MEDECINS SANS FRONTIERES
ARTSEN ZONDER GRENZEN

WATER TREATMENT UNIT

ASSISTED DIRECT RAPID SAND FILTRATION

OPERATORS MANUAL

Water, Hygiene and Sanitation-Unit
Medical Department
MSF-B

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PREFACE

A Medical Humanitarian organisation is confronted on a daily basis with the deadly interaction between conflict, violence, poverty and disease. Assuring the basic need for Water, Hygiene and Sanitation can be life saving in these specific context. In the conceptualisation of short and long term health programmes, MSF-B integrates appropriate Water, Hygiene and Sanitation activities to increase the quality and impact of their medical programs as these activities have a direct and documented influence on several major diseases.

INTRODUCTION

Field experience shows that victims of precarious situations mostly don't have any other resources for potable water than surface water of lakes, rivers or even marshes. Health problems and even epidemics are all too often the sad consequence of consumption of contaminated (surface) water. The supply of potable water for the population, the health structures and the expatriate teams is a "conditio sine qua non" to avoid a lot of health problems. Treatment of surface water is often the only rapid and effective manner to respond to an emergency.

For these reasons, specialists of Médecins Sans Frontières having a long experience in the field of humanitarian aid, have developed a mobile water treatment unit. The specifications asked for were for a rather small unit, that is not expensive, which is easy to install, has a good performance (10 m^3/h of good quality treated water) and which everyone who has received a short but specific training can use. Since then, several units have shown already their efficiency in the MSF missions of Rwanda, Democratic Republic of Congo, Sierra Leone and Guinea Conakry.

This Water treatment Unit (WTU) uses the principle of direct rapid sand filtration, assisted by coagulation and flocculation. It has been designed to treat physical polluted (surface) water up to 200 NTU, with peaks up to 300 NTU in order to perform correct disinfection (chlorination) against micro-biological pollution. By its size and modular set up, it is possible to install and use the WTU nearly everywhere, specifically in emergency situations, as long as the water is not chemically polluted.

The quality of the raw water has its influence on the treatment procedure. Each kind of water has its own characteristics which will need specific attention. To be able to perform correct water treatment, a certain amount of knowledge is required. Former experience or a training regarding water treatment is advisable before using the WTU on the field, because the correct functioning of the unit depends to a large extent on the manipulation of the operator.

To perform correct treatment, some basic rules regarding good water intake, an appropriate pump and enough storage capacity have to be respected as well. The pump and the water reservoir are not part of the WTU kit, but standardised equipment (see technical specifications) as used by most aid agencies on the field are mostly appropriate. All other accessories to run the WTU are foreseen within the kit under the form of modules.

The unit is delivered with 60 % active ferric chloride (FeCl3) granules because of its coagulation efficiency within a wide pH range of the raw water. However, with the right water quality conditions (mainly pH), aluminium sulphate (Al2(SO4)3) can be used as well as coagulant.

An automatic chlorination system for slow dissolving chlorine tablets is foreseen within the Water Treatment Unit kit. Nevertheless, it is recommended to do manual "batch" chlorination in most of the cases.

The flow-chart of the station is as follows:

1. Pumping: water will be pumped through a fuel driven moto-pump well known to humanitarian organisations. This kind of pump is sent to the field in most emergencies and should allow a yield of 10 m^3/h with a pressure of +/- 1 bar in the system. It is not part of the WTU kit, but is optionally available.

2. Coagulation: because of its' solid and concentrated formulation (60 %) and also for its efficiency on a wide range of pH, ferric chloride has been selected. It is being "injected" as a mother solution in the pump's suction pipe; its' flow is being regulated and controlled through a dosing valve and a flow meter. The use of another coagulant available on the field (e.g. aluminium sulphate) is possible, but in that event, a pH correction could be needed before coagulation; an injection device for the pH corrector, similar to that of the coagulant, is available as well.

3. Flocculation: The contact time between the raw water and the coagulant as well as the formation of flock precursors are made in a long flexible hosepipe under pressure.

4. Rapid direct filtration: water to be treated is directly being sent to a filtering device, which is composed of six pressurised filters (two lines in parallel of three filters mounted in series). The filtering material was specifically chosen in terms of its' granulometry to achieve a double layer filtration and of its' low density (thus low weight) when dry. The whole set of filters is controlled by a simple panel composed of three different valves allowing filtration, backwashes or washouts.

5. Chlorination: an inline device allows the continuous "injection" of a chlorine disinfectant in the filtered water. This device is included in the kit, but if necessary, it can be replaced by batch chlorination with HTH, well known within the humanitarian world.

6. Storage: After having been treated, the water must be stored before distribution, generally in bladder or onion tanks. The storing capacity needed is not included in the kit.

Controlled parameters are the following:

1. The pressure in the filters with a manometer in order to maintain +/- 1 bar in the system and to verify the possible clogging of the filters.

2. The instant yield with a flow meter, in order to regulate the unit's capacity and to allow the immediate visualisation of a possible problem (e.g. clogged filters, clogged foot valve)

3. The turbidity with an inline turbidimeter, which allows a continuous physical quality control of the treated water and to define the moment when the backwashes must start.

4. The turbidity of the raw water with a portable turbidity tube, in order to define approximately the main treatment parameters.

5. The pH and total iron contents of the raw and treated water with field colorimeters, in order to measure the impact of the treatment on these two parameters and, if necessary, change certain parameters to improve the treatment's efficiency.

6. Free and total residual chlorine with the famous "pool tester" in order to assess the efficiency of the disinfectant.

Although the unit has been designed for turbidities up to 300 NTU, raw water of 500 NTU and above has already been treated successfully, with a yield of 10 m^3/h (but with a reduced filtration period). The treated water has a turbidity of 5 NTU or less (WHO directive for efficient chlorination) and a free residual chlorine concentration of minimum 0.2 mg/l. For extreme high turbidities, a pre-treatment such as sedimentation has to be taken into consideration.

The unit is composed of six boxes (1200 x 800 x 850 mm) mounted on euro-pallets, each weighing +/- 150 kg (total 900 kg). The unit contains the equipment as well as the consumables needed for one-month treatment. The installation is quick and easy (about 1.5 h for an experienced person). No specific knowledge is necessary for the use of the unit, as it can be learned in a couple of days on the field (under supervision of an experienced person).

PACKING LIST

Crate 1

1 pre-filter with 150 l filtration material N° 2

3 spiralled hoses with connections

20 kg of coagulant

2 plastic 20 l jerry cans

1 small flexible hose (with band clips)

2 complete "injectors" (regulation and pump parts separated for transport)

1 gate valve with connections

2 Guillemin reductions 3" – 2"

1 measuring cup (inside coagulants recipient)

Crate 2

1 pre-filter with 150 l filtration material N° 2

2 spiralled hoses with connections

20 m of 4" flat hose with connections

15 m of 4" flat hose with connections

1 double elbow (180°)

2 Guillemin reductions 4" – 3"

1 T- piece with connections

Crate 3

1 filter with 150 l filter material N° 1

1 spiralled hose with connections

10 m of 2" flat hose with connections

1 control panel with front plate (separated for transport)

1 gate valve with connections

Tools:

- 3 hook spanners 4" / 3"
- 2 hook spanners 2"
- 1 spanner 10 / 11
- 1 spanner 12 / 13
- 1 cleaning rod
- 1 pack of plastic straps (cable binders)
- 5 rolls of Teflon tape

Analysis material:

- 1 turbidity tube
- 4 transparent 1 l beakers
- 5 syringes of 10 ml
- 1 residual iron analysis kit
- 2 pool testers

