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Report on:

Assessment of Design, Operation and Maintenance of Water Treatment Plants

By:
Mr. Eric Goessens

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Strengthening Provision of Services in Qena and Promoting Appropriate Rural Sanitation Options

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RODECO CONSULTING GMBH

GOPA WORLDWIDE CONSULTANTS

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Acronyms and Abbreviations

?	Data not available
BW	Back-Wash
DBP	Disinfection By-Product
ESWTR	Enhanced Surface Water Treatment Rule
FRC	Free Residual Chlorine
HTH	High Technical Hypochlorite
lps	Litter per second
NA	Non Applicable
NOM	Natural Organic Matter
O&M	Operation and Maintenance
PAC	Powdered Activated Carbon
PAChlor	Poly Aluminium Chloride
QWWC	Qena Water and Wastewater Company
STE	Short-term Expert
TOC	Total Organic Carbon
ToR	Terms of Reference
WTP	Water Treatment Plant
WTW	Water Treatment Works
WWTP	Waste Water Treatment Plant

1 EXECUTIVE SUMMARY

The purpose of this report is to summarize the main activities undertaken by the Consultant between the 16^{th} of November and the 14^{th} of December 2007 within the frame of the TC project “Strengthening Provision of Services in Qena and Promoting Appropriate Rural Sanitation Options”; to communicate the main findings and results, to propose recommendations and set out future priority “training” activities regarding design, operation and maintenance of the WTP in Qena District.

Design and operation of WTP – findings and recommendations

The water treatment plants (WTP) operated by QWWC and considered during the field mission are Armant, Esna, Qena (new), Naga Hammadi, Deshna, Qeft and Qouz plants. The main source of raw water for all water treatment plants is the Nile River. The WTP are conventional plants consisting of the same series of process units: pre-chlorination, coagulation and flocculation, sedimentation, rapid sand filtration and finally disinfection. Plants are generally operated at nominal flow (from 150 – Esna to 800 lps – Naga Hammadi) during day time and at ½ capacity at night.

Although most of the WTP are quite recent (1980 and after), they have been constructed following an "old fashion" process design and design parameters. All WTP constructed during the same period look very similar; mistakes have unfortunately often been repeated in the design, and operation and maintenance (O&M) experience not really considered.

Most of the WTP structures, buildings and electro-mechanical equipment (pumps, mixers, etc.) are generally in poor condition. They definitely require urgent refurbishment as negative impacts on the water treatment process and the water quality have been noticed.

The conventional water treatment process is moreover not adapted to the raw water characteristics in Qena (low turbidity, natural organic matter (NOM), algae, etc.). On a mid-term basis, the existing process should be reviewed to allow appropriate treatment, more specifically to respect the Enhanced Surface Water Treatment Rule (ESWTR), to avoid taste and odour, NOM and Disinfection By-Products (DBP) in the distribution network, and to cope with eventual corrosiveness problems and aluminium residuals.

The number of WTP staff seems significant; skills in terms of water treatment processes are however quite limited. O&M of the WTP has always been managed on a “routine” basis. When O&M practices require more than this well established “routine”, problems can generally be quickly identified by the plant personnel but the reasons and the solutions are mostly not clear and often impossible to even suggest. Optimisation of the water treatment process is definitely not a main concern of QWWC plant staff.

Training needs and on-site training

In addition to the assessment of WTP design and current operation practices, the short-term expert conducted a rough training needs assessment and several on-the-job / on-site training sessions for WTP operators and lab technicians of the various WTP. This process was divided into 2 different steps: site visits to identify and discuss the main problems and bottle necks for each WTP, and four indoor training sessions to present some process theory, to revise the main design parameters and to inventory the possible short-term mitigation measures. Additional training needs are outlined in chapter 6.

2 INTRODUCTION

The project "Strengthening Provision of Services in Qena and Promoting Appropriate Rural Sanitation Options" aims at supporting Qena Water & Wastewater Company (QWWC) in improving its utility management and operation, including the provision of decentralized wastewater services to rural communities. The project is implemented on behalf of GTZ by RODECO Consulting GmbH in association with GOPA Consultants.

As a need for WTP expertise had been identified, an international short-term expert (STE) in water treatment was assigned from 16th of November to the 14th of December 2007 to:

1) Assess the current operating practices of the Water Treatment Plants and compact abstraction/ treatment units,
2) Identify and provide appropriate 'best practice' operating standards that can be applied to the treatment processes (general/exemplary recommendations),
3) Propose operating improvements to the process, procedures, staffing, equipment, monitoring and record keeping (general/exemplary recommendations),
4) Carry out "on the job" coaching of selected personnel in the correct operation of the treatment facilities (application of procedures, monitoring, utilization of tools and equipment, quality control, etc.).

The purpose of this report is to communicate the findings and the recommendations made by the STE regarding the design, operation and maintenance of WTP. The report outlines the main activities undertaken, discusses the main findings and results, proposes recommendations and outlines future priority "training" activities.

3 WORK PLAN

The mission started with a discussion and a general assessment of the treatment facilities with the different plant managers, operators and laboratory technicians. During these field visits, principal WT process problems and bottlenecks have been listed, discussed ("what & where") and on-the-job training provided and short-term mitigation measures proposed ("why and how"). The detailed work schedule is presented in Annex 1.

Training support, such as notes and slides show has then been prepared and presented during four "on-the-job training sessions". Notes and slide show are provided for information in Annex 4.

The WTP visited are summarised in the table here below. Other details are shown in Annex 2.

Table 1 : WTP in the Qena District

WTP in Qena	WT line – date of operation	Nominal capacity (lps)
Armant WTP	New line (before only compact WTP) - 2007	400
Esna WTP	1948	50
	1976	50
	2004	50
Qena WTP (*)	New line 1998	600
Naga Hammadi WTP	2 x 400 LPS – 1999/2007	800
Deshna WTP	2 x 200 LPS – 1998	400
Qeft WTP	"OLD" - 2/4 filters operated - 1985	100
	"NEW" - 1995	100
Qouz WTP	"OLD" – 1981	100
	"NEW" – 1998	200

(*) The old plant of Qena has not been considered as it is supposed to be very soon replaced by new WTP infrastructures.

