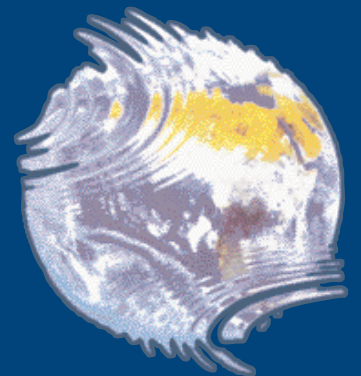


*DRINKING
WATER*



SNF FLOERGER®



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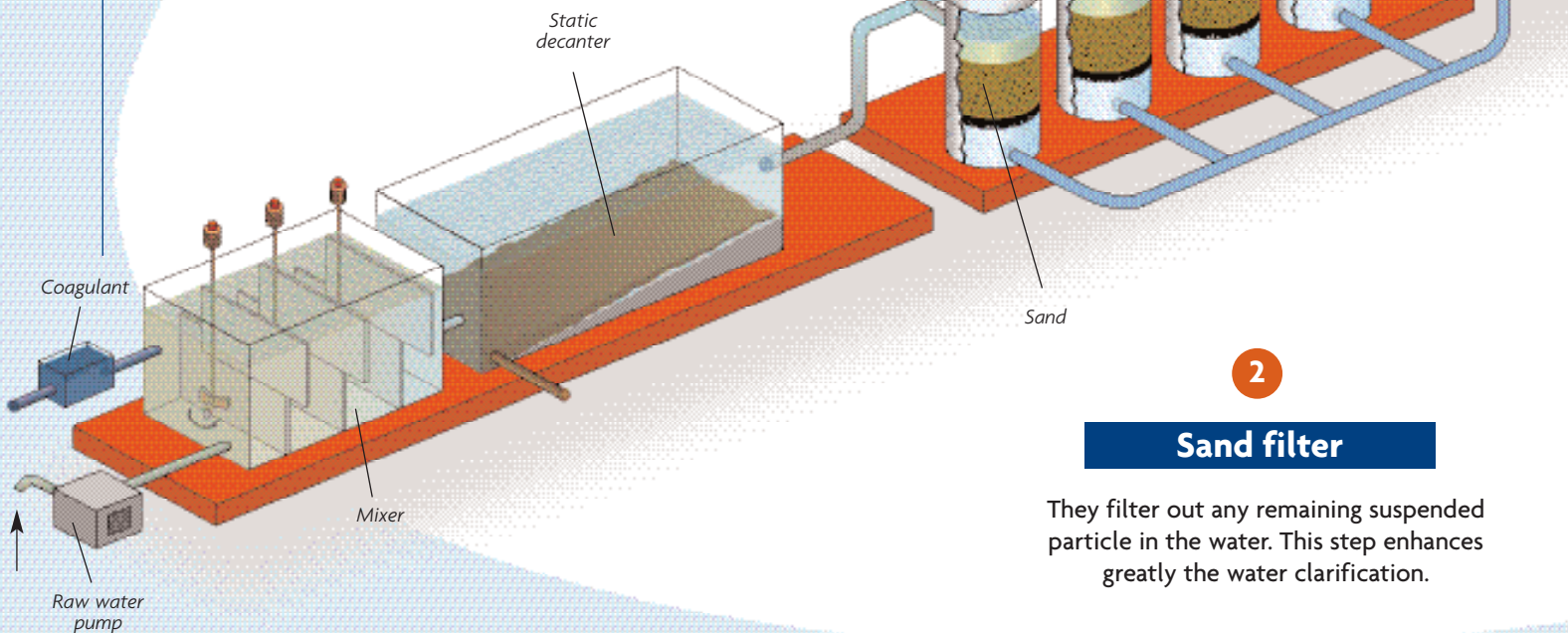
DRINKING WATER

Drinking water is a water whose quality must ensure the perfect health of the end user. Taken from the natural environment, it must undergo treatments that will render it apt for human consumption.

1

Decantation

During this stage, the coagulant and flocculant will accelerate the settling of the suspended particles.



2

Sand filter

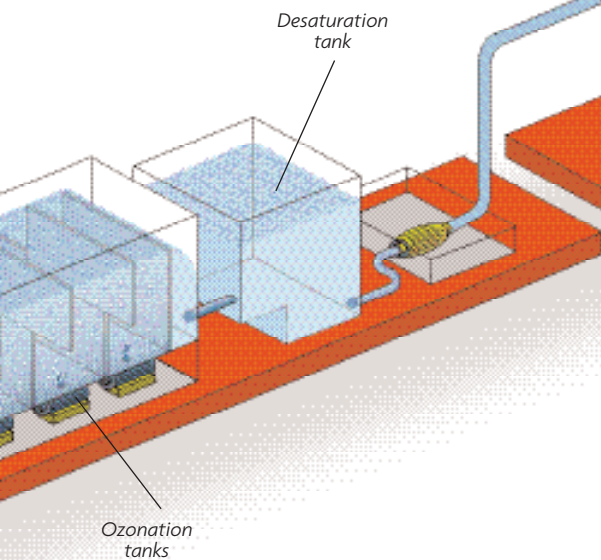
They filter out any remaining suspended particle in the water. This step enhances greatly the water clarification.

PRODUCTION

3

Ozonation

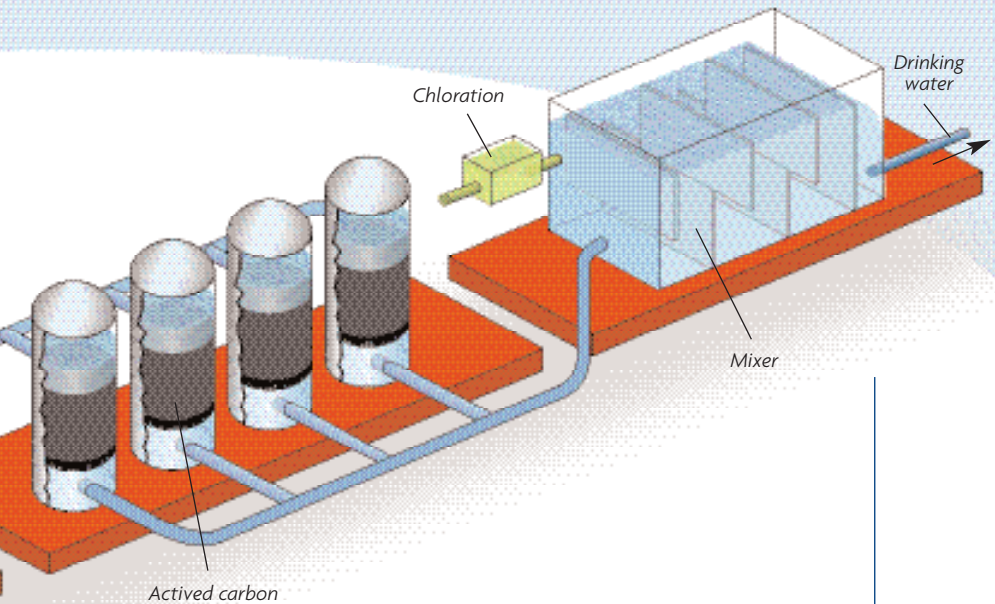
The oxidizing properties of ozone will totally disinfect water, destroying microorganisms. It also degrades large size molecules.