Spare parts:

- 6 elbow connection O' rings
- 3 drain caps
- 6 drain cap gaskets
- 3 manual air relief caps
- 3 air relief cap O' ring
- 1 dome (head)
- 1 dome (head) O' ring
- 2 bulkhead fittings
- 3 bulkhead fitting O' rings
- 3 spacer O' rings
- 1 manometer

Crate 4

1 filter with 150 l filter material N° 1

1 pressure – flow – turbidity (pQT) meter

3 spiralled hoses with connections

10 m of 2" flat hose

1 chlorinator

1 empty drum (for chlorine storage)

Crate 5 (only for 10 m^3/h unit)

1 filter with 150 l filtration material

1 spiralled hose with connections

2 plastic 20 l jerry cans

1 small flexible hose (with band clips)

20 kg of coagulant

Crate 6 (only for 10 m³/h unit)

1 filter with 150 l filtration material N° 1

1 spiralled hose with connections

15 m of 4" flat hose

1 double elbow (180°)

20 kg of coagulant

INSTALLATION

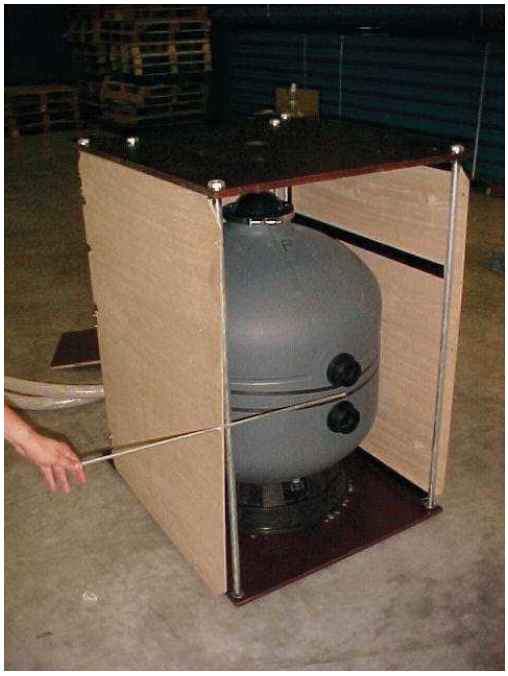
Choose if possible an appropriate site nearby the water intake of the river or lake. The site should nbot be prone to flooding, be as flat as possible, have an easy access. Enough space should be available for the set up of the Water Treatment Unit and the potential water storage facilities. The water intake should also be as far as possible (and preferably upstream) from polluted areas (e.g. outlet of waste water, latrines, waste pits).

Water Treatment Unit side

- Remove the split pen on one side of the outer tubes and slide the latter out of the panels.
    - Leave the middle tube in with its split pens.
    - Don't loose the tubes and pens as they will be useful when the unit needs repacking.

- Remove the top lid from the crate.

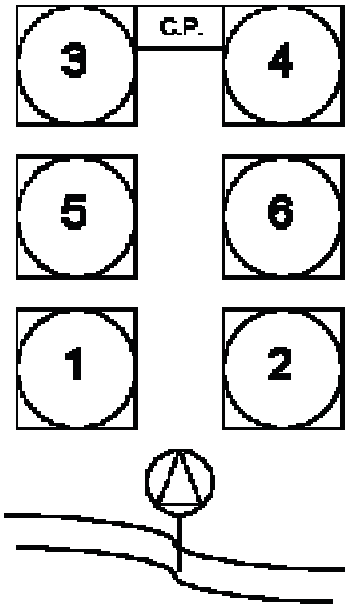
- Take out all the accessories (including the free wooden plank) that are located above the central tubes of the crate.
    - Do not remove the filters from the crate (don't cut their straps).
    - For the removal of the control panel, remove the last tube that holds the side panels together and fold them open. Remove the air relief cap from the filter. Detach the strap and rotate the control panel into a vertical position. Then tilt the control panel out of the crate via the top. Do not forget to replace the air relief cap on the filter.



- Put the crates into the upwards position and remove the remaining tubes that hold the side panels together.

- Fold the side panels open and bring the small L-profiles in the four corners of the bottom panel in a vertical position. Remove all the panels and put them aside for later potential repacking.

- Be aware that the panels of the crate can be transformed into a working table.
    - Leave the side panels connected to the bottom plate and connect the former under triangular form by means of the plastic straps included in the unit (tighten them through the existing holes in the side panels. Do this with the panels of two crates. The side panels of a third crate can be put on top of each other to form the flat working surface.



- Put the frames with (pre-) filters in the position as indicated on the figure, with their plastic connections facing the opposite (pre-) filter (e.g. Pre-filter 3 facing pre-filter 4, filter 1 facing filter 2).
    - Be aware of the location of the water resource.
    - For the **5 m³/h unit**, frames 2 & 4 and frames 1 & 3 need to be positioned directly next to each other as frames of filters 5 & 6 will be absent.
    - Verify as well if the dome (lids) flange clamps of all the (pre-) filter are well tightened to avoid leaks once in operation.

- Hang the control panel (C.P.) in between frames 3 and 4, with the red handles away from the frames.
    - Put the little pin of the control panel inside the tube of the frame, which should also be embraced by the lower profiles of the control panel. Repeat the same action on both sides of the control panel. This will avoid the control panel moving during operation of the Water treatment Unit.

- Turn all the valves of the control panel in parallel position, tighten their big nuts and remove their red handles.

- Position the aluminium cover plate over the valves of the control panel and replace the red handles.
    - Only one position is possible for the red handles on the valves, so don't try to force them if they don't fit easily.

- Roll off the 20 m of 4" flat hose and connect one side via the Guillemin 4" – 3" reduction to the 3" inlet of the control panel.

- Only for 10 m³/h unit: roll off the two 15 m 4" flat hoses and connect all of them.
    - If the distance in between the pump and the control panel is long, the three hoses can be connected directly one after another. When this distance is short, the whole length of the flocculation still has to be used anyway. The double elbows (180°) can be handy in this situation to put the hoses in a correct way between the pump and the control panel (with the 20 m hose connected to the unit).
    - For the 5 m³/hunit, only the 20 m of 4" flat hose should be used!

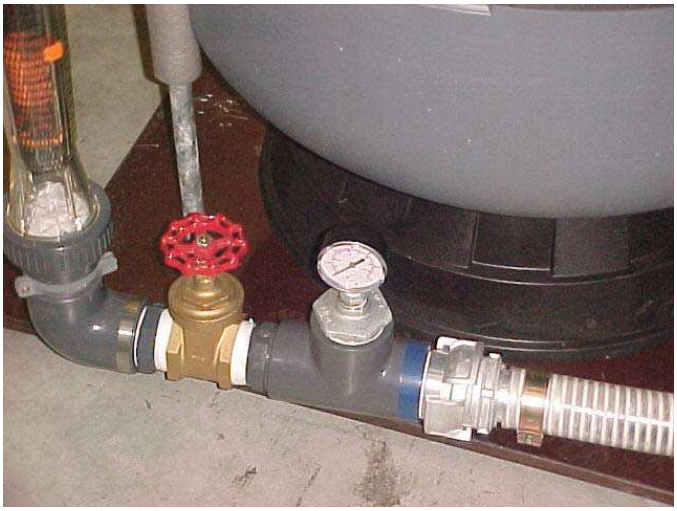
- Connect the upper fitting of the pre-filter (P) via the pipe to the control panels filter valve (according their colours). Do this for both lines.
    - Push the elbow connection completely into the fitting before screwing the big plastic nut on the thread. When it is difficult to turn the nut, don't force it as it might damage the thread. Instead loosen the nut and start again.

