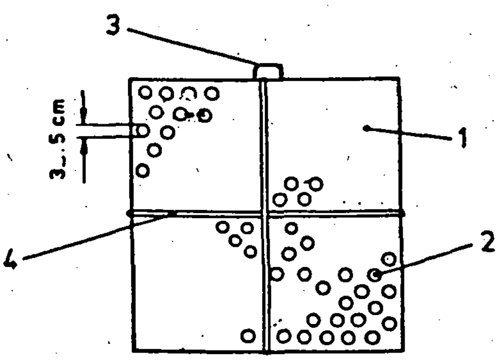


1 Frame made from angle, flat or tubular iron

2 Iron rods or bars

Fig. 23

- Simple screen made from scrap sheet metal (fig. 24)

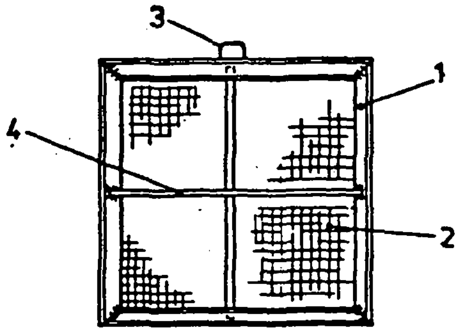


1 Screen made of sheet metal

2 Perforations

Fig. 24

- Simple screen made from wire mesh (fig. 25)



1 Frame

2 Strong wire mesh

3 Handle

4 Reinforcing rod

Fig. 25

4.2 Operation

Racks present no particular problems in operation, provided they are sturdily built, firmly fixed and regularly cleaned.

4.3 Maintenance

Racks should be inspected and cleaned about once a week. More frequent checks may be necessary when there has been heavy rain. Any matter caught in the rack is removed with the aid of rakes or levers. It sometimes happens that the bars of the rack are bent during this operation; if so, they must be re-straightened.

In corrosive waters (e.g. those with high salt content, low pH, aggressive carbonic acid), the paint or other protective finish on the rack should be inspected once a year and carefully repaired wherever necessary. The rack is removed for this purpose, a temporary structure serving as substitute for as long as necessary.

4.4 Auxiliary materials

Expensive tools are not necessary, simple fitter's tools being quite adequate. For the installation of larger racks, tripod cable supports, hoists, sufficient ropes and enough helpers should be available.

4.5 Parts needing special attention

None: racks must be robust and durable.

4.6 Safety measures

During the installation work, water may have to be kept out of the canal (cf. Section 3 above). Heavy loads must always be moved with care. Workmen must be warned not to stand underneath hanging loads.

The footbridge above the rack should be provided with a sturdy railing, so that workmen cannot fall into the raw water canal during cleaning operations. Any rubbish wedged in the rack must be removed from a well-anchored raft or boat. Workers should be roped up. Non-swimmers should not be assigned to this work.

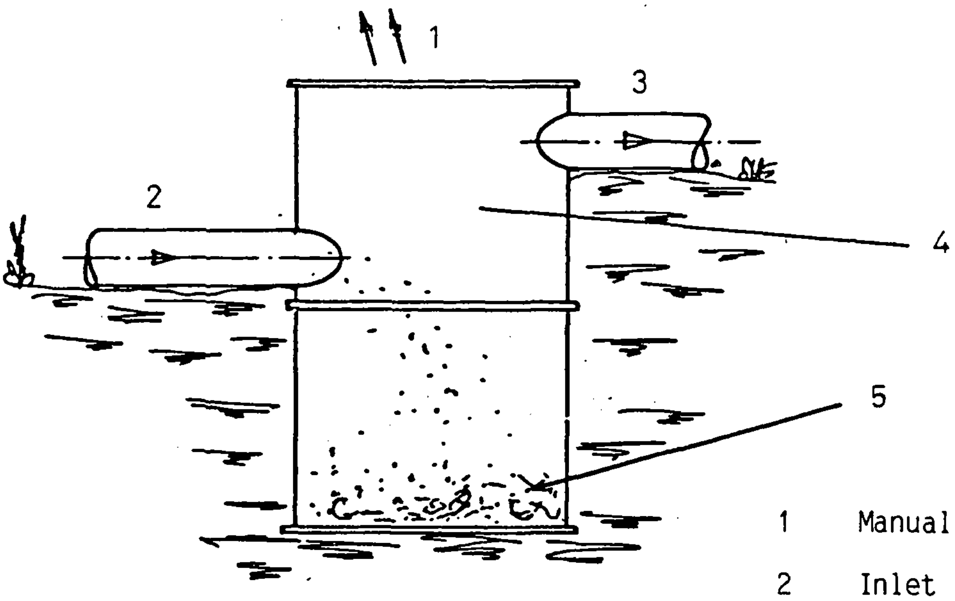
5 Sand traps

5.1 Methods of constructing simple versions

Inexpensive, locally available materials can be used. The work can be carried out by local workers and craftsmen, with some technical advice and assistance (e.g. provision of simple dimensioned drawings).

Simple structures

- Raw water canal with the function of a sand trap.
  If the raw water canal is designed so that the water flows through it slowly (i.e. at between 0.3 and 0.6 m/sec) and is at least 20 to 30 m long, relatively heavy solid particles can settle on its floor. The accumulated sludge is cleared out manually at certain intervals.
- A simple sand trap can be made out of an oil drum or concrete pipe section inserted in a bamboo, earthenware, metal or PVC pipe or small open channel (fig. 26).
- Sand trap made of wood, stone, brick (fig. 27).



1 Manual clearing

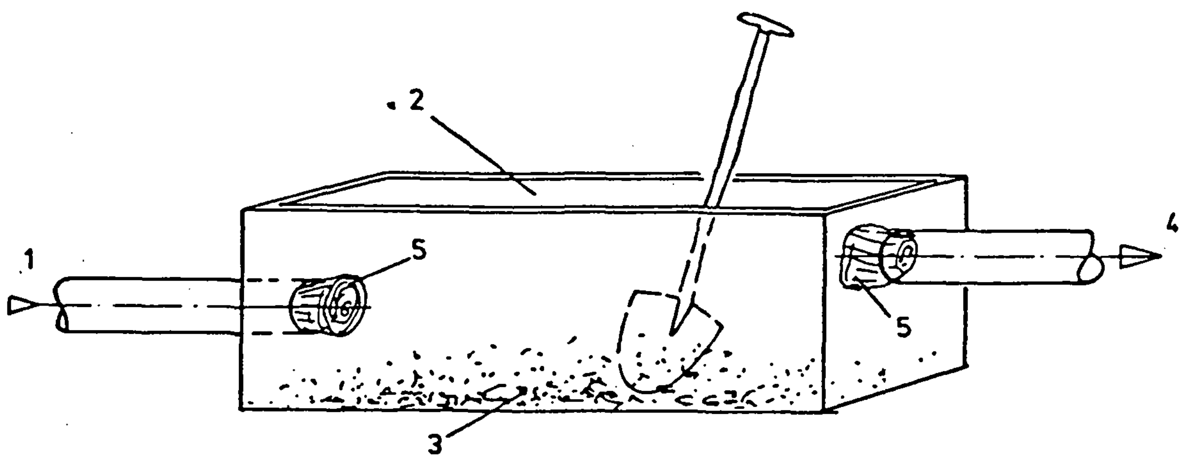
2 Inlet

3 Outlet

4 Sand trap

5 Silt

Fig. 26



1 Inlet

2 Sand trap

3 Silt

4 Outlet

5 Plugs (used when cleaning)

Fig. 27

Deep sand traps (fig. 28) are circular, deep sedimentation tanks through which the water flows directly. The water in the raw water canal (2) is diverted vertically downwards into the sand trap (1), flows under a downflow baffle (3) and returns at the top of the sand trap to the raw water canal (2 a). As the water flows through the sand trap, solid particles settle onto the funnel-shaped floor. A wear-resisting pump (4) or air lift transfers the silt to a container unit or to a collecting and dewatering tank, from where the silt is taken away for disposal. These structures may be made of brick, stone or concrete.