5

Chloration

This step will prevent the formation of germs during transport. It is necessary to guarantee a healthy water all along the distribution network.



4

Activated carbon filters

This secondary filtration will filter out any remaining organic compounds still present in the water.

SNF FLOERGER®

GENERAL INFORMATION ABOUT

The word coagulation comes from the latin *coagulare*, which means “to agglomerate”. In water treatment operations, coagulation is an essential mechanism for removing suspended colloidal particles which can cause objectionable turbidity, color, taste and odor in drinking water. It is accomplished by adding special chemical reagents to the raw water. These coagulants cause very small and widely dispersed colloidal particles to agglomerate into larger masses (flocs) which can then be removed, following flocculation, using solid-liquid separation processes such as settling, flotation and filtration.

Coagulation is an intermediary stage which is essential in drinking water treatment for the success of physico-chemical processes.

■ Basic principles of coagulation

If all of the suspended solids in raw water were large enough to be easily removed within the design parameters of the various clarification systems, treatment with chemical coagulants would not be required. Much of the suspended matter, however, is comprised of very fine and widely dispersed solids, a significant portion of which are colloidal. Because they are so small, these particles are virtually impossible to settle, float, or filter until they have first undergone coagulation.

Fundamentally, coagulation implies elimination of colloidal particles. Coagulation is the first stage of destabilization and, basically, its action is to neutralize or reduce electric charges and promote the agglomeration of these particles.

Colloidal particles

Colloids are particles suspended in water with a size smaller than 1 mm which are very stable in aqueous systems.

Colloidal particles are present in virtually all raw waters. They are a major cause of objectionable turbidity, color, taste and odor in drinking water.

These particles have different origins:

Mineral

→ silt, clay, silica, hydroxides and metallic salts,

Organic

→ humic and fulvic acids stemming from the decomposition of vegetable and animal matter, colorants, surface-active agents, etc.

Biological

→ micro-organisms (wether or not pathogenic).

→ including bacteria, plankton, algae and viruses.

■ Coagulation mechanism

The stability or instability of particles in aqueous suspension depends on several attractive and repulsive forces:

- **Van der Waals attraction forces,**
- **Electrostatic repulsion forces,**
- **Universal attraction,**
- **Brownian movement.**

Coagulation is a chemical and physical process wherein collisions between colloidal particles and coagulant chemicals result in their cohesion and eventual sedimentation as agglomerates.

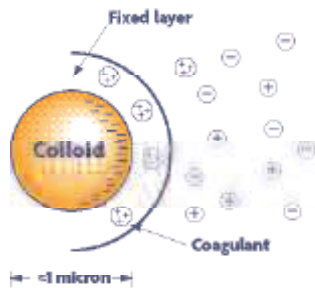
Cationic coagulants neutralize negative charges on the colloidal particles' surface and produce spongy masses called floc. Floc entraps or adsorbs particles of mineral, organic matters and micro-organisms.

COAGULATION AND FLOCCULATION

In order to destabilize a colloidal suspension, coagulation will provide the following effects.

1 Charge neutralization

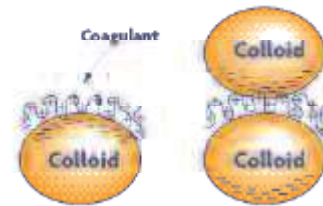
→ decrease of electric repulsive forces



Cationic coagulant neutralizes negative charge of colloid

2 Chemical bridging

→ particle aggregation by means of a cationic polyelectrolyte.



Initial adsorption

Initial coagulation

For the coagulation mechanism, cationic charge seems to be more important than molecular weight. In fact the cationic charge facilitates the destabilization and agglomeration of the suspended colloids by neutralizing their surface charges.

Basic principles of flocculation

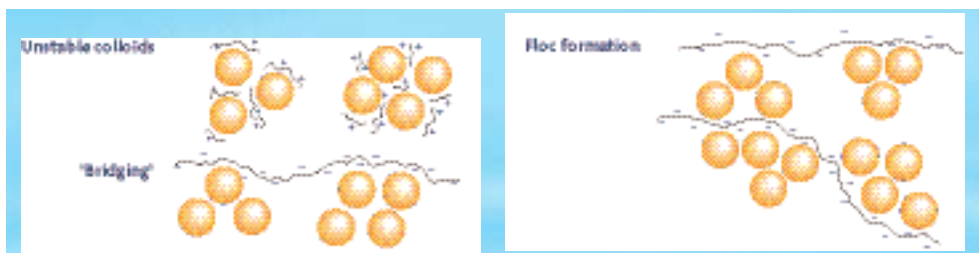
After colloidal suspensions have been destabilized by coagulants, flocculant polymers are frequently used to enhance the performance of clarification processes.

Destabilized particles

The variety of origins of the destabilized particles depend largely on the source of the water being treated. The flocculants **charge** (+ or -) will be selected according to the particles themselves. In general the following is true:

- More or less **anionic** for **mineral** particles
- More or less **cationic** for **organic** particles

Flocculation mechanism



Because of their very high molecular weights (very long chain of monomers), and of their ionic charge, flocculants will bridge destabilized particles together. This results in the **formation of large particles** suspended in water. This formation of **flocs** is called **flocculation**.

The forces involved in this bridging between particle and polymer are mainly **ionic and hydrogen bonding**.



ORGANIC COAGULANTS

FLOQUAT™ Series

Organic polymeric flocculants have been used in water purification processes for several decades as coagulant aids or floc builders, after the addition of inorganic coagulants like alum and iron salts. The application of polymers as primary coagulants in cleaning up low quality natural waters for drinking water production by direct filtration and weighted flocculation is discussed. Presently, the whole or partial replacement of inorganic coagulant by cationic polyelectrolyte can improve drinking water treatment processes.

The areas of application for organic coagulants include the following:

- clarification by settling
- flotation - clarification
- clarification by direct filtration

■ Organic Coagulation Advantages

Treatment Process Optimization

- *An increase in the solid-liquid separation rate*
- *Low consumption of reagent compared with inorganic salts*
- *A smaller sludge volume is produced (no metal hydroxide precipitate is formed)*
- *Extended filter runs are obtained in direct filtration*
- *The process is less pH dependent*
- *There is a reduction in usage of other treatment chemicals*
- *The treated water has a lower dissolved salt level*
- *Elimination of monocellular algae*

Two main types of cationic polyelectrolyte are commonly used in water treatment:

- **polyAMINE**
- **polyDADMAC**

The coagulants should provide a very high cationic charge to neutralize the negative charges of the colloids and therefore initiate the floc formation.