4 ASSESSMENT OF WTP DESIGN, OPERATION AND MAINTENANCE

4.1 DESCRIPTION OF WTP

The main source of raw water for all water treatment plants is the Nile River. The intakes are generally located a few meters below the WTP. The intakes of the Qena and Naga Hammadi WTP are located at 1 km and respectively 3 km from the WTP.

The raw pumping stations are supplied by gravity via multiple large diameter pipe lines. Most of them are equipped with a screen and a manually operated backwash system. The WTP are supplied by raw water pumping stations. WTP capacities vary from 150 lps (Esna) to 800 lps (Naga Hammadi). The WTP are generally quite recent (see Table 1).

Due to financial constraints, the design, construction and commission phases for the different WTP dragged on over a quite long period. It is indeed very common to have 10 years and even more between the design and the final commission phases.

Plants are generally operated at nominal flow during day time, sometimes over the nominal capacity (Esna), and at ½ capacity at night time. Water flows extracted from the Nile, treated and finally sent to the different networks are evaluated very approximately as flow meters do not exist, even in the new WTP infrastructures (Armant).

The WTP are conventional plants consisting of different process units: pre-chlorination, coagulation and flocculation, sedimentation, rapid sand filtration and finally disinfection. The treatment plants consist of 1 to 3 lines (extension); capacity and design criteria vary slightly between the different treatment lines. From the WTP, the treated water is pumped to a network storage tank or directly into the network.

Each process line is generally composed by:

- Injection of pre-chlorine in the main inlet pipe. Gas chlorine is used.
- 1 flow distribution chamber which divides the flow within the different process lines. The coagulant (aluminium sulphate) is often injected at the inlet of this structure.
- 1 mixing chamber equipped with an electromechanical mixer. This first “flocculation” room provides contact time and velocity gradient for further mixing of the raw water and the coagulant, aluminium sulphate.
- 1 hydraulic “serpentine” flocculator generally providing contact time and velocity gradient (1 only) for the flocculation process. The Naga Hammadi WTP is equipped with a two stage electromechanical flocculator.
- 1 rectangular or radial open settling tank. Sludge from the decanters is sent by gravity to a sludge underground reservoir where it is regularly pumped to irrigation ditches or directly back to the Nile.

- A series of rapid sand filters of "constant level – constant flow" type with variable dimensions. Backwash facilities include 2 to 4 water pumps and 2 blowers. The water storage reservoir located below the filters is used to store water for the backwash process.
- Injection of post-chlorine. Gas chlorine is used. Chlorination is done in the main pipe leading to the WTP storage reservoir.
- 1 main water storage reservoir and a pumping station to supply water to the network.
- A dosing unit for the preparation, dosage of aluminium sulphate. Low concentrations (1 to 3 %) – low dosages (4 to 12 mg/l) are generally used.
- A dosing unit for the preparation and dosage of gas chlorine.

The main design parameters for each WTP and process lines are given in Annex 2.

4.2 WTP LAYOUT AND DESIGN – O&M GENERAL ASSESSMENT

4.2.1 General

Although most of the WTP are quite recent, WTP have been constructed following an "old fashion" process design and design parameters. WTP constructed during the same periods look indeed very similar: A "copy and paste" technique for WTP design has been emphasised, and mistakes have often been repeated while O&M experience was not really considered.

As the process lines have been built at different periods, design parameters are often quite variable within the same WTP. Operation is therefore rather difficult to monitor as none of the operators is really familiar with design parameters.

An extension of WTP capacities has already been planned for most of the cities; works are even going on in a certain location (Qena new WTP). Extension is presently based on the same "copy and paste" concept. Cost and process efficiencies of these new WTP infrastructures are therefore questionable.

Most of the WTP structures, buildings and electro-mechanical equipment (pumps, mixers, etc.) are generally in poor condition. They definitely require urgent refurbishment as negative impacts on the water treatment process and the water quality have been noticed.

Plants are generally operated at nominal capacity except at night. The design criteria are quite conservative. Decanters are operated with a surface loading rate between 1 and 2 m/h and filters with a velocity of approximately 5 m/h.

Optimization of the process to improve water quality and plant efficiency, essentially the decanters and filters, is nevertheless required. O&M is actually organised on a "routine" basis; monitoring of the WTP performance is quite limited and optimisation is certainly not a main concern of plant staff. Water treatment plant manuals and documentation are generally not available on site.

The conventional water treatment process is not adapted to the raw water characteristics in Qena (low turbidity, NOM, algae, etc.).

Recommendations

On a mid-term basis, the entire process should be reviewed to allow appropriate treatment to respect the Enhanced Surface Water Treatment Rule (ESWTR), to avoid taste and odour, NOM and Disinfection By-Products (DBP) in the distribution networks, to cope with eventual corrosiveness problems and aluminium residuals. Supplementary chemicals should be considered in the process line. The rehabilitated WTP should at least be equipped with full option chemicals, including appropriate pre-oxidant, coagulant, polymer and pH correction and if needed activated carbon.

Standardisation of all electro-mechanical equipment should be proposed during the rehabilitation process as it does apparently not exist and makes O&M more complicated.

4.2.2 Intake and Raw Water Quality

The Nile River in Upper Egypt is generally considered to provide good quality water. General parameters monitored by the existing laboratories are indeed quite low (Turbidity – Fe – Mn – NO_3 – NO_2) or acceptable (Total Hardness and total Alkalinity) for the main ones.

The Nile River is however also subject to pollution by industrial, agricultural and domestic wastes. In “normal” conditions, important NOM concentrations are to be expected (algae blooms). The existing conventional WTP have not been designed to cope with this kind of parameters (pre-chlorination, limited chemical arsenal, etc.). Odour and taste are often noticed in the treated water.

The location of intake facilities has not always been properly designed, it is downstream of other towns and factories (Qeft) and even downstream the supplied town. Construction works are actually going on to relocate the Qeft intake to a more suitable position.

The O&M of the intake screens is done manually; some WTP intakes have indeed been equipped with backwash facilities.

Recommendations

On a short-term basis, the raw water quality should be investigated: TOC/ NOM – Algae – DBP precursors, etc. The existing WTP should be modernised accordingly and a new process concept should be proposed if new WTP units have to be built. New parameters should be introduced at laboratory level for regular follow-up.