- Interconnect the lower fitting of the pre-filter (P) with the upper fitting of the following filter (F). Do this for both lines.
    - Push the elbow connection completely into the fitting before screwing the big plastic nut on the thread. When it is difficult to turn the nut, don't force it as it might damage the thread. Instead loosen the nut and start again.
    - In case of the **10 m³/h unit**, the same interconnection has to be made in between the first filter and the second one on both lines.

- Swing the pressure – flow – turbidity (pQT) meter located in frame 4 out over about 270°.
    - In its end position, it should still be possible to see the cross on the top of the floater whilst looking through the top glass of the pQT meter.

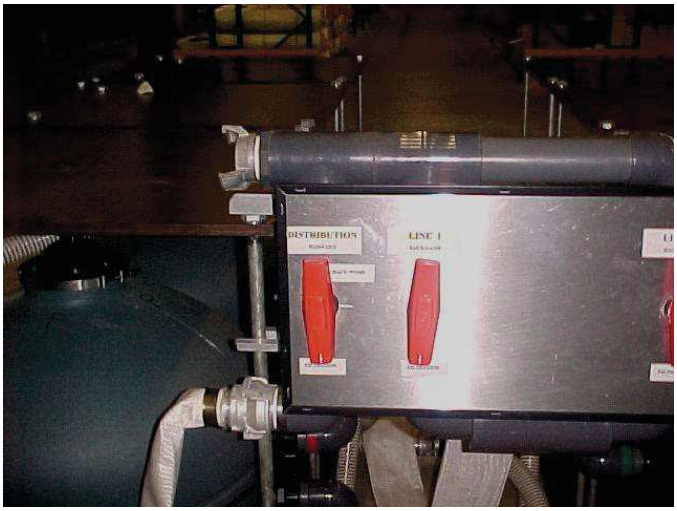
- Open the flow meter in order to remove all the items (net, paper) that block the floater during transport.
    - To be able to remove all the blocking items, take out the o' ring and cross section.
    - After removing the blocking items, put all the parts back before closing the flow meter and don't forget to tighten the nuts again.

- Connect the lower fitting of the last filter to the side connection of the free T-piece (according colours), positioned in the central lane in between all the frames. Do this for both lines.
    - Push the elbow connection completely into the fitting before screwing the big plastic nut on the thread. When it is difficult to turn the nut, don't force it as it might damage the thread. Instead loosen the nut and start again.
    - **5 m³/h unit:** T-piece should be positioned after the last filters.
    - **10 m³/h unit:** T-piece should be positioned before the last filters.



- Interconnect the centre opening of the free T-piece with the manometer of the pQT meter (according colour).

- Interconnect the outlet of the pQT meter with the distribution valve of the control panel (according colour).
    - The easiest access to both pQT meter and distribution valve is for the pipe to go around the pre-filter.



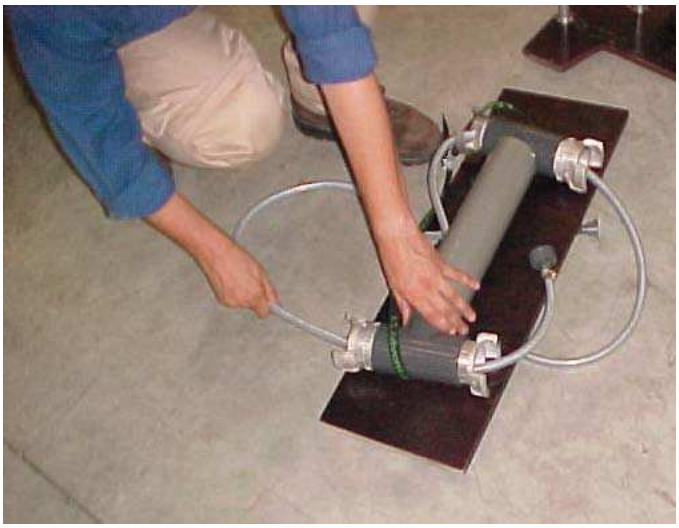
- Connect the 10 m of 2" flat hose to the lower Guillemin half coupling of the control panel. Direct the flat hose towards the storage reservoir.

- Put the chlorinator as close as possible to the potable water reservoir and connect it to the 2" flat hose coming from the control panel and a 2" hose going to the tank.
    - Make sure that the water will be flowing in the direction indicated by the arrow on the chlorinator.
    - Make sure that the water level in the reservoir isn't a lot higher than inside the chlorinator, otherwise it won't work.
    - It is best to fill the chlorinator completely with water after the chlorine tablets have been added (see later) to obtain the best results from the start.

- Connect the remaining 2" flat hose to the upper Guillemin half coupling of the control panel and direct it to the evacuation system for the backwash and washout water.
    - The gate valve that comes along with the flat hose can be installed on the control panel or at the end of the hose. The former is the preferred option.
    - It is recommend to dig a big hole where the backwash and washout waters can sediment. Where the first waste water will still infiltrate in the ground, after a while a small ditch will be needed to drain the liquids away from the pit towards the water source (as far as possible and down flow from the intake in case of a river).

- Verify if all Guillemin couplings and plastic connections are well tightened.

Pump side



- Loosen the strap around the pump connecting parts of the "injector", free the flexible hoses and pull the T-piece out of its transport container.
    - The "injectors" transport container is located on the free board within crate 1.

- Take the regulation parts of the "injector" out of its transport cylinder.
    - The transport cylinder is located at the back of frame 1.

- Assemble the regulation parts of the "injector".
    - Make sure that the arrow on the regulation valve is pointed away from the flow meter.

- Connect the pump part of the "injector" to its regulation part via the flexible hose.

- Interconnect the T-piece of the "injector" in between the "suction" pipe and the inlet of the pump.
    - The Guillemin half coupling with lock of the T-piece should be facing the pump entrance.

- Use the short spiraled hose in between the "injectors" T-piece and the pump inlet in following situations:
- **When water is taken out of a reservoir that has its level higher than the inlet of the pump.**
    - A gate valve will have to be installed in front of the T-piece (intake side) and closed to a certain extent to create under pressure at the "suction" side of the pump
- **When the second injector has to be installed to inject chemicals to adjust the pH of the raw water.**
- **When a pump with 3" inlet is used.**
    - As the 3" – 2" reduction Guillemin connected directly to the T-piece would put too much weight on the pump inlet, the risk of air leakage would be too big.

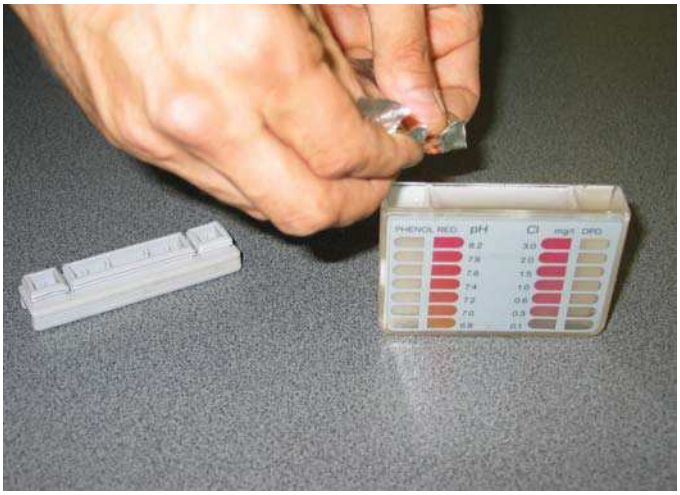
- Remove the cap of the jerry can and slide in the "injector", once the recipient has been filled with coagulant solution (see later).
    - Hold the "injector" upright by means of a plastic strap (to be found in the WTU kit).
    - It is possible to link two jerry cans by means of their taps and the small flexible hose, in order to increase the autonomy of the coagulant solution. Do not forget to open the taps when the jerry cans are interconnected.