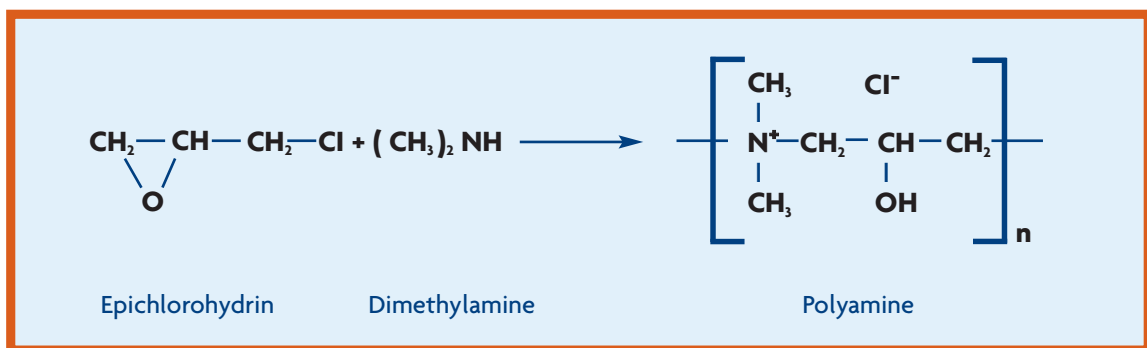
Their molecular weight should be very low to insure a good diffusion of the charges around the particles. Due to their low viscosity they can be readily mixed in the effluent.

POLYAMINES

FLOQUAT™ Series

Quaternary polyamines -poly (2 hydroxy propyl N,N dimethyl ammonium chloride)- are manufactured by a ring-opening condensation polymerization of epichlorohydrin and a secondary amine, such as dimethylamine, at high temperatures in concentrated aqueous solution.

Molecular weights can be varied from 10,000 up to 500,000 by controlling the sequence of addition of the monomers to the reaction vessel. The structure of the resultant polymer differs from the other polyelectrolytes, so that the cationic charges are situated along the backbone chain, and not as pendant side groups.



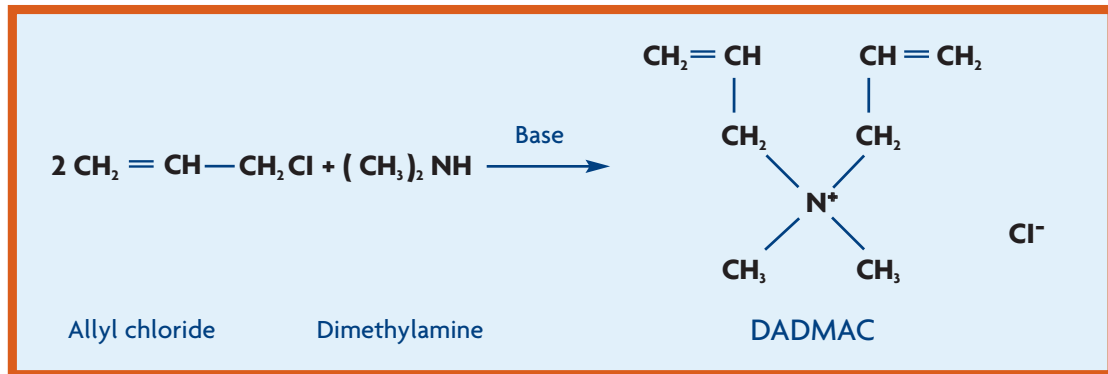
Industrial polymers produced this way present the following characteristics:

- Molecular weight from 10,000 to 500,000
- Liquid form, active content from 40 to 50 %
- Cationic site on the main chain
- Viscosity, at 50 %, from 40 to 20,000 centipoises
- Chlorine stability
- Compatibility with mineral coagulants
- Long shelf life
- Usable with or without preliminary dilution

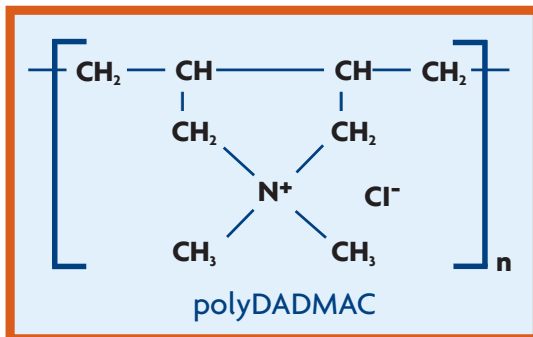
POLYDADMAC

FLOQUAT™ Series

DADMAC (Diallyl dimethyl Ammonium Chloride) is synthesized from allyl chloride and dimethylamine. In common with other monomers containing allyl groups, DADMAC forms a relatively stable allyl radical during vinyl polymerization. It limits, the molecular weight of the polymer.



Copolymerisation by cyclisation.



Industrial polymers produced this way present the following characteristics:

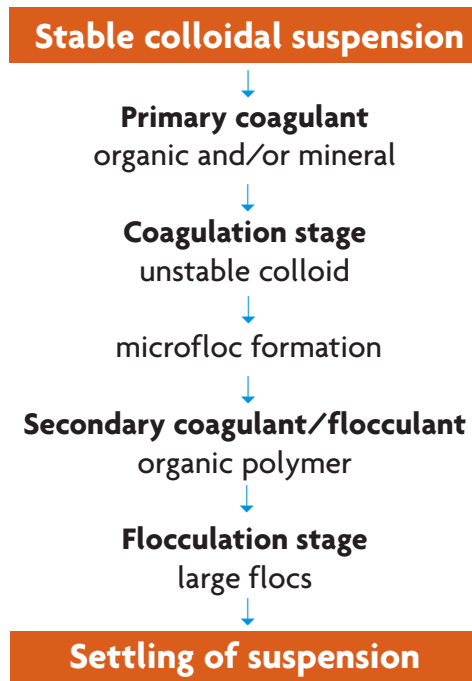
- Molecular weight from 10,000 to 3,000,000
- Liquid form, active content from 20 to 50 %
- Cationic site on the secondary chain
- Viscosity, at 40 %, from 1,000 to 22,000 centipoises
- Chlorine stability
- Compatibility with mineral coagulants
- Long shelf life
- Usable with or without preliminary dilution

ORGANIC FLOCCULANTS

FLOPAM™ PWG Series

FLOPAM PWG (Potable Water Grade) flocculants are used in conjunction with coagulants to increase the settling speed. After the destabilization of the colloidal suspension by coagulant, the flocculant with its high molecular weight encourages fast settlement, according to Stokes' law.

For drinking water, anionic (0 to 50 %) and low cationic (< 15 %) products with high molecular weight have been used with success.



During the coagulation/flocculation process, the organic or mineral coagulant quantity is limited to the necessary quantity for destabilization of colloids and does not require excessive amounts to produce a suspension which will settle.

■ Anionic and Non-ionic Polymers

Non-ionic polymers are Acrylamide homopolymers.

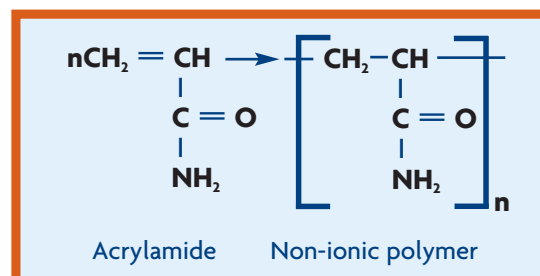
Anionic polymers are differentiated by a functional group. Two monomers are used: Acrylamide and Acrylic acid.