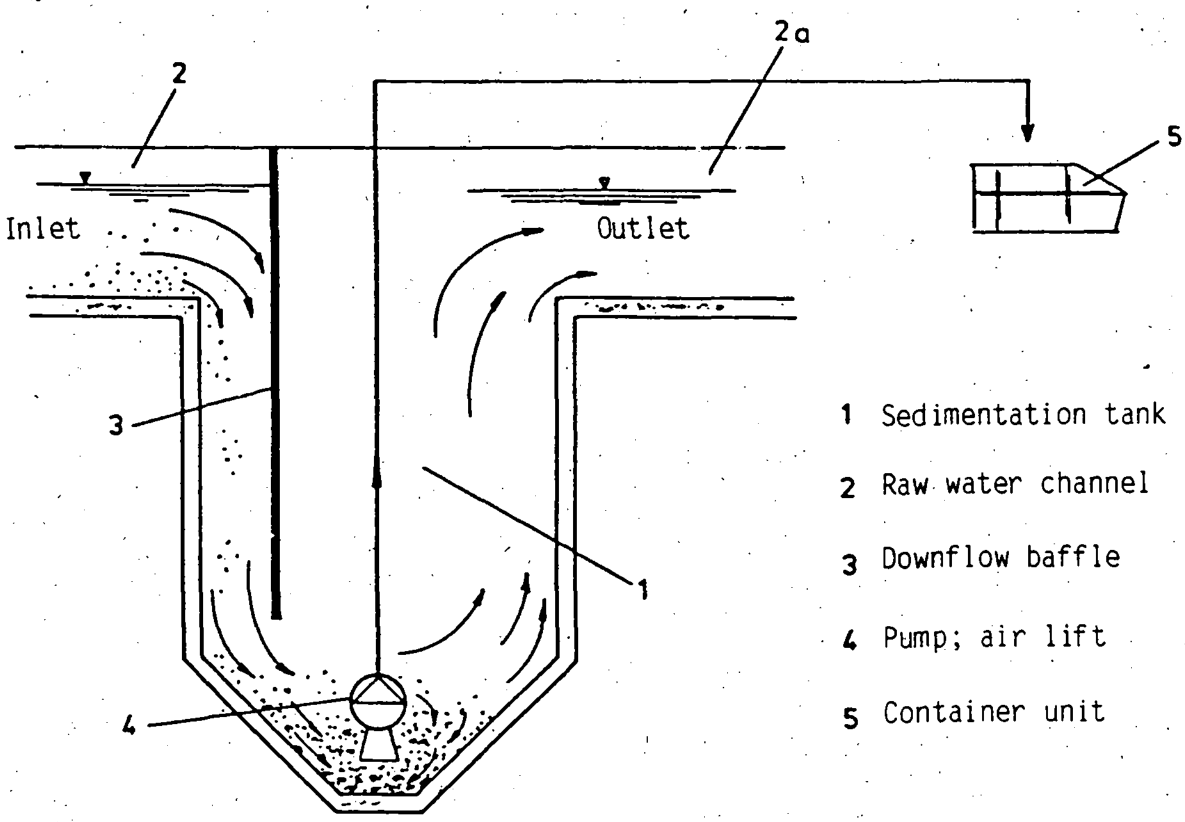
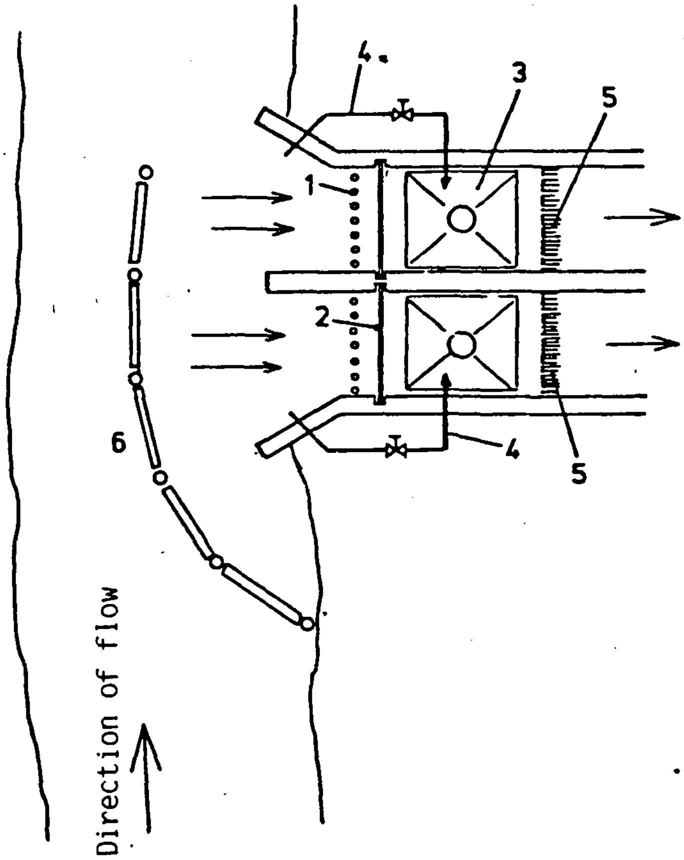


Fig. 28

The mechanical equipment required can be restricted, if necessary or expedient, by dispensing with the pump or air lift (4). The silt is then removed manually, using a shovel, bucket and hoist. In this case a by-pass and suitable stop structures must be provided.