- Connect the flocculation pipe (4" flat hose) via the Guillemin reduction(s) to the outlet of the pump.

OPERATION

Preparation

- Measure the turbidity of the raw water by means of the turbidity tube (included in the WTU kit).
    - See the Technical Brief in the annexes for more information on how to do this measurement correctly.



- Measure the pH of the raw water by means of strips or a pool tester (included in the WTU kit).
    - See the Technical Brief in the annexes for more information on how to do this measurement correctly.

- Prepare a 1 % mother solution of the chosen coagulant within the 20 l plastic jerry can(s).
    - See the Technical Brief in the annexes for more information on how to do the preparation correctly.
    - Ferric chloride FeCl3 is the preferred coagulant (to be found in the WTU kit) because of its higher efficiency at a wider pH range. However aluminium sulphate Al2(SO4)3 can be used as well as coagulant under specific conditions (pH limits).

- Perform a jar test to have an indicator what dosage will be needed to filter with the WTU.
    - See the Technical Brief in the annexes for more information on how to do the jar test correctly.

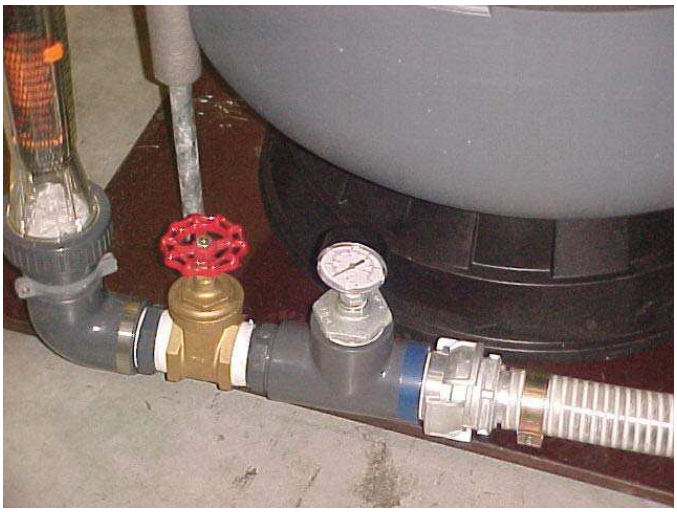
Note: When the jar test is performed just before the installation of the unit, the sedimentation can take place during the assembly and considerable time will be gained to start the real water production.

Starting procedure of filtration

- Put the distribution valve in its upward position (washout).
- Put the two other valves of lines 1 and 2 in their downward position (filtration).

- Open the manual air relief valves of all the (pre-) filters.

- Start the pump and let the unit fill up.
- Once water comes out of the air relief caps, close them.



- Regulate the flow to 5 or 10 m³/h (according to the unit) and the working pressure in between 1 and 1.5 bar.
    - The regulation is done by means of the gate valve on the pQT meter and the rotation speed of the pump.

- Regulate the "injection" rate of the coagulant according to the jar test that has been performed during the preparation.
    - Ex: jar test showed best results for 2 ml/l

    => "inject" 2 ml/l x 10.000 l/h = 20 l/h
    - In case the scale of the "injectors" flow meter doesn't reach to the needed coagulants flow rate, increase the concentration of the mother solution by adding the appropriate dose of coagulants granules in the 20 l jerry cans (see the table in the annexes).
    - In practice, the ideal coagulants dose for assisted rapid sand filtration is often lower than indicated by the jar test. The "ideal" dose will be found during the fine tuning of the practical test runs.
    - Be aware that the turbidity, or any other raw water characteristic might change over time, which might need an adapted coagulants flow rate.

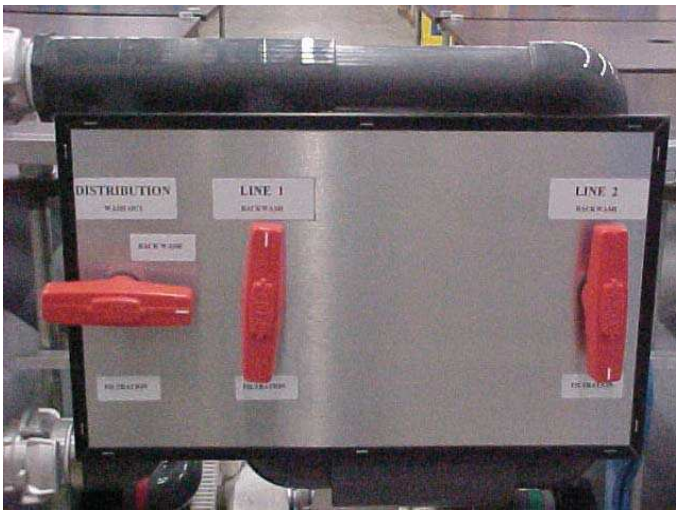
Filtration

- Once the turbidity at the outlet of the washout comes under 5 NTU, turn the distribution valve also in the downward position.
    - The turbidity can be measured at this stage with the turbidity tube (to be found at the back of frame 3).

- Follow up closely the water flow, the pressure within the system, the turbidity of the filtered water and the coagulants dose that is "injected".
    - The pQT meter indicates very well the turbidity of the filtered water. When the cross on the flow meters floater is well visible while looking through the tube from the top, the turbidity is under 5 NTU. When the water is getting cloudy, but the cross stays visible, the turbidity of the treated water is in between 5 and 10 NTU.

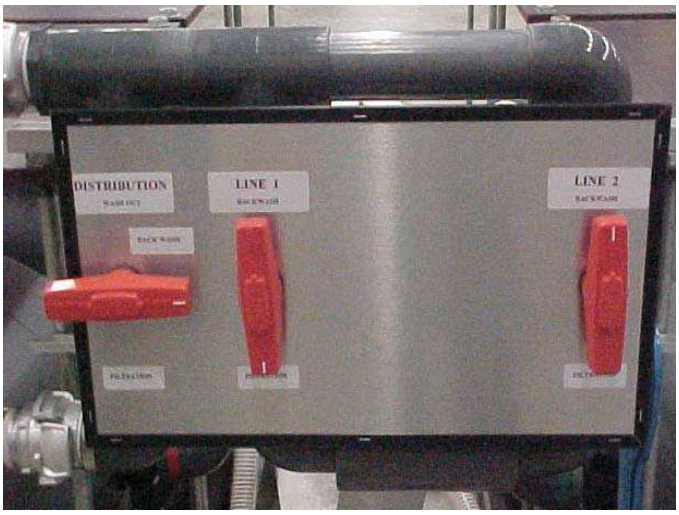
- Measure the residual metal concentration of the coagulant by means of the specific analysis kits.
    - As the WTU kit is delivered with ferric chloride FeCl3 as coagulant, a residual iron analysis kit is included as well. However when aluminium sulfate Al2(SO4)3 is used as coagulant, a residual aluminium analysis kit will need to be ordered.
    - If the turbidity is under 5 NTU, the residual metal concentration should be less or equal to 0.2 mg/l, if not try with fine tuning (often decreasing) the flow rate of the coagulant.