Non-ionic

FLOPAM™ AH 912 PWG - FA 920 PWG Series

These polymers are manufactured by polymerization of acrylamide monomer

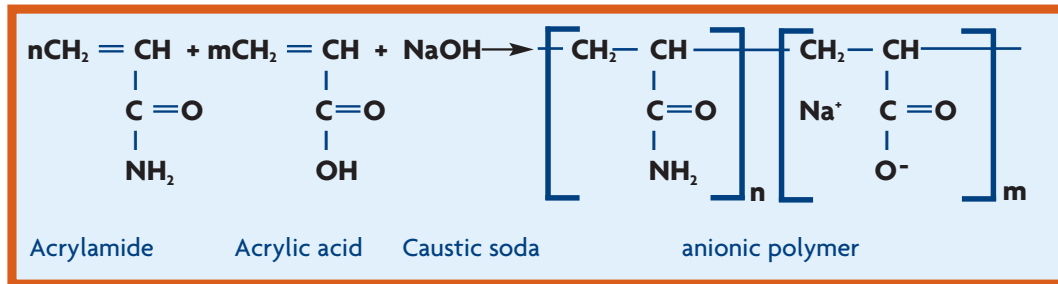
- Molecular weight from 5 to 15 million



Anionic

FLOPAM™ AN 900 PWG Series

These polymers are manufactured by copolymerisation of acrylamide and sodium acrylate.



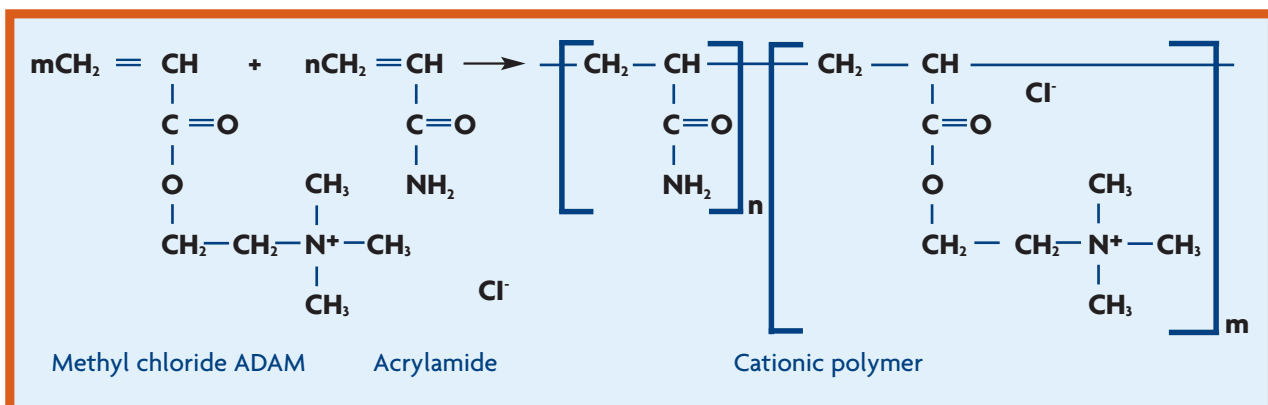
Polymer characteristics :

- Molecular weight from 5 to 22 million
- Easily absorbed by mineral matter

Cationic Polymers

FLOPAM™ FO 4000 PWG Series

Cationic polymers are manufactured by copolymerization of acrylamide and trimethyl ammonium ethyl acrylate chloride (methyl chloride ADAM).



Polymer characteristics:

- Molecular weight from 3 to 15 million
- Easily absorbed by organic matter (humic and fulvic acids) and some mineral matter (silica)

LABORATORY TRIALS

The aim of these lab tests is to define the conditions in which the coagulant will give a good clarification and a good sedimentation.

■ Coagulation and Flocculation Tests

Jar-Test Method

This standard method controls and compares, on many samples, the performance on clarification and sedimentation:

- of the reagent used (type, dosage, concentration, order of addition),
- of different operating conditions (intensity and length of agitation)

Procedure 1: Choice of primary coagulants dosage

example of a procedure

Stage A - measure temperature, turbidity, pH of raw water

Stage B - fill a beaker with 1 litre of raw water

Stage C - add organic coagulant in solution or neat (as a single product, or as a blend with mineral coagulant), varying the dosages

Stage D - quick agitation phase (hydrolysis) 250 rpm for 2 minutes

Stage E - slow agitation phase (floc growth) 40 rpm for 15 minutes

Stage F - sedimentation phase (stop agitation) settle for 20 minutes

Stage G - sample supernatant after 3, 5 and 20 minutes in order to measure improvement in turbidity

This test determines the minimal coagulant dosage used for destabilization of a colloidal suspension in raw water.

Procedure 2, as « procedure 1 » selection of flocculant to achieve optimum sedimentation.

Procedure 2 : Determination of flocculant dosage

- Stage A** - measure temperature, turbidity, pH of raw water
- Stage B** - fill any beaker with 1 litre of raw water
- Stage C** - add organic coagulant according to the results of procedure 1
- Stage D** - quick agitation phase (hydrolysis) 250 rpm for 2 minutes
- Stage E** - add flocculant solutions at various dosages into individual beakers
- Stage F** - quick agitation phase : mixing
- Stage G** - slow agitation phase (floc formation) 40 rpm for 5 minutes
- Stage H** - sedimentation phase (stop agitation) settle for 10 minutes
- Stage I** - take supernatant samples in order to measure turbidity

Remarks:

These two procedures are just examples that must be adapted to the conditions found in the treatment plants. The jar-test has been shown to reproduce in the laboratory the similar conditions specific to different treatment plants. Consequently, by using different agitation times, rapid or slow, or different sedimentation times, the jar-test method pinpoints the dosages of coagulant or flocculant necessary to obtain the correct quality of water.

■ Results to be Measured

- **Size of flocs:** visual appreciation of size and growth of flocs during agitation phase
- **Turbidity:** of supernatant during sedimentation phase
curves: turbidity = f (coagulant dosage) and turbidity = f (time of sedimentation)
- **Organic materials:** of supernatant after sedimentation
- Alkalinity, pH, residual Al

ACTIVATED CARBON

SORBOPOR™ and ANTHRAFILTER™ Series

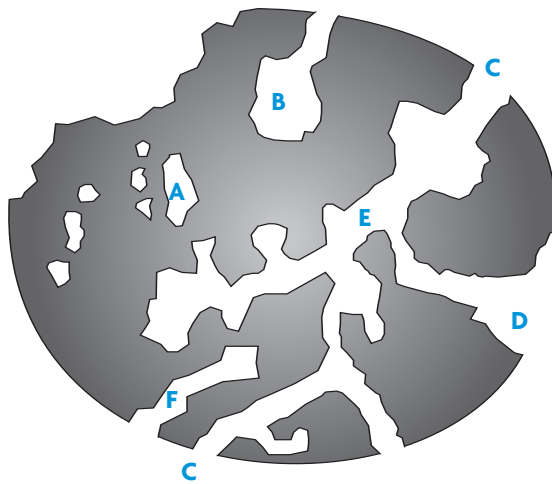
In the world demand for activated carbon, drinking water treatment ranks first. Indeed, activated carbon is widely used for drinking waters purification, either in powder or in granular form. For many decades, this cost effective product has proved it's ability to meet drinking water quality regulatory standards.