1 Rack

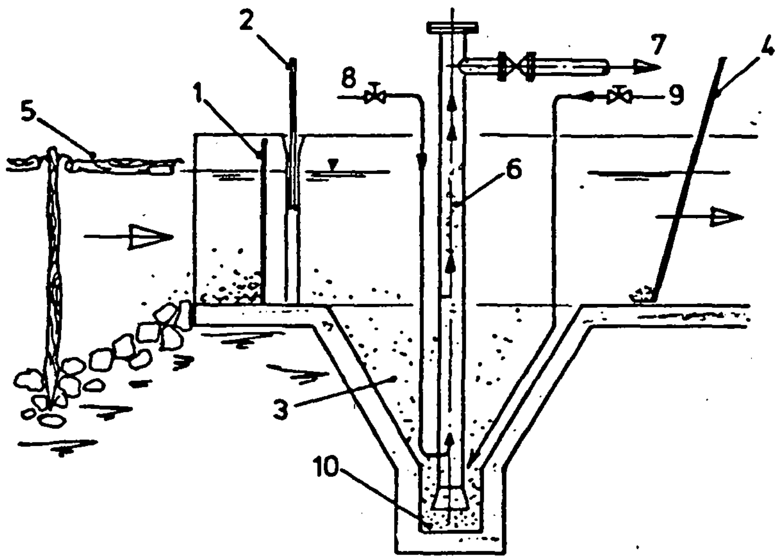
2 Stop plank

3 Sand trap

4 Bypass

5 Screen

6 Drift excluder



1 Rack

2 Stop plank

3 Sand trap

4 Screen

5 Drift excluder

6 Air lift

7 Washout

8 Compressed air 9 Flushing water

10 Silt chamber

Fig. 29

Short sand traps (fig. 29) are used where the available space is restricted. They are less efficient (lower degree of separation) than the type shown in fig. 28, but nevertheless still considerably reduce the amounts of solids reaching the machines and other equipment in the water-treatment plant. The short sand trap (3) follows the rack (1) and precedes the screen (4). These structures are square in cross-section, their exact size and shape depending on the intake structure, and have a funnel-shaped sedimentation zone. The silt collects in a chamber at the bottom (10), from where a wear-resisting pump or air lift transfers it to a container unit or to a collecting and dewatering tank. As above, the silt can also be removed manually, at intervals depending on how quickly it accumulates.

Long sand traps (fig. 30) are comparatively shallow, simple and cheap to build. Silt removal is either mechanical or manual, using simplest equipment. These sand traps are suited to the installation of an oil barrier with extraction device.

The rate of flow in the canal should not be more than 0.3 to 0.6 m/sec where sand and other easily settling solids are to be separated. The sand trap can be between 10 and 30 m long. The details of its design depend on the method of removing the accumulated silt (i.e. manual or mechanical). The trap should be between 0.4 and 1.0 m deep.

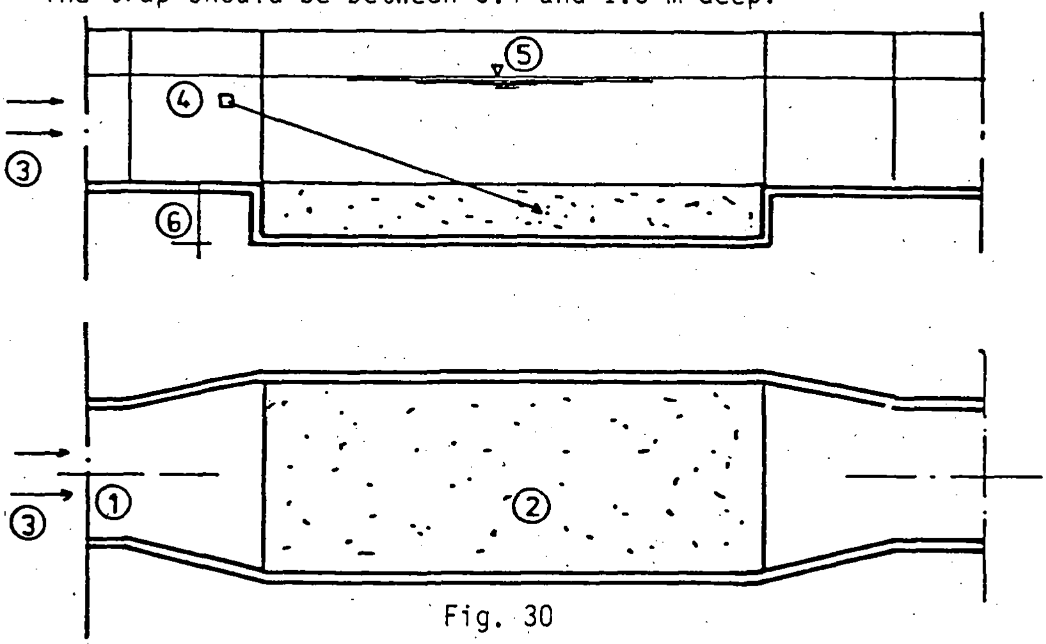


Fig. 30

5.2 Operation

Where sand traps are cleaned out mechanically, pumps and air lifts are subjected to considerable wear and tear from sand, stones etc. These machines must therefore be carefully observed and serviced.

It is important for the sand trap to be preceded by a rack (cf. Section 4 above). This keeps out coarse debris, which might otherwise complicate removal of the silt.

Manually cleaned systems are virtually proof against breakdown and are particularly suitable where adequate labour is available but machine installation, and especially maintenance, can cause problems.

5.3. Maintenance

All sand traps must be cleared at regular intervals of the accumulated silt. Where this is done manually, the amounts can be observed and the frequency of clearing operations scheduled accordingly - e.g. daily, etc. If the silt is not removed promptly, the sand trap fills up with sediment, the flow speed of the water automatically increases and sand is carried into the water-treatment plant. During manual silt-removing operations the flow of water must be cut off. Where the structure is cleared mechanically, pumps, air lifts, pipes, valves etc. must be inspected and serviced at least twice a year. Equally, the silt-collecting container must be emptied at least once a year, including removal of any thick deposits on sides and floor.

5.4 Auxiliary materials

Expensive tools are not necessary, simple mason's and fitter's tools being quite adequate. Various building materials are possible and they should thus be chosen according to availability: e.g. bricks, stone, concrete pipe sections, timber, old oil or tar drums, concrete or other suitable material which is easily available.

5.5 Parts needing special attention

Sand traps which are cleaned out manually have no parts requiring more than normal attention.

Where sand traps are cleared mechanically, special care has to be given to pumps and air lifts.

5.6. Safety measures

Whenever sand is removed manually or pumps and air lifts inspected, the inflow of water must be temporarily stopped.

In addition, all persons working in the sand trap (figs. 28 and 29) must always wear a safety helmet, and before beginning work in deeper structures should test for gas (methane, carbon dioxide etc.).

6 Screens

6.1 Methods of constructing simple versions

The construction of semi or fully automatic screens (cf. fig. 31) is not possible without sound knowledge of the principles of mechanical engineering. Only simple versions, for use in small-scale waterworks or as temporary measures, can be made locally and - where possible - with locally available materials (cf. Section 4, figs. 21 to 25). Installation of the screens can be entrusted to locally recruited workmen provided they are given qualified direction and assistance.

Very simply designed screens can be recommended for use under special circumstances, e.g. in very small plants, as temporary measures, or in rural areas where enough labour is available to clean the screen regularly by hand, but the proper maintenance of more sophisticated equipment would cause problems (cf. Section 4, figs. 21 to 25).

The size of the perforations or slits in these simple screens should not be more than 2.0 to 5.0 cm, however.

The screens are best installed directly following the sand traps or, if there is no sand trap, following the trash rack.

As a basic rule, sturdy structures are preferable to lighter versions, since they can be relied on to continue functioning efficiently over long periods even with minimum maintenance.