4.2.3 Water Metering and Flow

The water flow is neither metered at the inlet nor at the outlet of the WTP. Water meters do not work or have not even been installed. There is no water meter on the sludge and backwash facilities. Accordingly, water flows are roughly estimated from experience based on water pumps operation. The efficiency of the WTP is thus not properly monitored. Chemical dosages are difficult to apply and follow up during water treatment.

The water flow between the different process lines is generally not balanced and difficult to control. Negative impacts on treatment process have been noticed.

Recommendations

Flow control and regulation systems between the different lines should be included in a “rapid” investment plan. Distribution weirs and control valves within the WTP should be rehabilitated and flow meters installed. Portable sonic water meters should be made available at central level to regularly control the WTP process flows at regional level. This would allow the operators to follow-up the WTP efficiency, to properly monitor the treatment process and to improve the water quality.

Other meters (electrical consumption, timers on electro-mechanical equipment, etc.) should also be installed to properly plan the O&M.

4.2.4 Coagulation and Flocculation

The coagulation and flocculation processes are very poor. This has clearly negative impacts on the decanters and filters performance.

Dosage of aluminium sulphate is quite difficult to operate. The dosage defined during the jar test procedure is not strictly applied in the WTP. On a short-term basis, visual control and calibration of the dosage pumps, measure of the density and quality of the concentrated coagulant solution and follow-up of specific parameters on WTP are required (refer to training session support).

Flash mixing is often missing. Aluminium sulphate is simply poured in the inlet flow and hydraulic mixing very limited. The injection device has to be redesigned and, if possible, a greater aluminium sulphate dilution factor used. Static hydraulic mixers should eventually be considered on a short-term basis.

The mixer equipping the first flocculation chamber is generally out of use. Flocculation parameters are not modifiable. The hydraulic transmission between the coagulation and the flocculation units and even between the flocculation basins themselves has been poorly designed. This clearly affects the water quality at the outlet of the WTP. On a mid-term basis, modification and modernisation of these units are definitely required.

4.2.5 Sedimentation

The design surface loading rate of these structures varies from 1 to 2 m/h and is unfortunately not standardised within one WTP. O&M of the different process lines is therefore difficult. Although surface loading rates are quite conservative, the circular and/or rectangular decanters often present deficiencies. Conventional WTP are therefore often used as direct filtration units.

Recommendations

The structures are in a reasonable condition but should be rehabilitated as leaks and short cuts have been noticed on most of the structures. Inlet and outlet pipes and accessories should be checked in detail to provide smooth transmission to and from the sedimentation structures. Hydraulic tests should be performed to evaluate priorities.

Minimum design criteria should be provided to the operators (refer to training session support).

On a very short-term basis, the reduction of the inlet flow and the increase of aluminium sulphate dosage can be considered. Indicator parameters (turbidity – pH – etc.) should be controlled and strict guidelines established. The use of polymer or/and PAChlor should be investigated. A pilot test could easily be organised at one of the WTP (Armant – New WTP).

Sludge removal systems should be improved on certain structures as they do not drain properly (anaerobic decomposition of the sludge). If PAC is to be used on a mid-term basis (TOC/NOM – DBP), it is recommended to install a sludge recirculation system on the decanters.

Conventional sedimentation tanks have to be regularly emptied for maintenance; this has a serious impact on the plant efficiency as large water quantities are lost. New designs such as tube settlers, blanket clarifiers or even contact clarifiers should be proposed if new WTP have to be built.

4.2.6 Filtration

Filters are “constant level – constant flow” filters. They are operated manually (pneumatic valves). The filters are in a very poor condition. Automatic regulating systems are not operational, the flow distribution between the different units is not balanced, filter bottoms and launders require urgent rehabilitation and modernisation, sand parameters should be checked, etc. Filters are certainly the process units requiring the most attention. Available surfaces provide sufficient potential in terms of water production and process flexibility. Filtration rates vary from 5 to 6 m/h.

Recommendations

On a temporary basis, filters should be operated at "constant flow - variable level" (refer to training session support). Filtration process (indicator parameters) should be monitored on each filter.

Filters require "urgent" rehabilitation:

- Sand should be checked for D_{10} – D_{60} and Cu and sieved if needed.
- Regulation equipment should be urgently rehabilitated to restore the "constant flow – constant level" treatment process. Specific training sessions about automation - regulation of "constant flow - constant level" filters should be organised during the rehabilitation process.
- Weirs regulating the inlet flows should be rehabilitated or installed to make sure that flows are equally distributed between the different filter units.
- Other filter accessories and components should be rehabilitated (nozzles, etc.).

Backwash (BW) is generally realized with air and then with water. BW facilities are generally in good conditions and require minor rehabilitation only. BW process nevertheless needs to be optimised. Water used for backwash purposes shall be metered on a long-term basis. As for all electro-mechanical devices, control panels should be replaced to include appropriate operating and protecting devices.

4.2.7 Pre-chlorination and Disinfection

Pre-chlorine is actually used to limit biological growth within the WTP and to enhance the coagulation process. As contact time is quite limited (intake close to the WTP), a significant chlorine concentration is generally used; chlorine losses in the atmosphere have been noticed. Some algae are moreover resistant to chlorine and proliferate in the WTP. This requires specific attention, such as jar testing (break point chlorination) to maintain a minimum FRC at end of the sedimentation tank and filters and reinforcement of the O&M procedure for the sedimentation reservoirs and the filters.

Chlorine dosage (pre- and post-chlorination) monitoring is done on a regular basis by the different laboratories.

Recommendations

If possible, the pre-chlorine injection point should be reviewed after jar testing in order to increase t and possibly reduce C.

The use of pre-chlorine is questionable as taste and odour compounds and most probably DBP are formed; a detailed study regarding the taste / odour and DBP is required. The injection of other oxidants such as $KMnO_4$, the use of PAC, etc. should be investigated at least on a pilot water treatment unit (preferably Armant, which is a new and relatively modern WTP and has experienced staff). A first evaluation should be performed in the laboratory during a next training session (jar testing).