Basic principles

Activated carbon is a carbonaceous material characterised by a well developed pore structure, and a very large internal surface area and pore volume. Adsorption capacity is the most important property of activated carbon. Adsorption occurs when molecules are attracted to and held onto the surface of the carbon by weak Van der Waals forces (physical adsorption) or chemical bonds (chemical adsorption).

The adsorption capacity is determined by two factors:

- Internal surface area
- Pore size distribution



A: micropores
 B, F: mesopores
 C, E, D: macropores

Micropores and mesopores are supposed to be the most effective for the adsorption phenomenon and represent 80-90% of the pore distribution.

Advantages

The main treatment objectives are:

- Organic pollutants adsorption (pesticides, halogenated solvents, hydrocarbons,...)
- Oxidants removal (chlorine, ozone)
- Taste and odour removal

Depending on the type of water to be purified, surface water or ground water, and on the level and type of pollution the most suitable technology will be selected:

- Powder carbon dosing system and injection point
- Pressure or gravity granular carbon filters

Usually powder activated carbon is preferred for waters with variable or heavy pollutants concentration. Often it is used before granular carbon filters in order to extend the filters lifetime.

■ Products and services

SNF Floerger supplies different kinds of activated carbon for drinking water purification, each one with its characteristic quality in order to meet the field requirements.

■ Granular activated carbon

The main types are produced from coal or from coconut shell charcoal. Different sizes are available : 12x40, 8x30, 10x20 (U.S. Mesh).

The table below summarizes the applications of Anthrafilter activated carbon and specifies the recommended types. It is just a rough indication, to be confirmed case by case by our technical assistance according to the particularities of each treatment.

Application	Water type	Primary filtration (no sand pre-filtration)	Secondary filtration (after sand filters)
Taste and odour	Surface Ground	ZM 90 8x30 ZM 90 12x40	ZM 90 12x40 ZM 90 12x40
Pesticides	Surface Ground	ZM 85 8x30 ZM 85 12x40	ZM 85 12x40 -
Chlorinated HC	Ground	YV 110 12x40	-
AOX	Surface Ground	ZM 90 8x30 ZM 90 12x40	ZM 90 12x40 -
Organic matter (humic, fulvic acids)	Surface Ground	ZM 90 8x30 ZM 90 12x40	ZM 90 12x40 ZM 90 12x40
Ozone removal	Surface	YV 100 12x40	-
Sand filter conversion	Surface	ZM 90 10x20	-
Dechlorination	Surface Ground	YV 100 12x40 YV 100 12x40	YV 100 12x40 YV 100 12x40

ACTIVATED CARBON

SORBOPOR™ and ANTHRAFILTER™ Series

■ Powder activated carbon

About powder activated carbon, the two product lines are Sorbopor MV 118, coal based, and Sorbopor MV 125, wood based. Both can be supplied in many varieties, differing for activation level and size, depending on treatment objectives or customer needs.

■ Services

The products are supplied in small bags (20 Kg, 25 Kg, 50 lbs), in big bags (500 Kg, 600 Kg, 1000 lbs) or in bulk.

For bulk deliveries, the silotrucks can be filled with powder or granular activated carbon directly from the big bags or through storage silos.

Once on site, while powder activated carbon is unloaded by compressed air, granular activated carbon must be unloaded hydropneumatically, thanks to special silotrucks equipped with draining systems. These silotrucks are also used to collect the spent granular carbon: it is transferred from the filters to the silotruck by means of pressurized water or ejectors and then the motive water is drained out by the draining system.

SNF Floerger is able to carry out all the aspects related to the carbon handling with specialized personnel and devices (ejectors, pipes, pumps, trucks).

■ Activated Carbon Selection

Comprehensive laboratory evaluation is essential to define the activated carbon treatment features that will most effectively and economically achieve the best performance in actual plant scale application.

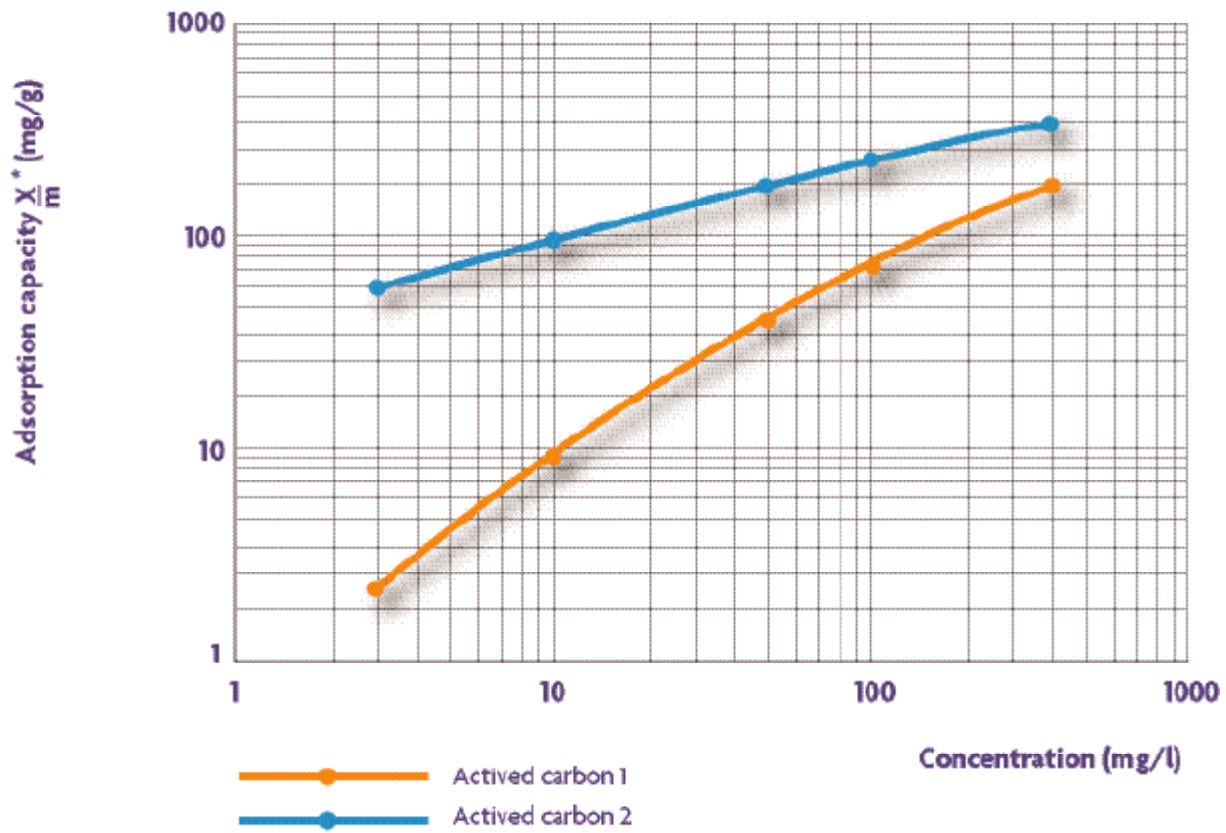
● Powder activated carbon

To determine the parameters for an adsorption process based on powder activated carbon, jar test trials are commonly used. This is a very easy procedure that produces a liquid phase adsorption isotherm, with the identification of the most suitable carbon and the necessary dosage. It requires little time and in many cases it is possible to scale up directly from laboratory to industrial equipment. This type of trials can be carried out according to the ASTM standard test method N. D 3860.