Generously dimensioned geared engines, shafts, bearings, chain or rope hoists, screen bars and cleaning mechanisms increase the reliability of the equipment and cut repair costs. Important are an overload safety device and a safety stop device for the travelling carriage. In addition, large eye bolts should be attached to this, so that in an emergency it can be pulled up quickly. If the screen is installed in the open, it is advisable to cover the exposed parts with a hood as protection against the weather. This hood must be easily removable, so that inspection and repair work is not hampered. A number of ventilating slits should be provided.

If it is decided, because of costs, to dispense with a standby screen, a generously dimensioned bypass pipe should be provided, so that the treatment plant can still be supplied with raw water when inspection or repair work - even if of relatively short duration - is carried out on the screen. To protect the treatment equipment, this bypass conduit is often fitted with a simple strainer.

As solids accumulate on the screen, the flow of water through it automatically diminishes. As a result, the water level on the downstream side of the screen drops to such an extent that in extreme cases the suction chambers of the raw-water pumps may be empty. As a preventive measure, the screen should always be cleaned regularly so that the water can flow through it without hindrance.

Mechanical cleaning of screens - e.g. those made of bars - is performed by a rake mechanism moved by a geared motor via chains or ropes. Switching takes place on the basis of a water-level differential pressure measurement in such a way that the cleaning operation is initiated when the water behind the screen is at a minimum level, and can be performed once or several times, depending on the setting.

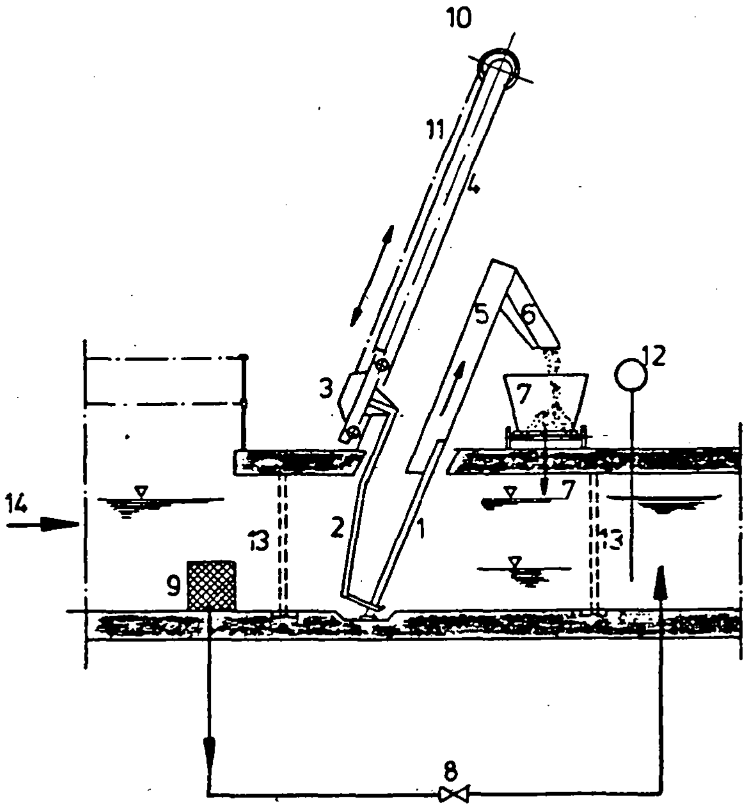
Many plants have, in addition to the system described above, an adjustable operational/non-operational switching system. The advantage of this is that the cleaning operation can be repeated as often as required.

In a simplified version, the cleaning device is operated manually with a winch. Equally, screens not reaching down to very great depths can be cleaned quite successfully by hand, using a rake.

If the screen is cleaned manually, the amounts of solids which have accumulated on it, or the water level following it, should be checked at frequent intervals and the screen cleaned as necessary. This may be as often as once an hour. Monitoring can be facilitated by installing a simple float device which shows the water level via a vertical pointer on a board graduated in centimetres, thus indicating when cleaning is necessary.

The choice of system depends solely on the specific circumstances. Thus e.g. in remote rural districts, cleaning should be manual wherever at all possible. As a basic rule, screens must be installed so that they are easily accessible. A suitable method of taking away and disposing of the removed solids must be devised.

<u>Under no circumstances may the solid matter removed from the screen be thrown back into the water source!</u>



Concurrent-flow screen with rake mechanism

1 Screen bars
2 Cleaning rake
3 Travelling carriage
4 Rig
5 Stripping plate
6 Chute
7 Transport container with drainage
8 Bypass
9 Large-surfaced strainer
10 Drive
11 Toothed rack; chain; rope
12 Level measurement
13 Stop plank
14 Direction of flow

Fig. 31

6.2 Operation

The solids carried by the raw water are caught by the bars of the screen (1). One of the control systems described above causes the travelling carriage (3) to move into the lower end position. The rake (2) engages between the bars of the screen and, moving upwards, takes the contaminants with it. Via the stripping plate (5) the solid matter reaches the chute (6), through which it falls into a channel with drainage provision. In colder climates it is advisable to heat the chute (6) to prevent it icing up.

Simple versions (cf. Section 4, figs. 21 to 25) must be kept under constant observation and cleaned by hand.

6.3 Maintenance

To allow maintenance work to be performed, screens should be removed, or otherwise taken out of commission, about once a year. All parts are then thoroughly cleaned. Any bent screen bars or parts of the rake mechanism must be carefully straightened and the stability of the complete structure checked. If necessary, additional reinforcement should be provided.

Following this, the protective coating is examined, any corroded areas thoroughly de-rusted and given several new coats of paint. Adequate time for each coat to dry thoroughly must be allowed before applying the next layer.

During these operations, some kind of substitute must be provided for the screen, to allow careful and unhurried performance of the work without interrupting the supply of water to the waterworks. Such measures can be:

- Installation of a portable screen of elementary design.
- Diversion of the water through a permanently installed bypass conduit with a strainer at its entrance.

Simple structures should also be taken out twice a year, cleaned, straightened and re-painted where necessary.

6.4 Auxiliary materials

Simple tools and, in the case of larger structures, tripod cable supports, ropes and hoists are needed; otherwise no special materials.

6.5 Parts needing special attention

- Screen bars, if not sturdy enough.
- Cleaning mechanisms, where not strongly constructed.
- Chains and rope hoists, shafts, bearings and geared motors, where inadequately dimensioned.
- All parts exposed to the interaction of air and water and areas where metal moves on metal (e.g. screen bars, travelling carriage).

6.6 Safety measures

When inspection or maintenance work is carried out on larger screens, the flow of water must be reliably stopped and the water also pumped out of the working area. Where the equipment operates automatically, the power supply must be cut off before beginning work by removing the fuses.

7 Aerating systems

7.1 Methods of constructing simple versions

Cascades, tricklers and other simple types of aerating systems can be built with locally available materials such as stones, timber, bricks etc. (cf. figs. 32 to 37). The work can be carried out by local craftsmen provided expert guidance is available. Small systems can be of ultra-simple design. Such solutions are also recommended for temporary use or in remote rural areas, where proper maintenance of more sophisticated versions cannot be guaranteed and spare parts are not easily obtainable.