For both pre- and post-chlorination, "C*t" parameter are not known by the laboratory staff. C*t should be monitored by the laboratory together with the FRC. FRC manual monitoring and eventual "in line" follow-up should be done accordingly.

Flash mixing is in general appropriate as chlorine is directly injected in the main inlet pipes.

4.2.8 Dosage Facilities

The plants have to be operated with injection of different chemicals, chlorine and aluminium sulphate. Preparation units for aluminium sulphate solution are in poor condition and difficult to operate. Dosage is performed by dosing pumps or by gravity. The design of dosage facilities does not respect internationally recognised standards: devices such as pressure release valve or by-pass, calibration unit, pulsation damper, flow meter, pressure valve, rinsing system, etc. have not been installed; dosage is impossible to correlate to the inlet flow without water meter; the laboratory is not equipped to control the concentrate aluminium sulphate solution; etc.

The chlorination facilities are in a poor condition. Some of the units are even operated above their dosage capacity. The chlorination facilities do not conform to safety regulations. "Safety" elements such as neutralization, appropriate ventilation, etc. do not work or do not even exist.

Chlorine dosage is controlled by the laboratories on a regular basis for both pre- and post-chlorination. The chlorine dosage is manually adjusted according to water quality analysis, outlet of the sedimentation tanks, outlet of the filters and the outlet of the WTP.

The FRC and the "C*t" value at the outlet of the WTP are however difficult to guarantee. Due to the limited storage capacity at certain WTP, chlorine dosage has to be regularly adapted following the water demand and the level in the reservoir.

Recommendations

Urgent rehabilitation of preparation units and dosage facilities is required as negative impacts on the process have been noticed. Moreover, the chemical arsenal should consider the "aluminium residual", "corrosion", "TOC / NOM", "DBP" and "taste and odour" problematic. On a mid-term basis, the existing plants should indeed be equipped with "full option" dosing rooms:

- The use of appropriate pre-oxidants, such as $KMnO_4$ should be tested to reduce odour and taste, eventually DBP.
- The use of polymer should be tested to improve sedimentation efficiency and reduce the negative impact of aluminium sulphate on the pH. The injection of PAChlor can eventually be proposed.
- The use of activated carbon should be investigated to reduce taste and odour, TOC/NOM and eventual DBP in the treated water. PAC should be preferred as it does not require important investment, is very flexible to operate as it could be injected at different stages into the treatment process and could be used in case of pollution only.
- Corrosion control should be investigated and pH correction chemicals proposed if needed.

4.2.9 Laboratory and Drinking Water Quality

Water samples are taken before, during and after treatment, following a standardised procedure. Limited physical and chemical tests are performed by the WTP laboratories, including bacteriological tests. Temperature, Turbidity, pH, Conductivity, Total hardness, Total alkalinity, NO_3, NO_2, Fe, Mn, Total plate count, Total coliforms and Faecal coliforms controls are regularly performed in the best equipped laboratories.

The pH of the raw water is around 7.8 to 8. After coagulation and flocculation, the pH drops to around 7.0. Water corrosiveness (pHs) and aluminium residual are not monitored. Taste and odour, TOC and DBP are not monitored at all.

There is no functional inline monitoring equipment such as T° - OCl^- – pH – NTU electrodes. Data are recorded by hand in standardized follow-up data sheets. Data are not processed in a computer.

The proposed standard list is too limited and equipment not always functional to provide efficient monitoring of the water treatment process and WTP efficiency. Process trouble shooting and process optimisation are moreover impossible on a strictly scientific basis.

Recommendations

On a short-term basis, minimum laboratory facilities should be provided at decentralised level to monitor the minimum WTP operating parameters on an hourly / daily / weekly basis. Supplementary parameters should be analyzed on a monthly basis at the central laboratory level in Qena. Decentralized laboratories should perform the minimum physico-chemical analyses. Portable, user friendly and ready to use equipment and reagents should be proposed as well as a standardisation of equipment and methods.

Additional WTP training courses should be organised to properly monitor WTP performances, diagnose problems based on laboratory results and optimise WTP performances. Operators and laboratory staff should be involved as both are the reference staff in terms of WTP process monitoring.

On a longer-term basis, inline monitoring equipment should be installed / rehabilitated.

4.2.10 Electro-mechanical Equipment in General

Most of the pipes and accessories are operational and in relatively acceptable condition. Control valves require minor rehabilitation only.

<u>Recommendations</u>
Electromechanical devices should nevertheless be modernised; this includes:

- Raw water pumps (priority), including the water hammer protection devices (Naga Hammadi and Qena only).
- Mixers for coagulation and flocculation (priority),
- Dosing pumps and related equipment (priority).

  Note: Flocculators (at least the last flocculation stage) and dosing pumps shold be “frequency” regulated.
- Sludge removal – raking systems,
- Backwash water pumps and blowers,
- Pre- and post-chlorination equipment (priority).
- Treated water pumps.

The electric control panels for the protection and operation of all electromechanical equipment require modernisation. All equipment should indeed be protected (low water level – high pressure – etc.) and alarms installed (low and high levels).

The WTP are manually operated. Information is not dispatched to a centralised place. On a long-term basis, minimum automation – regulation should be installed.

4.2.11 Storage

The plants are generally operated at nominal flow during day time and at ½ flow at night time. Some plants are operated on an intermittent basis (OFF/ON) and sometimes over the nominal capacity as sufficient storage capacity is not available, neither at the WTP nor on the distribution network.

Recommendations

Flow changes in the water treatment process have negative impacts on the water quality and should therefore be properly operated. Storage capacity should be operated in order to maintain constant flow at WTP level and should provide sufficient capacity to maintain “C*t” parameter.

4.2.12 Sludge and Treatment By-products

Sludge from the sedimentation tanks and wastewater from the BW process are temporarily stored in an underground reservoir and then pumped, untreated, to irrigation ditches or sometimes directly back to the Nile.

Recommendation

In this kind of environment, drying beds to concentrate the sludge are certainly the best and cheapest option in terms of operation and maintenance.

4.2.13 Staff

The number of WTP staff seems significant; skills in terms of water treatment processes are however rather limited at QWWC’s WTP; the O&M of the WTP has always been managed on a “routine” basis.