● Granular activated carbon

In case of treatment with granular activated carbon on fixed beds, the process is mainly regulated by adsorption kinetics, based on diffusion laws. For this reason, the carbon treatment parameters must be evaluated in dynamic conditions. The trial is carried out in a fixed bed column, where the liquid to be purified will be added downward through the carbon bed at a constant and monitored flow rate. From this test, the design criteria for the pilot or plant scale application will be obtained. Also in this case the test, when adsorption of soluble contaminants from water is concerned, can refer to an ASTM standard method, in particular the N. D 6586.

Adsorption Isotherm



X_m^* : mg of adsorbed pollutants per g of activated carbon

INDUSTRIAL APPLICATION

The treatment of drinking water with organic polymers must be adapted to the characteristic of the raw water.

The use of coagulants and flocculants is dependent on the different parameters, eg. pH, turbidity, alkalinity, hardness and organic compounds of the raw water.

■ Coagulants

The main application for organic cationic coagulant is as a primary coagulant or a coagulant aid in the clarification of drinking water.

When it is used as primary coagulant, organic coagulant will effectively reduce, and in some cases eliminate, the dosage requirements for conventional inorganic coagulants such as aluminum and ferric salts.

Mineral coagulant dosage is usually reduced by half and organic coagulant dosage is less than 10 % of the new dosage of mineral coagulant.

Depending on the type of water, we must determine optimum condition of mixing. Organic and mineral coagulant can be mixed before injection but separate injection of the two reagents has proved more effective for good coagulation. A sufficient delay between addition of the inorganic coagulant and the organic coagulant must be allowed for optimum coagulation.

When raw waters are soft and have low mineral content (Brittany, equatorial Africa), organic coagulants are efficient as they are effective at low alkalinity.

As sludge treatments can be expensive (dewatering, incineration) the organic coagulant may be more economic as smaller volumes of sludge are produced.

Organic coagulants are less pH sensitive so are effective over a wider pH range.

■ Flocculants

The addition of a flocculant after coagulation may be necessary if the settling time available (linked to the size of the installation and the flow rate) is short. The use of flocculant would allow increased flow throughput to be achieved while still maintaining satisfactory settlement.

The dosage of flocculant to be added is very small, 0.01 ppm to 0.5 ppm.

INDUSTRIAL MAKE-UP EQUIPMENTS

■ Liquid Organic Coagulants

The different liquid coagulants are readily soluble.

Mixing of water and organic coagulant is easily and quickly accomplished by mechanical agitation in a stirring tank.

On a plant scale, mixing of water and organic coagulant is readily obtained by metering the concentrated product directly to the system and diluting in-line. In order to optimise results, organic coagulants should be added to the system when there is a sufficient turbulence to ensure good initial dispersion and adequate mixing. Ideally, after the initial point of addition flows should then be reduced to an acceptable level of turbulence.

Coagulants are not sensitive to mechanical degradation. All types of pumps have been used (gear, piston pumps etc).

■ Powder Organic Flocculants

Industrial scale dissolving of flocculants requires a procedure which has to be adapted to the flocculant specifications:

- Concentration: solutions of flocculant when diluted are still very viscous,
- High shear should be avoided during mixing,
- flocculant particles if not properly dispersed tend to agglomerate in lumps of flocculant which do not dissolve easily.

A make-up unit has the following components:

- A dispersion system to ensure proper wetting of the powder without agglomeration.

Static wetting

- Powder ejector (manual system)
- Wetting shovel (automatic system)

Dynamic wetting

- FLOQUIP WU® Type

- Dissolution tanks with continuous or discontinuous systems
- Transfer and dosage pumps

It is recommended that the flocculant is dissolved at the highest possible concentration and diluted after the metering pump. Technical Data Sheets of product give the concentrations recommended with the different viscosity.

Remark:

SNF manufactures make-up units under the FLOQUIP® trademark.



DRINKING WATER TREATMENT

Overview of the different stages for drinking water production

- **Primary treatment (screening unit, straining unit, grit chamber, surface deoiler)**

It is designed to remove coarse particles likely to interfere with the subsequent treatment processes.

- **Physical (aeration) or chemical (O₃, Cl, Cl₂O₂) preoxidation**

for extraction of excess gases (CO₂, H₂S).

for oxidation of organic matter, Fe²⁺ or Mn²⁺.

- **Coagulation, flocculation**

primary stage for the success of the solid-liquid separation treatment.

- **Flotation**

solid-liquid separation by air bubble and reagent injections.

- **Settling**

solid-liquid separation by sedimentation.

- **Filtration**

solid-liquid separation by filtration

Filtration consists of passing a solid-liquid mixture through a porous material which retains the solids and enable the liquid to pass through.

- **Additional treatments (O₃, activated carbon adsorption)**

removed excess of organic matter.

- **Disinfection (O₃, UV, Cl, Cl₂O₂)**

Disinfection removes all pathogenic micro-organisms from the water with persistent effect.

- **Special treatment**

removal of iron oxidation of Fe²⁺ by aeration (decrease of CO₂)

removal of manganese oxidation of Mn²⁺ by aeration

decarbonation decrease hardness of water (excess of Calcium)

neutralization of aggressive water (rich in CO₂, poor in carbonate)

membrane filtration (μ Filtration, Ultra-Filtration, Inverse osmosis)

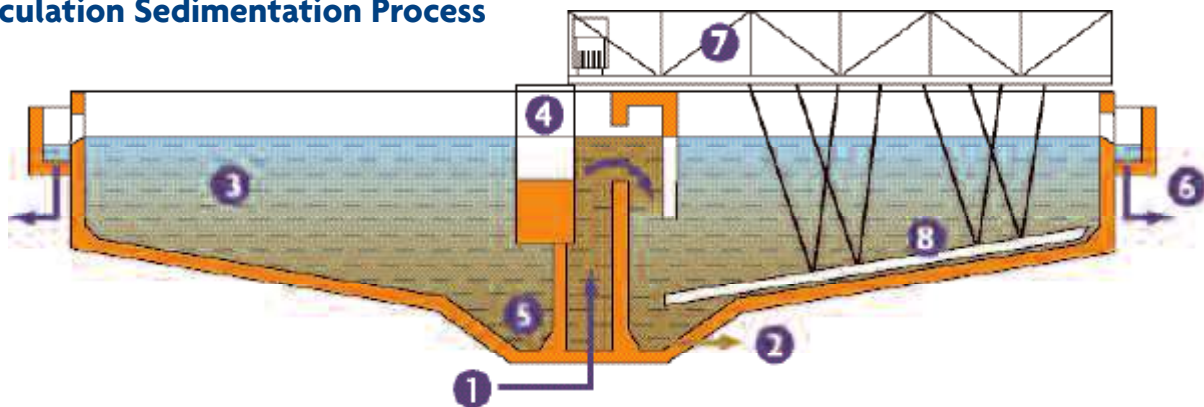
PROCESSES

Drinking water production equipment

■ Coagulation, Flocculation

Water chemical treatment can be divided into two processes : a reaction phase, wich consists of destabilization of colloids and the formation of flocs, and a separation phase, where the flocs are separated from the water. The flocculation process requires an energy input in order to be able to create collisions between reagents and the colloidal particles. Mixing must be fast for coagulation (flash mixing) and slower for flocculation.