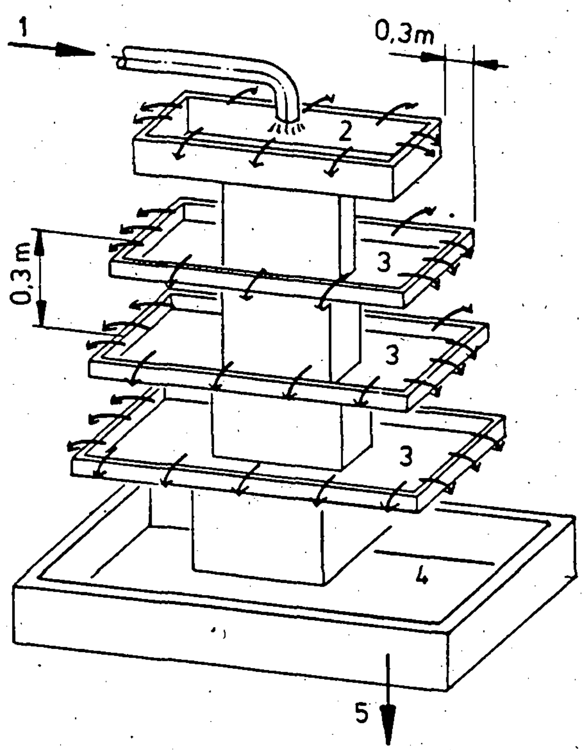
The design should be chosen to fit the given conditions, e.g.:

- is there an existing gradient which could be exploited,
- is there a reliable supply of electricity,
- can existing tanks or other structures be used,
- what inexpensive building materials are available locally,
- what building methods are traditionally used in the area,
- what is the level of qualification of the available operating personnel.

Cascades (figs. 32 and 33)

Cascades are corrosion and blockage proof aerating systems. The raw water first flows through a pipe or channel (1) into a distributor (2). From there it overflows, evenly spread, onto the successive steps of the cascade. There should not be fewer than 3 steps.

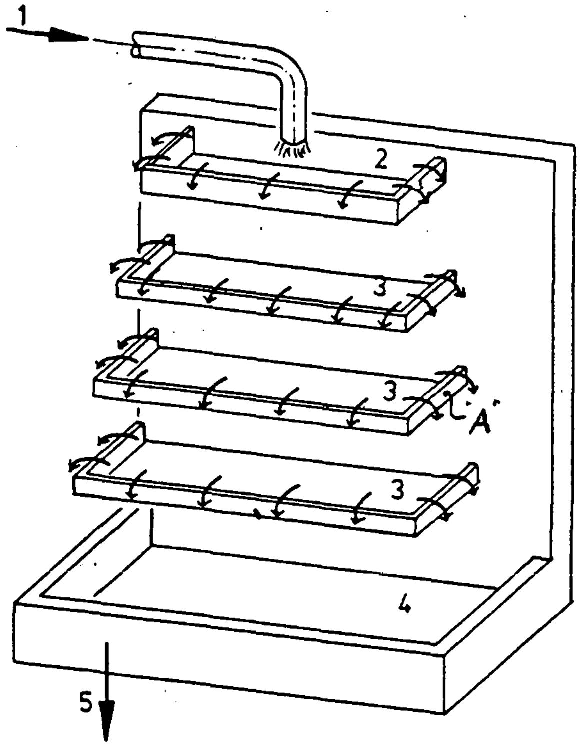
To prevent water losses, the receiving basin (4) at the bottom of the cascade should be generously dimensioned, i.e. approx. 1.5 m wider all round than the last step of the cascade. Since silt deposits must be expected in this receiving basin, a sufficiently large washout must be provided. The most important requirement, and simultaneously the most difficult to meet in terms of construction, is that all overflow sills must be absolutely horizontal. If necessary, they may have to be re-worked to meet this condition.



Unilateral cascade

1 Raw water inlet
2 Distribution
3 Cascade step
4 Receiving basin
5 Outlet

Fig. 32



Multilateral 3-step cascade

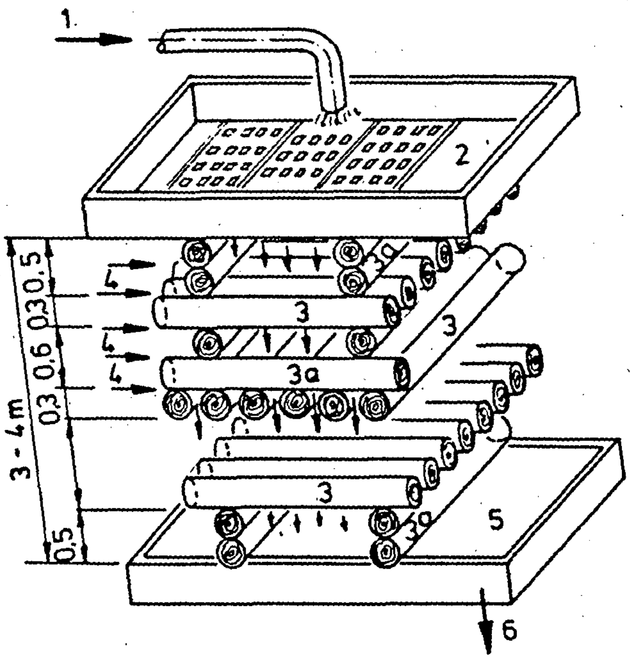
1 Raw water inlet
2 Distribution
3 Cascade step
4 Receiving basin
5 Outlet

Fig. 33

Simple log-type cascade (fig. 34)

A water distributor (2) is made of e.g. boards, a metal drum, halved plastic or bamboo pipes with holes punched in the bottom and installed as nearly horizontal as possible on a simple support roughly 3 to 4 m above ground level. Underneath this are arranged distancing logs (3a) and logs forming the steps of the cascade (3). The logs of each successive step run alternately in opposite directions. A generously dimensioned receiving basin, made of earth, concrete or masonry, collects the aerated water at the bottom.

Aeration takes place through natural entrainment of air into the water. Wherever possible, the aerated water, together with the oxidized contaminants it contains, should then be fed by gravity with minimum turbulence to the flocculation and sedimentation or filtration stage. The choice of material depends on cost, availability and experience.



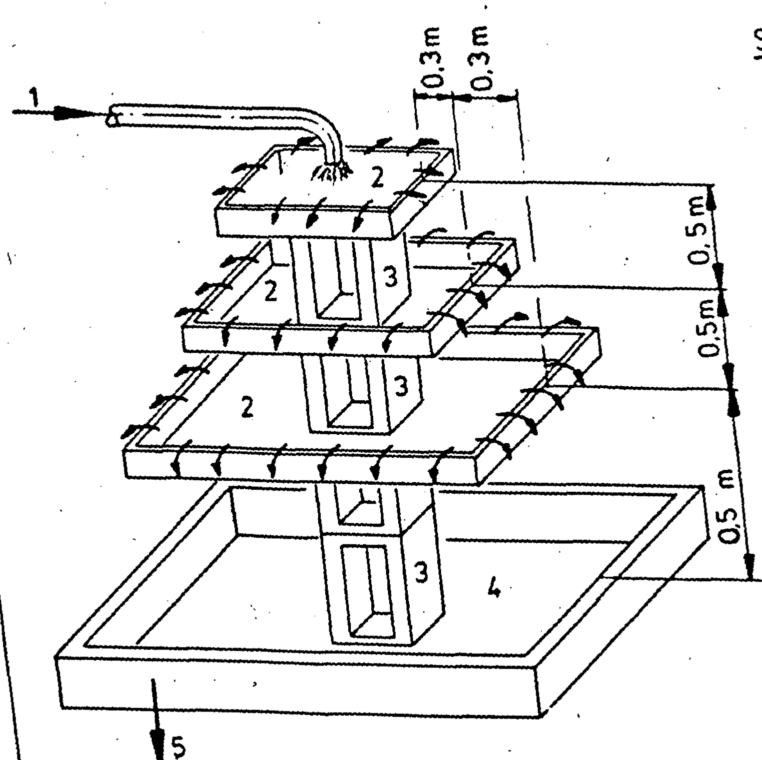
Simple log-type cascade

1 Raw water inlet
2 Distribution
3 Cascade step (logs)
3a Distancing logs
4 Natural aeration
5 Receiving basin
6 Outlet

Fig. 34

Simple cascade (fig. 35)