When O&M practices require more than the well established “routine”, problems can generally be quickly identified by the plant personnel but the reasons and the solutions are definitely not clear and often impossible to even suggest. Optimisation of WT process is definitely not a main concern of staff.

The next WTP training session should focus on developing risk information and assessment procedures and a reference manual. Training of identified "trainers" should then be organised by the project in coordination with the HCWW and QWWC. Exchanges and contacts between WTP should be encouraged as the problematic is very similar.

5 KEY RECOMMENDATIONS

5.1 OPERATION AND MAINTENANCE OF WTP

Parameters to be monitored on a short-term basis are listed here below. All proposed parameters have been discussed during the different training sessions.

- **WTP**
  - Water treatment efficiency …. **Objective 90 %.**
    - Follow-up of raw water pumps operation (operation time) – estimated flow (design capacity by default – evaluation of pumping capacity via time % known volume).
    - Follow-up (if possible) of drinking water pumps operation (operation time) – estimated flow (design capacity by default – evaluation of pumping capacity via time % known volume).
  - Energy consumption.
    - Electrical meter when existing, if not operation time and design energy consumption.
  - Operation & Maintenance of E&M equipment.
    - Operation period …. **Objective 8 H/period.**
    - Follow-up (repairs – etc.).

- **Pre-chlorination**
  - Breakpoint chlorination at laboratory level (jar test).
  - Determination of contact time and improve if possible.
  - Control of dosage (kg/h) between the different process lines.
  - Monitor monthly consumption.
  - FRC at outlet of sedimentation tanks …. **Objective 0.2 to 0.4 mg/l.** Avoid FRC losses in atmosphere. Increase C if needed ("C*t" not sufficient for resistant organism) or clean sedimentation tank regularly with high HTH concentration.
  - FRC minimum at outlet of filtration units … …. **Objective 0.05 mg/l.**
  - Control of taste and odour – refer to standard method.

- **Sedimentation**
  - Verification of design parameters.
  - Verification of residence time and control of possible short-circuits (tracer testing if needed).
  - Verification of sedimentation performance …. **Objective 1 NTU in 95 % of the time as raw turbidity is below 10 NTU.**
  - Limit losses of FRC in atmosphere.
  - If possible modify structures accordingly.

- **Filtration**
  - Verification of design parameters.
  - Control of inlet flow – flow distribution between different process lines and filters.
  - Verification of filtration performance …. **Objective 0.3 NTU in 95 % of the time.** Follow-up of filters individually. Monitor filter run periods and evolution.
  - Avoid WTP flow modification if filters are at the end of the run period. BW filters if needed before flow modification.
  - Control of D10 – D60 – Cu parameters.
  - Constant flow – variable level: Maintenance of minimum 20 cm water above the sand after

BW (temporary basis solution). Do not exceed 80 cm – 100 cm of head losses before BW. Preferably limit the head losses to the filter static head.
    - Monitor filters profile regularly.
- Optimization of the BW procedure. For "Conventional filters – Uniform media » start with air for <u>3 to 5 minutes</u> max. and then water for <u>5 to 10 minutes</u>. Repeat the procedure if needed.
    - Monitoring of clean sand head loss evolution.
    - Monitor backwash turbidity profile.
    - Sludge retention profile to be check after BW procedure optimisation.

- **<u>Disinfection</u>**
    - Check contact time via water level in water reservoir. Evaluation of "C*t".
    - Control of dosage (kg/h) and monthly consumption.
    - FRC at outlet of water tank …. **Objective min 0.2 mg/l – max. 1.5 mg/l at first customers.**
    - Control of taste and odour … refer to standard method.

- **<u>Chemical dosage - Aluminium Sulphate</u>**
    - Control of dosage pumps flow (calibration).
    - Control of concentrate solution of aluminium sulphate (density). Perform similar jar test with "in situ" solution.
    - Control of laboratory parameters on WTP (pH & turbidity mainly).
    - Visually comparison between "in situ" results and jar test results.

5.2 DOCUMENTATION

General knowledge and understanding of water treatment issues should be improved at plant personnel level. Reference documentation and documents (user manual, technical specs, etc.) should be provided at central and decentralized levels. Access to Internet should eventually be provided to chief operators and laboratory technicians. Inter-WTP communication and exchange should be reinforced via seminars, reporting, meetings, etc.

Training issues are detailed in the following chapter.

5.3 REHABILITATION

Existing water treatment facilities are generally in poor to very poor condition. This is mainly due to poor process and infrastructure design, construction failures, poor O&M and lack of trained staff.

It is quite obvious that "training" alone will not solve all technical issues. A short-term ("Rapid" rehabilitation) rehabilitation programme, including financial issues should urgently be designed and priorities defined. A detailed assessment for plant rehabilitation and "urgent" investment plan should be proposed. To this aim, international expertise in Upgrading WTP would be required: 3 working days per WTP – Esna / Qena New / Deshna / Naga Hammadi / Qeft and Qouz + 3 days reporting for a total of 21 working days.

WTP improvements should cover:

1. Measures to improve WTP efficiency in terms of water quantity (reduction of losses, optimisation of treatment process, etc.) and measures to guarantee the water quality (optimisation of treatment process, chemical injection, supplementary process units, laboratory monitoring, etc.). Supplementary treatment processes should be evaluated to improve water quality. One of the existing WTP could eventually be selected as pilot plant for the evaluation of new chemicals ($KMnO_4$, Polymer, PAChlor, PAC, etc.).
2. Measures to monitor WTP performances including flow meters– electricity consumption meters – timers for electro-mechanical equipment, etc. The water treatment process (injection and mixing of chemicals, contact time, sand, etc.) and related facilities (water pumps - backwash pumps – blowers – mixers – etc.) should be evaluated and eventually replaced / rehabilitated to provide better process performance and reduce electrical consumption.
3. Measures to ensure safety at the WTP for plant personnel and neighbouring population (chemical preparation & dosage, electrical supply, etc.).
4. Environmental issues: environmental issues are generally limited to the generation and disposal of process by-products (sludge, backwash water, etc.). In case of WTP using conventional chemical on a permanent basis, pilot infrastructures can be proposed to treat process by-products.
5. Minimum automation – regulation should be restored to allow the plants to work as originally designed (filters, etc.). Rehabilitated or new electro-mechanical equipment should include all accessories for future automation & regulation.
6. Redundancy: redundancy of equipment and process facilities has to be provided. Dosage facilities for coagulant and chlorine injection are certainly the main priorities.