Flocculation Sedimentation Process

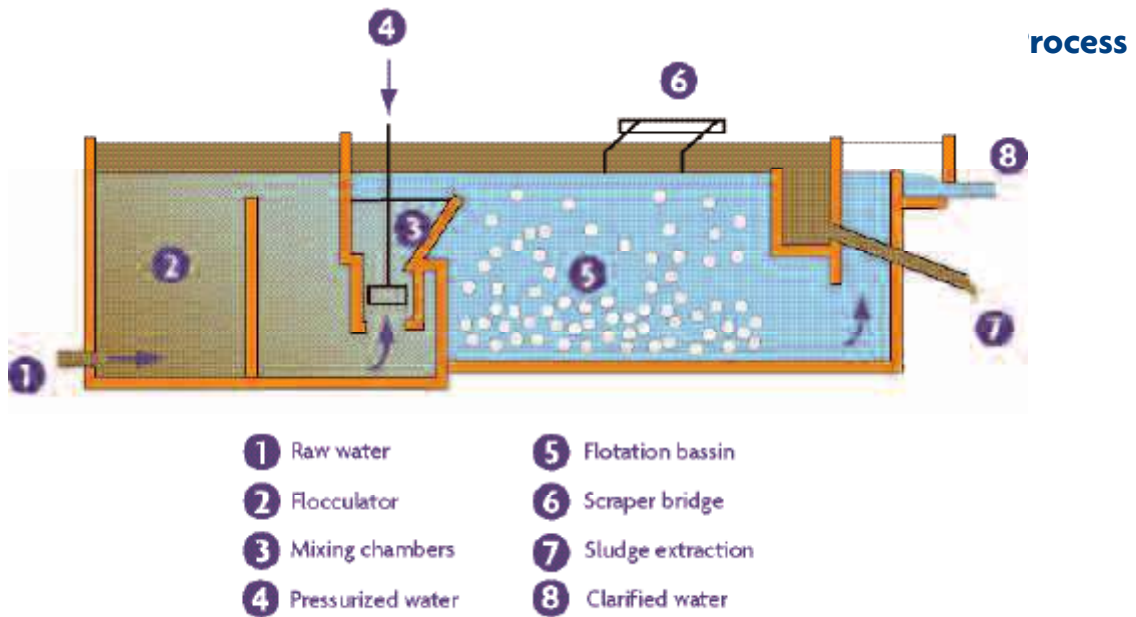


- | | |
|------------------------------|---------------------------|
| ① Raw water | ⑤ Mud pit |
| ② Sludge extraction | ⑥ Clarified water channel |
| ③ Settling zone | ⑦ Bridge |
| ④ Effluent distribution zone | ⑧ Sludge scraper |

DRINKING WATER TREATMENT

■ Flotation

Air can be used to float particles to the surface, where they can be separated as sludge. Chemical flocs have a low density and a large surface area, are particularly suitable for flotation separation.



PROCESSES

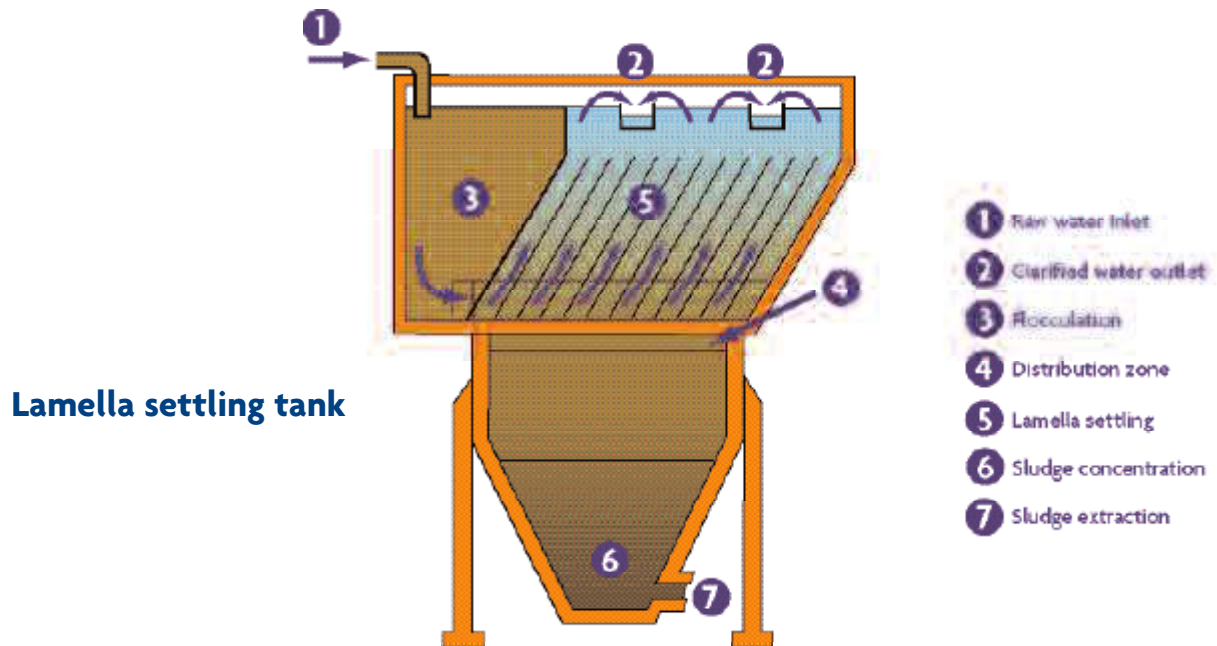
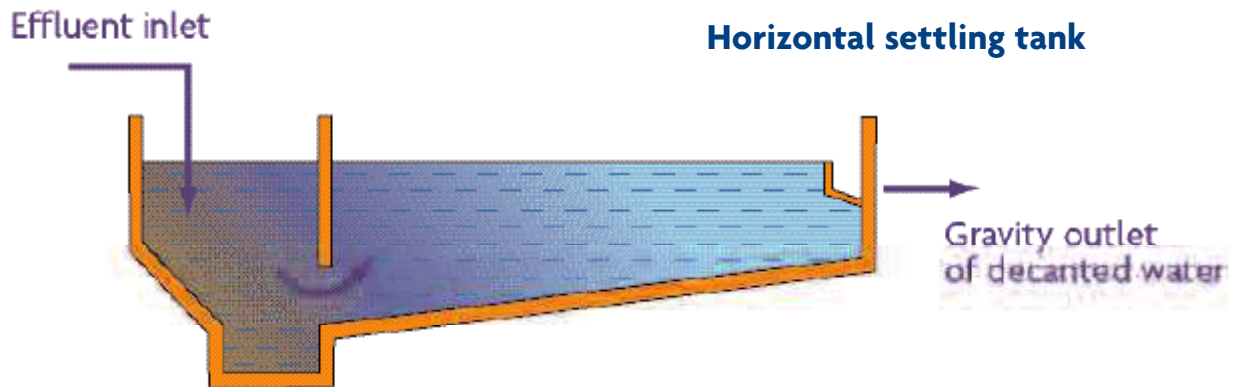
■ Settling