Central column of concrete pipe rings or bricks (3), cascade steps (2) of prefabricated, lightly reinforced concrete slabs or sheet metal.



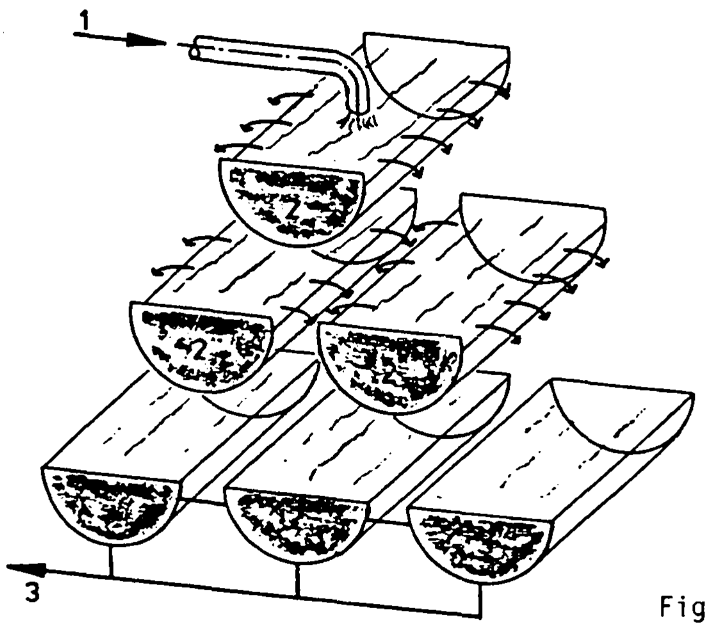
Simple cascade

1 Raw water inlet
2 Cascade step
3 Concrete pipe rings
or bricks
4 Receiving basin
5 Outlet

Fig. 35

Simple cascade (fig. 36)

Made of halved 200 l drums (oil/creosote drums etc.).



Simple cascade

1 Raw water inlet

2 Cascade steps made of halved metal drums

3 Outlet

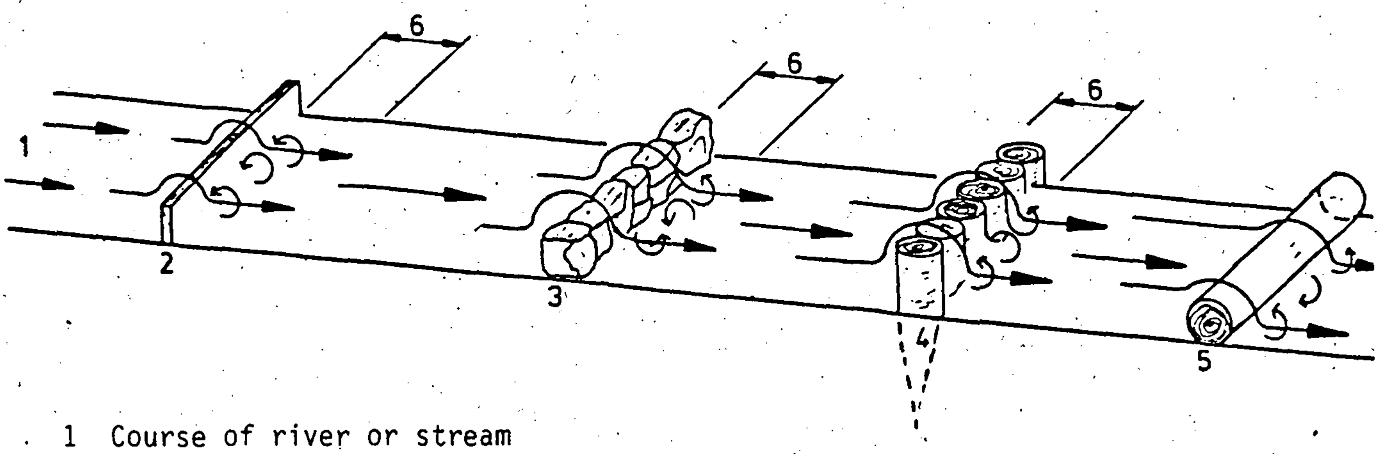
Fig. 36

Other aeration systems (fig. 37)

At every few metres in a stream or other water channel with a certain gradient (1), obstacles are built which hold back the water and thus cause it to fall from a height of at least 0.3 m. Boards (2), metal plates, stone or concrete rubble (3), horizontal or vertical wooden or bamboo posts (4) and (5), drums filled with sand, old pipes, etc. can all be used.

The number of steps can be varied as conditions allow and as required. Any solid matter settling after the steps must be periodically removed.

Aeration via simple obstacles



1 Course of river or stream
2 Baffle
3 Stone or concrete rubble
4 Vertical pile
5 Horizontal pile
6 Degasification/Aeration

Fig. 37

In some cases the raw water is available with a high supply pressure (e.g. due to a steep downhill gradient), or reduction of the aggressive carbon dioxide content to a very low level may be required. For these reasons the atomization process is described below, although use of this system is limited since it requires considerably more material and maintenance.

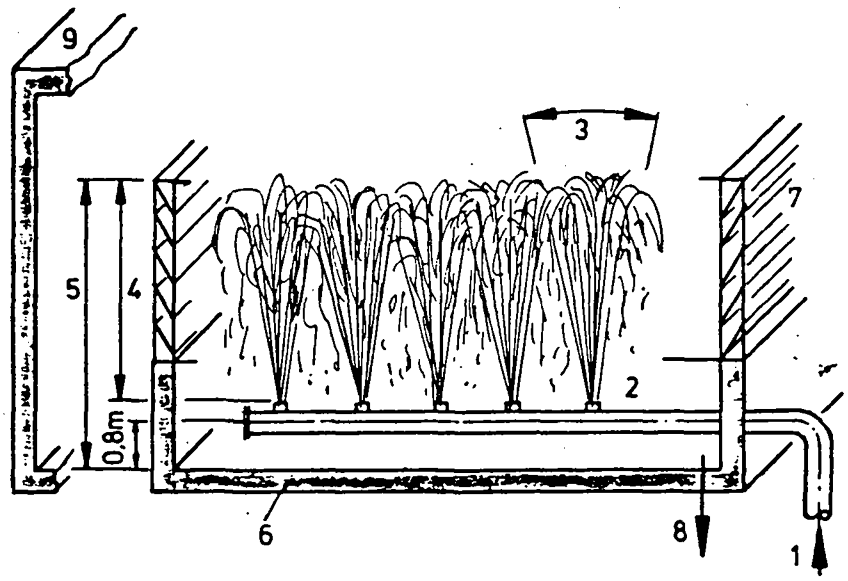
Atomization (fig. 38 and 39)

The atomizing equipment is installed in or above a receiving basin (6). The raw water is fed to the nozzles (2) via a pipe (1) in a number of runs, depending on the volume of water. The width and height of the jets from the nozzles is governed by supply pressure and nozzle type. The height of the jet (4) should not be less than 2.0 m. The atomization installation should be surrounded on all sides by louvred walls (7) permitting a natural exchange of air. In moderate climates the system may be open at the top and sides, whilst colder climates make full enclosure (9) necessary.