6 TRAINING COURSE

6.1 CONTENT

The training conducted by the STE was divided into 2 different steps:

1. Site visits:
    a. Identification of the main problems and bottlenecks for each WTP. All process units were considered.
    b. Discussion with the plant personnel about the problems identified and possible mitigation measures. Practical short-term solutions were discussed.
2. Indoor training sessions: presentation of the process theory and main design parameters behind all identified problems and inventory of possible mitigation measures.

Issues discussed are presented in an annexed document and slide show (Annex 4).

6.2 TRAINING RECOMMENDATIONS

The above first training session regarding WTP issues should preferably be followed by different other inputs, such as:

- **2008**:
    - Technical documentation - users manuals – etc. to be sent to each WTP on request (laboratory equipment, regulation valves, etc.).
        - Listing to be prepared by the local operators. Project office to follow-up.
    - Reference bibliography to be provided at project office + operator levels.
        - Refer to reference bibliography + Internet available documentation. Project office to follow-up.
    - Elaboration of a general WTP guideline including risk information & assessment procedures (troubleshooting guide-line), minimum O&M activities and contingency plans.
        - Expertise required. +/- 10 working days.
    - "On the job" WTP training session N° 2 – International expertise in WTP optimisation and troubleshooting required - 4 working days per WTP – Esna / Qena New / Deshna / Naga Hammadi / Qeft and Qouz for a total of 24 working days. This includes:
        - Troubleshooting and follow-up of WT unit processes using simple, user friendly laboratory techniques.
        - Inventory and evaluation of technical solutions on site.
        - Jar test of different chemicals such as $KMnO_4$, PAChlor, Polymer, PAC, etc.
        - Preparation of standard follow-up sheets (indicator parameters).

- **2008 – 2009:**
    - “Automation / regulation of filters” training programme in parallel with the “rapid” rehabilitation programme.
        - Local expertise required, such as automation & regulation Company (CEGELEC, etc.). 1.5 working days per WTP (Esna / Qena New / Deshna / Naga Hammadi / Qeft and Qouz).
    - “Training of trainers” training programme. This training session should cover WTP design parameters and O&M of WTP. This session, if organised in Egypt, can eventually be extended to other water agencies / partners (National Design Company).
        - International expertise required in Designing WTP (IHE Delft, OIE Limoges, WEDC Loughborough, etc.).
    - Production of a reference manual with minimum recommended standards in water works and general design parameters. This manual should propose a standardisation policy for all WTP structures and equipments (equipment type - specifications - etc.).
        - Expertise required. +/- 10 working days.
    - Inter-WTP exchanges on regular basis (technical meetings – training sessions – etc. on specific issues).
        - Project office to follow-up.
    - Training regarding temporary and final commissioning of WTP works.
        - International expertise required in Designing WTP (IHE Delft, OIE Limoges, WEDC Loughborough, etc.).

APPENDICES

1. Work Schedule of STE
2. WTP General Design Parameters
3. Summary of WTP Weaknesses & Recommendations
4. Support for Trainees and Slide Show
5. Pictures
6. Jar Testing (guideline)

1. WORK SCHEDULE

Table 2: Work Schedule of STE

	NOVEMBER 2007
16/11	BRU-CAI-LXR
17/11	Briefing David Banner - Planning first week input - Clarification of TOR - Project doc. consultation
18/11	Introduction to QWWC and Project personnel - visit Qena old WTP - Visit Qena WWTP - Visit Qena new WTP (Dr Abd Al Fatah & Mrs Samira - Chief Operator)
19/11	Visit of Armant WTP (Ahmed Rushdi - Chief Operator)
20/11	Visit of Esna WTP (Mr. Hany - Esan Manager & Mr. Abdoul Hassan - Chief Operator & Mr Youssef - Chief Lab)
21/11	On the job training Esna WTP - Visit of compact unit (Mr. Abdoul Hassan - Chief Operator & Mr Youssef - Chief Lab)
22/11	On the job training Qena WTP (Mrs Samira - Chief Operator & Mr Monthasser - Chief Labo)
23/11	Project administration - Preparation of training support - documentation
24/11	Preparation of training support - documentation
25/11	Visit of compact units around Qena - On the job training in Qena old WTP (Mr. Abdel Raziq - WTP supervisor Qena)
26/11	Visit of Naga Hammadi WTP (Mr. Mahmoud - Chief Electrician)
27/11	Visit of Deshna WTP (Mr. Sahid Adouldwafa - Chief Operator & Mr Mahmoud - Water quality supervisor)
28/11	Visit of Qouz WTP (Mr Fat'hy - Plant manager)
29/11	Visit of Qeft WTP (Mr Mohammed Ibrahim - Chief operator & Mr. Ghalid - Qeft Water Supply manager) - Planning & organisation of training sessions with David Banner
30/11	Project administration - Preparation of training support - documentation
	DECEMBER 2007
1/12	Preparation of training support - documentation
2/12	On the job training Naga Hammadi WTP - Mr Kamal WTP responsible
3/12	On the job training Qouz WTP - Lab technicians (Mr. Mustapha, Mr. Hahlam, Mr. Ahmed) & Mrs Zineb (Power Eng.)
4/12	Preparation of training support - documentation
5/12	On site training session in Naga Hammadi for Naga Hammadi & Deshna WTP operators & Lab technicians (26 trainees)
6/12	Revision of training material - documentation
7/12	Revision of training material - documentation
8/12	Revision of training material - documentation
9/12	On site training session in Qouz for Qouz & Qeft WTP operators & Lab technicians (27 trainees)
10/12	On site training session in Esna for Esna & Armant WTP operators & Lab technicians (16 trainees)
11/12	On site training session in Qena for Qena new & old WTP operators & Lab technicians (15 trainees)
12/12	Report
13/12	Report - Debriefing with David Banner
14/12	LXR-CAI-BRU