Backwash



- Once the treated water is getting cloudy whilst looking through the pQT meter and certainly before the cross on the floater disappears, the backwash should be started by turning the distribution valve in its horizontal position and the valve of line 1 in the upright position.
    - The backwash is done with raw water.

- Regulate the backwash flow by means of the rotation speed of the pump and the gate valve on the backwash flat hose.
    - Try to reach to highest backwash flow possible without losing filtration material (high risk with new filtration material that hasn't had the chance yet to absorb water).



- After about 15 minutes (or when the backwash water obtains more or less the same turbidity as the raw water), inverse the position of the valves of both lines.
    - The first line from upwards to downwards position, the second line from downwards to upwards position. The distribution valve stays in its horizontal position.
    - The backwashes should be alternated every cycle (1st cycle: first backwash line 1, then line 2; the 2nd cycle: first backwash line 2, then line 1).

Washout

- After another 15 minutes (or when the backwash water obtains more or less the same turbidity as the raw water), reverse the position of the line valve that is still upwards and turn the distribution valve in its upward position (washout).
    - Continue the procedure as described in the starting up phase and the following stages of the cycle.

Chlorination

- Open the lid of the chlorinator and fill it with a number of slow dissolving chlorine tablets. Start the pump and let the chlorinator fill up with filtered water, at least until all chlorine tablets are submerged. Screw the lid back on the chlorinator until it clicks.
    - The positioning of the chlorinator is very important (see installation)
    - The dosage of chlorine dissolved in the filtered water is regulated by the number of tablets and the position of the small knob on the chlorinator.

- The Free Residual Chlorine must be measured after 30 minutes by means of the pool tester and rapid dissolving DPD 1 tablets (included in the kit).
    - FRC = 0.2 – 0.5 mg/l if pH =< 8
    - FRC = 0.4 – 1.0 mg/l if pH > 8
    - The Total Residual Chlorine can be tested as well by adding rapid dissolving DPD 3 tablets once the FRC reading has been done.

Note: **With some water qualities (e.g. high chlorine demand, high Combined Residual Chlorine concentration), the results obtained with the chlorinator might not be responding to the expectations. In these cases, it is recommended to do the disinfection with a manual batch chlorination (see annexes).**

MAINTENANCE

Internal cleaning of all the (pre-) filters

Every 2 weeks or at least once a month

- Loosen the nut of the flange clamp and remove the dome (head) from the (pre-) filter.
    - Make sure not to loose the nut.

- Remove the two parts of the diffuser, and plug the top elbow inside the filter with the red cap (included in the kit).

- Connect the cleaning rod directly to the pump and slide it in the filter via the hole in the frames top plate. Start the pump and move the cleaning rod carefully up and downwards, left and right so that the whole volume of filtration material is reached.
    - Regulate the pump flow in such a manner that only mud and dirt will overflow out of the filter without loosing filter material.
    - The jet of the cleaning rod will break all the mud balls immediately, which can't be removed with a normal backwash.
    - Continue this procedure as long as high turbidity water is coming out of the (pre-) filter (about 10 minutes per (pre-) filter).
    - Watch out not to damage the strainer at the bottom of the filter.

- Once the (pre-) filter cleaned, take out the cleaning rod. Take out the red cap and put the two parts of the diffuser back on the top elbow inside the filter.
    - Slide carefully the plastic air relief pipe through the hole in the diffuser parts.

- Put the dome carefully back on the filters flange and tighten the flange clamp.
    - Make sure the dome is well positioned and that the clamp is in line with the (pre-) filter flange and the dome, in order to avoid leakage).
    - Do not over tighten the flange clamp as this might break the plastic dome.
    - Do the whole procedure for all (pre-) filters.

Internal cleaning of the control panel

At least once a month

- Disconnect the interconnection pipes in between the control panel, the pre-filters and the pQT meter.
- Remove the control panel from the filter frames.
- Take the three red handles of the control panel.
- Take the aluminium cover plate of the control panel.
- Put back the red handles.
- Unscrew the big nuts of the 3 way valves and remove them from the control panel.
- Rinse the valves in a bucket with clean water.
- Turn the red handles and rinse all valves again to make sure that the whole ball is clean.
    - This cleaning avoids abrasion of the valves which could lead to leakage.
- Rinse also the inside of the static parts of the control panel.
- Reassemble the control panel.
- Reinstall the control panel within the WTU as described in the "Installation".

Internal cleaning of the flocculation pipe

At least once a month

- Disconnect the flocculation pipe from the control panel.
- Pump clean water through the flocculation pipe at high speeds.
    - When the pipe is really dirty inside, lower the RPM's of the pump and the rub the upper side of the hose over the whole length against its lower side and finish with a last high speed pumping.
- Reconnect the flocculation pipe to the control panel and tighten the Guillemin half couplings.

External cleaning of the Water Treatment Unit

- Rinse once in a while the WTU with clean water.

Winterising

- Completely drain the (pre-) filters by unscrewing the drain cap at their base. Leave the cap off during the freezing periods.
- Make sure all the valves are in an opened position.

Note: To extend the lifespan of the Water Treatment Unit, install it under some kind of shelter (tent, plastic sheeting, local material) to protect it against U.V. – radiation or harsh weather conditions.

ANNEXES

Control of turbidity

Method

The turbidity (cloudiness) of water which has its origin in suspended matter (e.g. clay, algae, organic particles, micro-organisms) plays an important role in the efficiency of chlorination. The measurement of the turbidity has the objective in determining the necessity or not to treat the water (e.g. assisted sedimentation, rapid sand filtration) before disinfection.

The turbidity is expressed in Turbidity Units, and depending on the method used in Jackson Turbidity Unit (JTU), Nephelometric Turbidity Unit (NTU). The simplest way to test the turbidity is to use the turbidity tube. This is a long transparent tube which is graduated in Turbidity Units and has a black marking on its bottom.

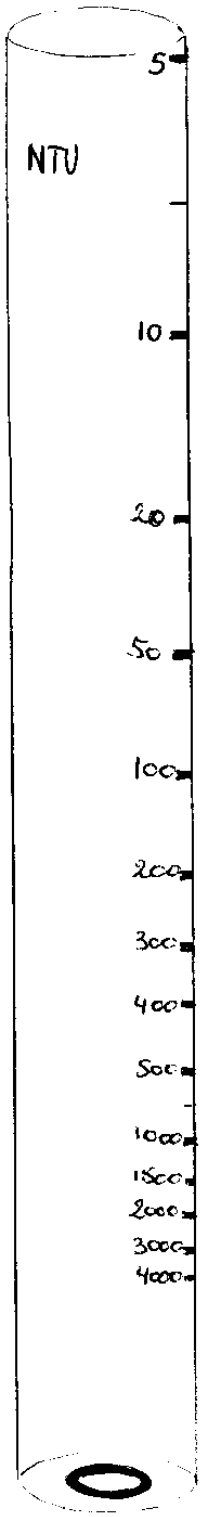
Operation

1. Rinse the turbidity tube thoroughly three times with the water to be tested.
2. Fill the turbidity tube completely with the water to be tested and wait some seconds for the liquid to stabilize and the air bubbles to disappear.
3. Look through the mass of water from the top and try to see the black marking on the bottom of the top.
4. If the marking isn't visible, retrieve slowly some of the water until it starts to show.
5. Read the results by comparing the water level in the tube and its graduation.