Sedimentation enable the flocs to settle to the bottom in a sedimentation tank with horizontal flow or vertical flow.

There are different types of settling tanks:

- Rectangular or circular horizontal flow tanks
- Rectangular or circular vertical flow tanks
- Lamella settling tanks

Vertical flow tanks are recommended for sedimentation of a chemical sludge, as they provide greater surface removal of the water phase.



DRINKING WATER TREATMENT

■ Filtration

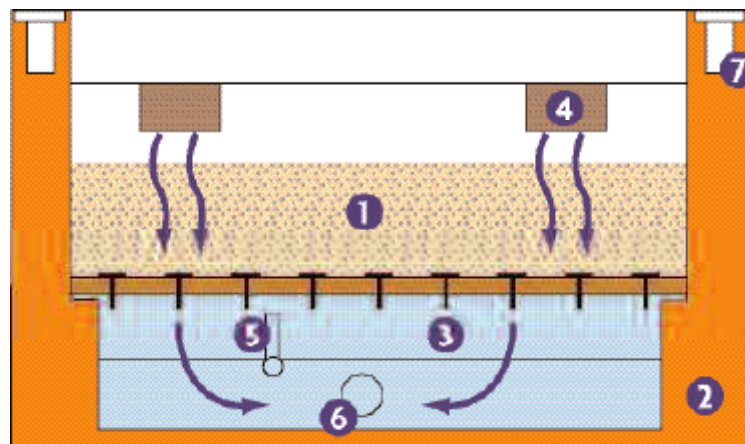
Filtration is normally used only as a complement to sedimentation and flotation in order to provide a final finish to the water treatment.

However, in drinking water, some types of filters are designed to serve as the only separation stage necessary for chemical flocculation (clarification by direct filtration).

There are two types of filter:

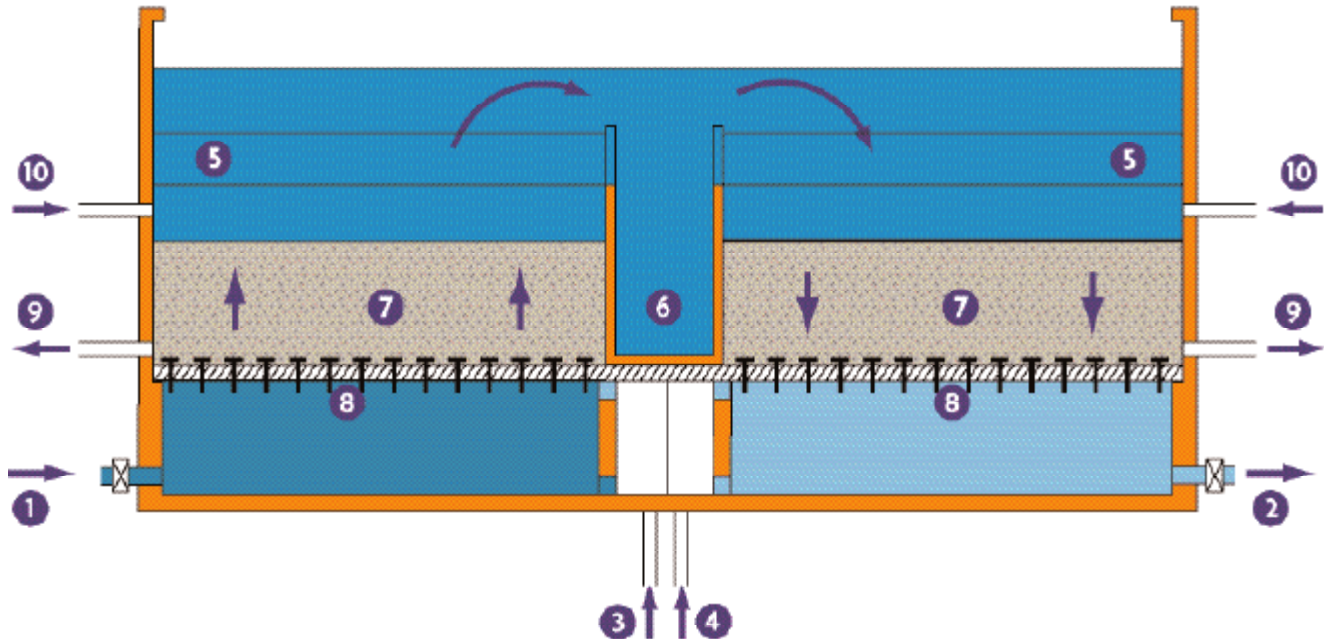
- Downflow filtration
- Upflow filtration

Sand filter process



- | | |
|------------------|--|
| ① Sand | ⑤ Air header |
| ② Concrete floor | ⑥ Wash water inlet and filtered water outlet |
| ③ Nozzles | ⑦ Sludge draining |
| ④ Raw water | |

Activated carbon filter



- | | |
|-------------------------------------|---------------------------|
| ① Raw water inlet | ⑥ Wash water outlet |
| ② Filtered water outlet | ⑦ Activated carbon |
| ③ Wash water and air inlet (cell 1) | ⑧ Nozzles |
| ④ Wash water and air inlet (cell 2) | ⑨ Activated carbon outlet |
| ⑤ Wash water collection zone | ⑩ Activated carbon inlet |

■ Sludge Dewatering

Regulation in many countries impose treatment of settling and filter washing sludges. Dewatering is generally carried out by centrifuging, belt filter or filter press.

Usually, water is neutralized and re-injected at the head of plant. In this case, flocculants approved for drinking water have been used.

The sludge would normally require treatment with a cationic flocculant or a combination of coagulant and anionic flocculant.

The polymer quantity used is of the order of 5 to 15 kg per dry tonne.

Remark:

SNF's brochure "SLUDGE DEWATERING" presents in details the different existing processes.





SNF SAS
ZAC de Milieux
42163 Andrézieux Cedex - FRANCE
Tel : + 33 (0)4 77 36 86 00
Fax : + 33 (0)4 77 36 86 96
info@snf.fr

SNF FLOERGER®