2. WTP GENERAL DESIGN PARAMETERS

Table 3 : WTP Design Parameters

WTP	WT line	Nominal capacity	Sedimentation					
			Type	N°	L	l	S unit	Surface load
		LPS			M	M	M²	M/H
Armant WTP	New line - 2007	400	Circular	2	7.6	5.8	383	1.88
Esna WTP	1948	50	Circular	1	3.4	4.3	150	1.20
	1976	50	Rectangular	1	10	12.75	127.5	1.41
	2004	50	Rectangular	1	10.7	12.75	136.4	1.32
			New filtration line 2004 not in use due to difference in level - 100 LPS					
Qena WTP	New line - 1998	600	Rectangular	2	51	12.5	637.5	1.69
Naga Hammadi WTP	2 x 400 LPS - 1999/2007	800	Rectangular	4	60	12	720.0	1.00
Deshna WTP	2 x 200 LPS - 1998	400	Rectangular	2	34	11	374.0	1.93
Qeft WTP	"OLD" - 2/4 filters operated - 1985	100	Rectangular	2	10	12.69	126.9	1.42
	"NEW" - 1995	100		1	30.4	10	304.0	1.18
Qouz WTP	"OLD" - 1981	100	Rectangular	2	10	12.81	128.1	1.41
	"NEW" - 1998	200		1	31.5	18.1	570.2	1.26
Compact Units		25	Plate settler	1	4.5	1.8	8.1	11.11

WTP	WT line	Nominal capacity	Filtration					BW		AIR	WATER 1	WATER 2
			N°	L	l	S unit	Surface load	BW Blower	BW Pumps	BW Velocity	BW Velocity	BW Velocity
				M	M	M^2	M/H	M^3/H	LPS	M/H	M/H	M/H
Armant WTP	New line	400	6	7.8	8.8	68.64	**3.50**	4500	250	66	13	26
	BW position min		5	7.8	8.8	68.64	**4.20**					
Esna WTP	1948	50	2	5.15	8.8	45.32	**3.97**	?	200	?	16	NA
	1976	50	Filtrated on 1948 filtration line									
	2004	50	2	2.7		22.90	**3.93**	?	100	?	16	NA
			2	7.4	5.9	43.66	**4.12**	?	250	?	21	NA
Qena WTP	New line	600	8	10	6	60	**4.50**	?	417	?	25	NA
Naga Hammadi WTP	2 x 400 LPS	800	10	10	6	60	**4.80**	?	417	?	25	NA
	BW position max		9	10	6	60	**5.33**					
Deshna WTP	2 x 200 LPS	400	6	10	6	60	**4.00**	?	417	?	25	NA
Qeft WTP	"OLD" 2/4 filters operated	100	2	6	5.6	33.6	**5.36**	4407	110	**131**	**12**	NA
	"NEW"	100	2	8	4	32	**5.63**	4407	100	**138**	**11**	NA
Qouz WTP	"OLD"	100	4	7.7	6	46.2	**1.95**	2645	220	57	17	NA
	"NEW"	200	4	7.9	4.6	36.34	**4.95**	?	225	?	22	NA
Compact Units		25	3	0.9		2.54	**11.79**	?	28	?	39	NA
	BW position		2	0.9		2.54	**17.68**					

3. SUMMARY OF WTP WEAKNESSES & RECOMMENDATIONS

Table 2 : WTP Weaknesses and Recommendations - Summary

Process	Troubleshooting in general	Comments	Short term recommendation (GTZ training programme)	General recommendation
WTP Process in general	"Old fashion" process design and design parameters			Design to be subcontracted to specialized company
	Copy and paste technique for WTP design	Mistakes often repeated / O&M experience not considered	**WTP design training to be organised. Training support to be proposed to the National design company. ????**	Existing WTP extension plan to be reviewed and updated
		Cost efficiency of new WTP questionable		
	Location of the intake not always appropriate	High risk of contamination		Intake location to be reviewed
	Design parameters variable in same WTP due to different design parameters for different process lines	Operation difficult to monitor without access to basic design parameters	**Redaction of WTP trouble shooting manual including O&M activities and contingency plans + general design parameters**	
	Process not adapted to raw water characteristics	Low turbidity - high algae - NOM contents		New process to be studied (low raw water turbidity - DBP, etc.)
	Design criteria questionable	Location of intake – pre-chlorination - limited chemical used - etc.		Pilot WTP to be tested (contact coagulation - direct filtration - membrane filtration - etc.)
	Quality of infrastructures and equipment	Contractors to be supervised	**Training of operators for the temporary and final commissioning of construction works** **Redaction of manual for minimum recommended standards in water works**	
	WTP in general poor condition	Lack of financial resources / Direct negative impact on treatment process		**"Rapid" investment plan for all WTP to be defined covering technical and financial aspects - Detailed WTP assessment - rehabilitation & investment plan**
	Standardisation policy not existing for equipment		**Standardisation policy to be developed (equipment - specifications - etc.)**	

	Manual operation and follow-up of WTP		**Standard follow-up sheets to be prepared - follow-up of indicator parameters**	Automation - regulation
	General process not optimised - Monitoring of the WTP limited	Low efficiency - water quality questionable	**Full diagnosis of WTP required based on laboratory analysis - Optimisation of WTP process units**	
	WTP used on "OFF / ON" basis	Negative impact on WT process		Automation - regulation
	WTP operated above capacity	Limited storage capacity at WTP and in the network		Rehabilitation - extension of water capacities
	Water treatment plant manual and documentation not available		**Listing of documents to be prepared by operator - research on Internet** **Reference bibliography to be provided by project (refer to technical report) - Access to Internet for operators**	
	E&M equipment in poor condition	Raw water - treated water pumps - dosing pumps etc.		Rehabilitation required - Automation - regulation + security devices to be installed
Pre-chlorination	Chlorine questionable	DBP ???	Use of KMnO4 to be evaluated in Jar tests (test to be preformed during the laboratory expertise)	Detailed study required - use of KMnO4 or other oxidants
				Detailed study of taste / odour - eventually DBP
	Chlorine losses in atmosphere - algae resistance to chlorine		Jar testing - Break point chlorination - Min FRC at end of sedimentation tank / filter O&M to be intensified (mainly sedimentation tank)	
	Contact time limited or not exploited			Injection point to be reviewed if possible / jar test results to reduce C and Increase T
	Flash mixing	In general appropriate - injection in main inlet pipe		
	Dosage monitoring	Follow-up by lab parameters only	FRC between treatment process units to be monitored	