Attention

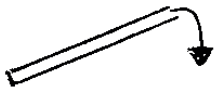
- Do the measurement in the right light conditions, meaning in the daylight but never in the direct sunlight (turn your back to the sun and use your body to provide shade on the tube). Do not ware your sunglasses during the measurement as this may falsify the results.
- To have an efficient disinfection (chlorination), the turbidity should be less than 5 Turbidity Units (directives WHO < 5 NTU). In the first phase of an emergency however, values up to 20 NTU are accepted to perform direct chlorination. This is following the principle that it's better to give out big quantities of water with a reasonable quality than a little bit of water of very high quality.

TURBIDIMETRE
(NOT TO SCALE)

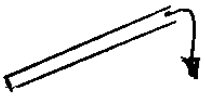


CONTROL DE LA TURBIDITÉ

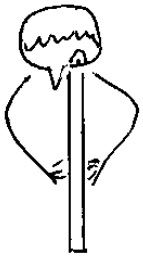
• remplir completement le turbidimètre
• essayer de voir la bague noire située au fond du tube

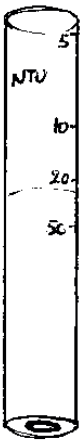


• Si la bague noire n'apparaît pas, vider un peu d'eau du tube



. Et ainsi de suite jusqu'à ce que la bague noire apparaisse au fond du turbidimètre





. lire les résultats en comparant le niveau d'eau dans l'éprouvette et sa graduation

Coagulants / flocculants

Method

When the turbidity of raw water has a high value, chlorination isn't effective any longer. This maximum turbidity value for efficient chlorination is set at 5 NTU, although that turbidities up to 20 NTU are acceptable for the population during the first phase of an emergency. In case these values are exceeded, the suspended particles in the raw water will have to be eliminated. When these particles are rather big and heavy, they will settle down in a natural way. If this is not the case, a chemical or a biological product called a coagulant can be added to assist the sedimentation, the direct rapid sand filtration or a combination of both.

These coagulants have the potential to neutralise the electrostatic repulsion and hydratation phenomena that keep the particles in suspension. Once the right concentration of coagulant (solution) has been added and mixed well with the raw water, the neutralised particles can join each other and start to grow into flocks (flocculation). As these flocks are bigger and heavier than the original particles, the will start to settle down and the assisted sedimentation is a fact. Some additional products, so-called flocculants (some times integrated in the coagulant) can be added to speed the flocculation process even more.

Capturing the flocks by a rapid sand filtration is also possible, which will improve the quality of the treated water even more. A combination of both procedures is possible as well when extremely high turbidities need to be treated and high quality water is expected.

For the coagulation/ flocculation procedure to be effective, the right dose of the coagulant / (flocculant) has to be injected in the raw water. A jar test will help determine the correct dose (see Technical Brief: *"Jar test"*).

Different products

-Aluminium sulphate Al2(SO4)3 is the worlds' best-known coagulant and it can be found nearly everywhere.
-Ferric chloride FeCl3 is less known, but does have quite some advantages over aluminium sulphate Al2(SO4)3.
-Polymers as PAC are very efficient modern coagulants based on aluminium which enhance flocculation. These liquids are sold under liquid form, which makes them more difficult to transport.
-Some biological products such as Oleifera Moringa (tree seeds) exist as well, but are (unrightfully?) less used on big scale treatment.

The following table gives a comparison of the different chemical coagulants:

Product	Advantages	Inconveniences
Ferric Chloride FeCl3	- crystallised (but also available as a liquid) - high concentration (60 %) - usable with wide pH range (5.0 to 9.0) - no optimum pH of the raw water - not very expensive - stable during long period - easy to dissolve - no air transport regulation (IATA) yet	- rarely available on the field - water might turn yellowish - corrosive
Aluminium Sulphate Al2(SO4)3	- crystallised (sometimes lumps) - available on the field - not expensive - stable during long period	- low concentration (18 %) - usable with 6.0<pH<7.4 - optimum pH of 7.2 - rather difficult to dissolve
PAC	- extremely good coagulant (flocculant) - usable with wide pH range (4.0 to 9.0)	- only available as liquid - low concentration (< 10 %) - dosage is difficult - not available on the field - not stable over long period -air transport regulation (IATA)

- Based on efficiency, PAC is by far the best coagulant for assisted sedimentation. It can be used in a wide pH variety of the raw water and forms big flocks that settle down rapidly. The formation of big flocks has however as result that the product is less suited for direct rapid sand filtration as they clog up the filtration medium. This product is such an efficient coagulant / flocculant that only very little amounts need to be used. Unfortunately the little amounts of PAC needed can only be "injected" under its pure form, which renders the regulation quite difficult.
- An alternative for unknown raw water characteristics, is Ferric Chloride (FeCl3) as it is also usable in a rather wide pH range. This product can be used for as well for assisted sedimentation as for direct rapid sand filtration. With short sedimentation times and/or when the dosage is incorrect (for both sedimentation as filtration procedures), the treated water might turn a little yellowish. This extra iron colour isn't harmful to public health, but the users might reject the water due to its colour. High iron concentration might turn the treated water unpalatable.
- Aluminium sulphate Al2(SO4)3 is interesting for assisted sedimentation and direct rapid sand filtration if the pH of the raw water stays in between 6.0 and 7.4, certainly as it can be found nearly everywhere in the world for very reasonable prices. Beyond this pH range, the needed amounts of aluminium sulphate rise drastically. There is also a lot of discussion and confusion on the negative health impact that aluminium sulphate might have. Some scientists claim that a residual aluminium (in water) could lead to Alzheimer or neurological disorders in the long run. More worrying is that high concentration of residual aluminium could have an impact on malnourished children who would not take up their weight. Although that there arte still a lot of discussions on these topics, it is important, certainly when coagulants based on aluminium are used, to measure the residual concentration of metals in the treated water and to keep them as low as possible. It is recommended to buy aluminium sulphate under crystallized form because the breaking of the lumps into crystals to ease the preparation of the mother solution requires a lot of work and protective clothing (e.g. gloves, mask, goggles).

Preparation of the mother solution

PAC is used under its pure liquid form because it would already start to coagulate / flocculate with the elements within the clean water needed to make the solution. Ferric chloride and aluminium sulphate should be prepared under a liquid form, mostly a 1 % mother solution although other concentrations might sometimes be required as well. The preparation is similar as for chlorine solutions:

X = Y x (100 / N)

X = grams of products to be added per litre of water to reach the wanted solution concentration
Y = % of 1000 (e.g. 1 % of 1000 = 10 g)
N = concentration of coagulant

Example: Ferric chloride 1 % solution: X = 1/100 x 1000 x (100 / 60) = 16.666 g/l (about 17 g/l)

Jar test

Method

A jar test is a method that permits the determination of the quantity of coagulant or its (mother) solution required to treat a certain volume of turbid water.

Operation

Pre-tests

- Control the pH and the turbidity of the raw water. These analyses can be done with the pool tester and the turbidity tube (see technical Briefs).
- Additional analysis on the conductivity and alkalinity (pH buffer effect) are recommended but not always essential.