In all atomization installations it is important to ensure that the water droplets can fall unhindered to the floor, since the degassing effect follows spontaneously on impact. Combined atomization/receiving basins must therefore be provided with a special impact shelf.

Ventilation immediately above the impact zone must be particularly intensive, so that the heavy gases gathering just above the floor are immediately and continuously replaced by air. To achieve pressure conditions which are as uniform as possible, distribution through a ring pipe is advisable. To allow inspection and maintenance, the atomization plant can be built with several chambers; one chamber can then be isolated with the aid of a stop valve.

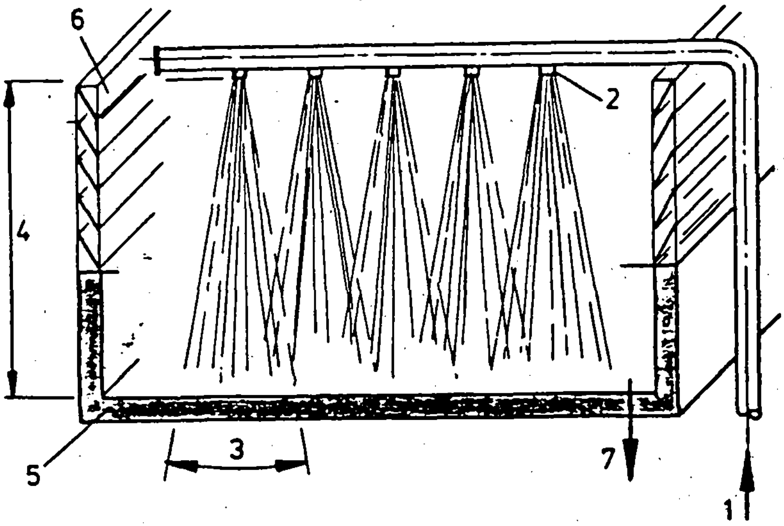
Atomization installation: water sprayed upwards
- natural aeration



1 Raw water inlet
2 Nozzle
3 Width of jet
4 Height of jet
5 Depth of fall
6 Receiving basin
7 Louvred wall (wood, asbestos cement, plastics)
8 Outlet
9 Enclosure

Fig. 38

Atomization installation - water sprayed downwards
- natural aeration



1 Raw water pipe
2 Nozzle
3 Width of jet
4 Height of jet
5 Receiving basin
6 Louvred wall (wood, asbestos cement, plastics)
7 Outlet

Fig. 39

1.2 Operation

In waterworks with simple primary cleaning systems (rack), there is a risk of the nozzles becoming blocked (figs. 38 and 39). In such cases, blockage-proof cascades (figs. 32 to 37) are more suitable.

Proper functioning of whichever aeration system is chosen is very important for the water-treatment process as a whole. If there is bivalent, non-filtrable iron in the raw water, this is oxidized during aeration to its trivalent form, which can be removed by a simple gravel filter. Inadequate aeration or oxidation allows bivalent iron to pass straight through the filters and enter the water supply system, where after a certain length of time it leads to blockages, deposits, corrosion etc.

If aeration is followed by flocculation and sedimentation, residues of iron flocculate and settle in these stages.
If the raw water contains aggressive carbonic acid, this must be driven out in the aeration stage until lime/carbonic acid balance is achieved. Where this is not possible, the water remains aggressive, subsequently attacking and damaging water mains and domestic installations.

Where excessive residual amounts of aggressive carbonic acid remain in the water after aeration, the addition of a certain amount of lime water can have a positive effect. The chance of success is greater if there is a flocculation and sedimentation stage allowing enough time for the reaction to take place and sedimentation products to separate.

If this is not the case, the result may be that lime is deposited in the filter. Within a very short time the filter "cements up" and becomes useless.

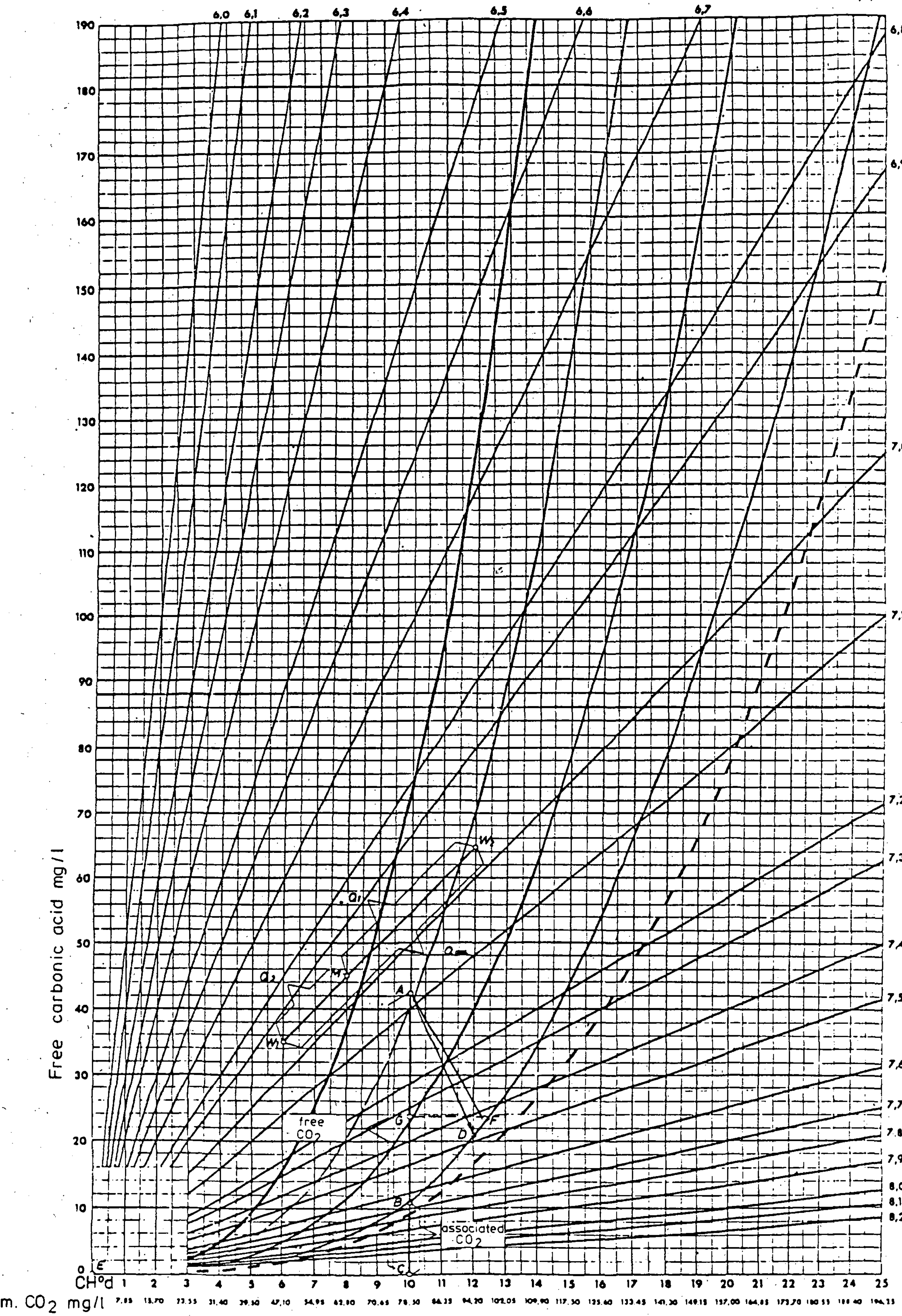
The lime/carbonic acid graph (fig. 40) demonstrates the relationships described above.

Layout of the cascade is calculated for the middle sill (cf. fig. 33), Index "A". Between 8 and 16 m^3/h of water can be aerated per linear metre of the edge of the middle step. The vertical distance between each step in the cascade should not be less than 0.3 m. Equally, the horizontal lateral distance from the front edge of one step to the front edge of the next should be at least 0.3 m. As shown in figs. 32 to 35, cascades can be unilateral or multilateral and made of concrete, steel, plastics, asbestos cement or similar materials.

7.3 Maintenance

Open cascades should be cleaned roughly once a year. Where atomization systems are used, cleaning may be necessary rather more often, especially when primary cleaning of the raw water is by simple racks only and relatively large amounts of contaminants, such as pieces of wood, leaves, reeds, water plants, dead fish etc., reach and may block the nozzles. Nozzles must be examined at frequent intervals and cleaned if found to be blocked. This also applies to louvres, grids, filters etc. Receiving basins should be emptied and cleaned regularly.

LIME / CARBON DIOXIDE GRAPH after Tillmans



Equilibrium curves: 10°C; 17°C; 40°C; 60°C; 80°C; —— lines of theoretically equal pH

The curves give an overall view of the interrelationships between combined carbonic acid, associated carbonic acid and aggressive (iron-attacking/lime-attacking) carbonic acid. In the graph, a water is represented by a point, the position of which is determined by the concentration of free carbonic acid in the water and by its carbonate hardness (combined carbonic acid content). If there is lime/carbonic acid equilibrium in the water, this point must be on the appropriate equilibrium curve, depending on the temperature of the water examined.

The various forms of carbonic acid are shown in the graph as follows:

Line EC = carbonate hardness (combined carbonic acid)
Line AC = free carbonic acid
Line BC = associated carbonic acid
Line AB = aggressive (iron-attacking) carbonic acid
Line AG = aggressive (lime-attacking) carbonic acid.

AB (aggressive carbonic acid) + BC (associated carbonic acid) = AC (free carbonic acid).

If the water is deacidified by the MAGNO method, the aggressive carbonic acid combines, with a simulataneous increase of hardness. This increase of hardness can be put on average at 1°d per 10 mg/l of combining carbonic acid. Deacidification is in the direction AD. The equilibrium water is indicated by point D. If a water is treated with crushed marble according to Heyer's method, deacidification in the direction AB occurs. The lime-attacking aggressive carbonic acid to be combined (line AG) is then given as the result of the test.

Determination of the position of a mixed water in relation to lime/carbonic acid equilibrium

Example: Volume of mixed water 60m³/h

Water I		Water II	
Share of total volume:	40 m³/H	Share of total volume:	20 m³/h
Carbonate hardness:	6°d	Carbonate hardness:	12°d
Free CO_2:	35 mg/l	Free CO_2:	65 mg/l

Points W_1 and W_2 for the two waters are plotted on the graph and the two points joined by a straight line. The total volume of mixed water is 60 m³/h. The straight line is divided into six sections, each representing 10 m³. From point W_2, the volume of water I = 40 m³ is then marked off along the straight line. The end point M is characteristic for the mixed water.

Thus there result for the mixed water:

Carbonate hardness = 8°d
Free CO_2 = 45 mg/l

The vertical projection of the point M onto the equilibrium curve represents the concentration of aggressive carbonic acid in the water. The aggressive carbonic acid content of the mixed water can thus be read off as 39.5 mg/l.

These curves are fully applicable to waters which contain no other dissolved substances apart from lime and carbonic acid. Additional information is given in MAGNO guideline No. 140, page 12 ff.

Closed systems especially may suffer from deposits of iron and calcium carbonate or other contaminants; these must be removed mechanically or by an acid treatment. In timber structures, any rotted parts should be replaced.

The simpler the design of the aeration system, the less maintenance it needs.

7.4 Auxiliary materials

Normal tools are quite adequate for construction and maintenance of the system. Larger plants may require the use of ladders, scaffolding and lifting tackle.

7.5 Parts needing spescial attention

In atomization systems, windows, doors, ventilation openings etc. should be protected on the inside by coping strips.

The body of the structure and all installations, e.g. pipes, louvres, windows, doors etc. should be proof against corrosion caused by humid air enriched with aggressive carbonic acid and sometimes containing hydrogen sulphide. In addition to a good protective finish, stainless steel, ceramics, stoneware, hardwood and plastics are suitable materials for this application.

If the raw water contains large amounts of iron or solid matter, blockage-proof systems such as cascades and pressure oxidizers are more reliable than atomizing, trickling or mixed-element aerators.

7.6 Safety measures

The inflow of water must be reliably stopped during inspection or repair work. Where acid is used, personnel must always wear protective clothing, goggles, etc..

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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
2.3a	Maintenance and repair of diesel engines and petrol engines
2.3b	Maintenance and repair of electric motors
2.3c	Maintenance and repair of simple driven systems
2.3d	Design, functioning, operation, mainte nance and repair of power transmission mechanisms
2.3e	Maintenance and repair of pumps
2.3f	Maintenance and repair of blowers and compressors
2.3g	Design, functioning, operation, mainte-nance and repair of pipe fittings
2.3h	Design, functioning, operation, mainte-nance and repair of hoisting gear
2.3i	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
3.3a	Design and working principles of diesel engines and petrol engines
3.3b	Design and working principles of electric motors
3.3c	–
3.3d	Design and working principle of power transmission mechanisms
3.3e	Installation, operation, maintenance and repair of pumps
3.3f	Handling, maintenance and repair of blowers and compressors
3.3g	Handling, maintenance and repair of pipe fittings
3.3h	Handling, maintenance and repair of hoisting gear
3.3i	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
3.8a	Construction in concrete and masonry
3.8b	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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