Aluminium sulphate / Ferric Chloride

- Prepare a 1 % mother solution of the coagulant (See Technical Brief: *"Coagulants"*).
- Fill at least 5 one litre transparent plastic measuring beakers with the raw water to be treated. The advantage of transparent recipients is that the flocks can easily be noticed. The inconvenience of small recipients is however that the dosing has to be more precise.
- Inject by means of a syringe (e.g. 10 ml) a dose of 1 % coagulant solution in every recipient, by increasing progressively the dosing (e.g. 0.5 ml, 1 ml, 3 ml, 5 ml and 7 ml). Preferably mark the injected doses on the recipients to avoid confusion afterwards.
- The moment the coagulant is injected, mix it thoroughly with the syringe (or a fork) during about a minute. Ideally, slow mixing should continue for a couple of minutes.
- After several minutes, the first flocks should start to appear in one or more recipients. But wait about 30 minutes for the flocks to settle down. Compare the turbidity in every recipient. The recipient with the lowest turbidity indicates how much coagulant should be added per certain amount of raw water. If there is hesitation in between two recipients, the “ideal” dose will be probably in between both of them. Fine tuning is then recommended.
- However, if no flocks are formed about 5 minutes after the coagulant solution has been injected, the dosing will be probably too low (although there might be other reasons) and the test should be started all over with higher dosing.
- Once a rough estimation of the required dose is made, a fine-tuning around the most favourable values can be done in the same way as described above (only the quantities of coagulant solution need to be adapted). After about 30 minutes, poor the supernatant gently in a turbidity tube, without having flocks coming along or breaking up. If it is still difficult to determine the best result because the turbidity of several jars is the same, choose the one where the least coagulant solution was injected. The measurement of the residual aluminium or iron (depending which coagulant is used) could give also some information on the ideal dose, but this requires (very) long waiting times. Anyway, the jar test is **only an indicator** of how much coagulant solution needs to be added in reality.
- Once the “ideal” dose is determined for a certain small quantity of raw water, it can be extrapolated how much is needed for a big production of potable water.

Example for aluminium sulphate:

2 ml of 1 % Al2(SO4)3 solution per litre extrapolated for 30.000 l tank =>
2 ml/l x 30.000 l = 60.000 ml / tank = 60 l of 1% mother solution per batch of 30.000 l

PAC

- The realisation and interpretation of a jar test with these coagulants are extremely difficult. This is because of the very low volumes of these coagulants that are required to treat turbid water (in the order of 0.01 to 0.15 ml/l of raw water).
- Therefore is the jar test often skipped for PAC in emergency situations, and the tests are often done in situ on large scale. PAC is anyway a less critical in its dosing than aluminium sulphate Al2(SO4)3. Nevertheless, regular residual aluminium analyses should be done on the treated water.
- In practice, PAC doses of 1.5 to 3 l per reservoir of 30 m³ are often required. This is an indication in which range reality tests should be made.

Key	**Input**
1. Recipients	- 1 l transparent beakers (or similar)
2. Syringe	- 10 ml syringe (& fork)
3. Fork	- Watch
	- Turbidity tube
	- Pool tester
	- (Alkalinity test / conductivity meter)

Important

- If transparent beakers aren't available, plastic buckets with all the same size can be used as well. The doses of coagulant introduced in the raw water have to be according to the content of the recipients (e.g. for 10 l buckets, the quantities of added coagulant solution should be tenfold the dosages used with the 1 l beakers).
- When the alkalinity of the raw water is low, its pH can lower significantly the moment coagulants are added, as most of them are (slightly) acid. This can have a serious influence on the quantity of coagulant needed, certainly when aluminium sulphate Al2(SO4)3 is used. The pH of the raw water can be adapted (higher or lower) with certain products, but due to its specific difficulties, it's best to look for advice at your Head Quarters.
- A very low concentration of ions (low conductivity) in the raw water can cause problems as well with the coagulation / flocculation process. Rendering the conductivity a little higher might solve the problem, but it is recommended to contact your Head Quarters for further information.
- The presence of algae or other organic material can have a serious influence on the efficiency of coagulation / flocculation and thus require a lot more coagulant.

Jar test with 1% M.S.	5 m³/h unit		10 m³/h unit	
Injected dose (ml/l)	**Concentration**	**"Injection" rate (l/h)**	**Concentration**	**"Injection" rate (l/h)**
0.5	1%	2.5	1%	5.0
1.0		5.0		10
1.5		7.5		15
2.0		10		20
3.0		15	2%	15
4.0		20		20
5.0		25		25
6.0	2%	15	5%	12
7.0		17.5		14
8.0		20		16
9.0		22.5		18
10		25		20

Remarks: M.S. = Mother Solution

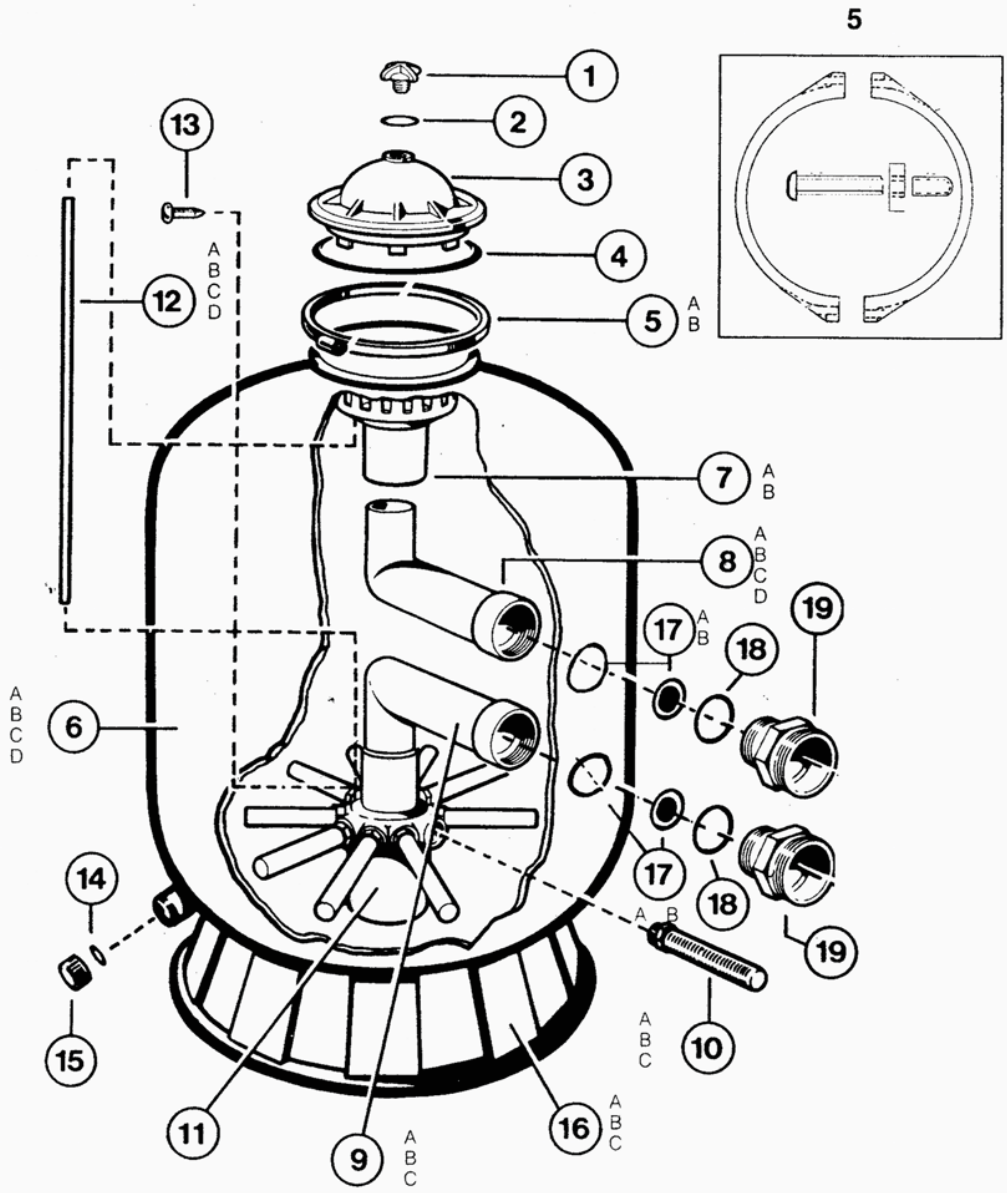
High concentrations of M.S. are more difficult to dissolve

High concentration M.S. are more difficult to regulation ("injection" rate)

High doses of coagulant cause normally early breakthrough

TECHNICAL SPECIFICATIONS

	5 m3/h unit	10 m3/h unit
Turbidity of the raw water:	0 - 200 NTU Peaks up to 300 NTU possible If > 300 NTU, do sedimentation before	0 - 200 NTU
Practical daily production (per 12 h):	45 - 50 m3/day	90 - 100 m3/day
Number of prefilters (S 310 SE):	2	2
Filtration material prefilter:	Hydro - filt n° 2 (150 l/filter)	
Number of filters (S 310 SE):	2	4
Filtration material filter:	Hydro - filt n° 1 (150 l/filter)	
Working pressure:	1.0 - 1.5 bar	1.0 - 1.5 bar
Maximum pressure:	3.0 bar	3.0 bar
Consumables included:		
Granular ferric chloride 60% active:	25 kg	50 kg
Trichloro-S-Triazine Trione tablets:	15 kg	30 kg
Weight when packed:	600 kg	900 kg
Volume when packed:	4 m3	6 m3
Characteristics pump needed:		
Centrifugal surface pump	Q >= 30 m3/h	TMH >= 28 m



Source: Hayward

PIECES DE RECHANGE **PARTS** **ERSATZTEILE** **PIEZAS DE REPUESTO**

Réf. Réf. nº Nummer Nº Ref.	Description Description Beschreibung Descripción	Nombre requis Nº required Benötigte Anz. Qdad necesaria	TYPE DE FILTRE - FILTER TYPE - FILTER TYP - TIPO DE FILTRO				
			S 166 S	S 210 S	S 244 S	S 310 SE	S 360 SE
1	PURGEUR MANUEL - MANUAL AIR RELIEF CAP ENTLÜFTUNGSSCHRAUBE - PURGADOR	1	S 200 G				
2	O'RING DE PURGEUR - AIR RELIEF CAP 'O'RING 'O'RING ENTLÜFTUNGSSCHRAUBE - 'O'RING DE PURGADOR	1	S 200 Z 5				
3	DÔME - DOME - DECKEL - DOMO	1	S 244 K				
4	O'RING DE DÔME - DOME 'O'RING 'O'RING DECKEL - 'O'RING DE DOMO	1	GM 600 F				
5	COLLIER DE SERRAGE - FLANGE CLAMP SPANNING - ABRAZADERA	1	GM 600 NM			S 310 N	
5 A	BRIDE DE FIXATION - CLAMPING BAND FLANSCHRING - BRIDA DE FIJACIÓN	2	GM 600 NM 1				
5 B	VIS DE BRIDE - CLAMP SCREW FLANSCH SCHRAUBE - TORNILLO DE BRIDA	2	GM 600 N 2				
5 C	ECROU DE BRIDE - CLAMPING NUT MUTTER SCHRAUBE - TUERCA DE BRIDA	2	GM 600 N 3				
5 D	CAPUCHON - PROTECTOR CAP SCHUTZKAPPE - TAPÓN	2	GM 600 N 1				
6	CUVE - TANK - KESSEL - DEPOSITO	1	S 166 AA (S)	S 210 AA (S)	S 244 AA (S)	S 310 AA 2 (S)	S 360 AA 2 (S)
7	DIFFUSEUR - DIFFUSER - VERTEILER - DIFUSOR	1	S 244 G		S 200 L	S 244 G	S 244 GNS
8	COUDE SUPERIEUR - TOP ELBOW OBERER WINKEL - CODO SUPERIRO	1	S 166 CD	S 210 CD	S 244 CD 2 E	S 310 CD 2	S 360 CD 2E
9	COUDE INFERIEUR - BOTTOM ELBOW UNTERERWINKEL - CODO INFERIOR	1			S 244 CD 1 E	S 310 CD 1	S 360 CD 1E
10	REPARTITEURS - LATERALS - VERTEILER - CREPINAS	10	S 200 Q		S 240 D	S 310 HA	
11	SIEGE DES REPARTITEURS - LATERAL HOLDER VERTEILERSITZ - ASIENTO DE CREPINAS	1	S 240 MAE 1	S 240 MAE			
12	TUBE DE PURGE D'AIR - AIR RELIEF TUBE ENTLÜFTUNGSROHR - TUBO DE EVACUACIÓN DE AIRE	1	C 3000 Z 2 1	C 300 Z 2	C 1100 Z 4	S 220 Z 1	S 360 Z 2
13	VIS DE TUBE PURGEUR - AIR RELIEF TUBE SCREW - ENTLÜFTUNGSROHRSCHRAUBE - TORNILLO DEL TUBO DE EVACUACIÓN DE AIRE	1	S 200 Z 2				
14	JOINT DE BOUCHON DE VIDANGE - DRAIN CAP GASKET ENTLEERUNGSTOFENDICHTUNG - JUNTA DEL TAPÓN DE VACIADO	1	S 180 G				
15	BOUCHON DE VIDANGE - DRAIN CAP ENTLEERUNGSSTOPFEN - TAPÓN DE VACIAADO	1	S 180 H				
16	JUPE DE SUPPORT - SUPPORT STAND SOCKEL - BASE DE SUPORTE	1	S 164 B	S 200 J		S 310 J	
17 A	ADAPTATEUR D'ETANCHEITE - BULKHEAD SPACER ANPASSUNGSRING - ADAPTADOR DE ESTANQUEIDAD	2	S 244 DE				S 360 DE
17 B	'O'RING d'ADAPTATEUR - SPACER 'O'RING 'O'RING FÜR ANPASSUNGSRING JUNTA DEL ADAPTADOR DE ESTANQUEIDAD	2	S 244 DE 1				S 220 Z 2
18	'O'RING DE TRAVERSEE DE PAROI BULKHEAD FITTING 'O'RING 'O'RING FÜR WANDDURCHFUHRUNGSDICHTUNG 'O'RING DEL TRAVERSERA DE PARED	2	S 220 Z 2				
19	TRAVERSE DE PAROI - BULKHEAD FITTING WANDDURCHFÜHRUNG - TRAVERSA DE PARED	2	S 200 DL				S 311 F

Source: Hayward

TROUBLE SHOOTING

Problems	Reasons	Solutions
Coagulants' flow unstable	Air leakage at the suction hose	Look for leakage and repair
	Strainer is getting clogged	Clean strainer Look for a better protected place for the strainer
	Water level higher than the inlet of pump (I.e. pumping out of a sedimentation reservoir)	Install gatevalve in front of coagulants' injector Close it to create under pressure at the pumps' inlet
Coagulants' jerrycan empty very quickly	Human error in regulating	Adjust if necessary
	Clogged strainer	See above
	Coagulants' regulating valve mounted upside down	Mount it in the right direction (arrow upward)
Yellowish water when turbidity < 5 NTU	Too high residual iron (do test with kit)	Reduce the coagulants' flow a little
	Natural colouring of the water	Add active carbon filter (not included in WTU kit)