Coagulation - flocculation	Flash mixing very poor		Injection point to be reviewed / dilution factor to be improved if possible with existing pumps	Static mixer to be considered
	Dosage	Jar test results not applied on WTP - Confusion between conventional WTP and direct filtration WTP	Review aluminium sulphate dosage - jar testing	
		No raw water meter - No follow-up of concentrate solution - No control of flow of dosage pumps	Control of dosage pump flow - density & quality of coagulant concentration - follow-up of specific parameters on WTP Follow-up of indicator parameters required	
	Flocculation parameters fixed	Hydraulic flocculator - RPM of EM flocculators not modifiable		Modernisation required
Sedimentation	Design parameter from 1 to 2 m/h not standardised even within 1 WTP	O&M of different process line difficult	Min. design criteria to be provided to the operators (refer to technical report)	
	Short-cut (temperature - wind - construction defaults)		Hydraulic test of sedimentation tank	Rehabilitation required
			Reduction of flow - Increase of aluminium sulphate dosage	
			Introduction of indicator parameters to be controlled	
			Use of polymer - PAC - etc. (test to be performed during the next WTP expertise)	
	Sludge removal not optimal	Anaerobic decomposition of organic sludge		Rehabilitation required
	O&M heavy	Sedimentation tank to be completely emptied - O&M requiring losses of large water quantities		
Filtration	General very poor condition - flow distribution difficult to control between filters	Filter bottom - gutters in poor condition		Rehabilitation required
	Constant flow - constant level operating system not working		Filters to be transformed to constant flow - variable level on a temporary basis	To restore automatic regulation system as urgent measure

			Specific training session about automation - regulation of constant flow - constant level filters	
	Follow-up of filtration process	Not existing - outlet of all filters only	Introduction of guide-line parameters to be controlled on each filter	
	BW procedure to be optimised		Introduction of guide-line parameters to be controlled on each filter	
	Quality of sand	Cu - D10 & D60 to be checked	Sand to be tested (guide-line to be provided during the next WTP training session)	
Disinfection	General condition very poor			Urgent rehabilitation required
		CT not considered		
	In line follow-up questionable			
	Flash mixing	In general appropriate - injection in main inlet pipe		
Chemical dosage	General poor condition			
	Design of dosage facilities not according to standards			Urgent rehabilitation required
	Chemical arsenal limited to Al sulphate & Chlorine	Al - corrosion - TOC - DBP issues not considered	PAC - polymer - etc to be used	
	O&M questionable	Control of dosage parameter / chlorine dosage over the flow meter capacity	Follow-up of treatment indicators	
	Safety standards not respected (chlorination)			Urgent rehabilitation required
	Corrosion parameters not considered		Follow-up of treatment indicators	
Storage	Limited capacities at WTP	C*T questionable	Follow-up of FRC and CT	
		Operation of the WTP on a off / on basis		
	O&M not performed		Guide-line for O&M of storage reservoir	
	Level monitoring not existing			Automation - regulation to be installed

Metering / flow control	Not existing / not working even for new WTP	WTP efficiency not monitored	Flow control to be included in the "urgent" investment plan	
		O&M programme improvised		
		Chemical dosage follow-up difficult		
	Flow distribution between process line - structures - etc. poor	Negative impact on treatment process	Regulation system to be included between process lines	
Laboratory	Standard list limited to few parameters - list incomplete	Detailed monitoring of WTP efficiency / trouble shooting impossible.	**Laboratory training course, including detailed diagnosis of WTP process**	Laboratory to be improved - process follow-up parameters
	Standardisation of equipment - methods not existing			Standardisation to be proposed - Reference laboratory in Qena WTP - Field kits in other WTP to be considered
	Limited capacity in terms of equipment and reagent	Aluminium - TOC - corrosion - diagnosis of process unit not considered		
	Laboratory technician = reference staff for WTP process monitoring		**WTP training course, including follow-up of treatment process units**	
State of infrastructures	Poor in general	Direct negative impact on treatment process Short-cuts - Residence T reduced		Rehabilitation required
Staff	Staff important - skills limited	Operation of WTP = routine	**Redaction of risk information & assessment manual**	
		"What" and "where" generally identified but "Why" not clear and "How" often not possible	**WTP training session N° 2 required**	
			Training of identified "trainers" in Qena - preferably abroad	
	No exchange / contact between WTP while problematic very similar			
Training (summary)			Technical documentation - users manual to be sent to WTP - Listing to be prepared by local operators	January - February 2008

	Reference bibliography at project office + operator level	January - February 2008
	Elaboration of guide-line WTP procedures - translation	January - February 2008
	WTP training follow-up N° 2 - Laboratory technique and WTP optimisation - test of new chemicals - etc.	March - April 2008
	Detailed plan assessment and “rapid” investment plan	March - April 2008
	Automation / regulation of filters	
	Training of trainers	
	Inter-WTP exchanges on regular basis (technical meetings on specific issues)	
	Training regarding temporary and final acceptance of works	

4. SUPPORT FOR TRAINEES AND SLIDE SHOW

Annexed document – support for trainees.

Annexed CD – slide show.

5. PICTURES

Annexed CD - pictures.

6. JAR TESTING (GUIDELINE)

Sludge retention profile

- Drain filter
- Collect samples in min 3 locations
  - 0 to 5 cm
  - 5 to 15 cm
  - 15 to 30 cm
  - 30 to 45 cm
  - 45 to 60 cm
  - Etc. if needed.
- Place media samples in marked baggies
- Wash the filter (backwash procedure as designed)
- Drain filter
- Repeat step 2 and step 3.
- Prepare a 50 ml test sample from each bag
- Place media sample in wide-mouth 500 ml flask
- Add 100 ml of tap water and shake for 30 seconds
- Drain water into a 1 l beaker
- Repeat washing procedure 4 more times
- Measure and record turbidity of wash water
- Multiply results by 2 (Turbidity for 100 ml media sample
- Plot the results

Conventional jar testing

The jar testing process can be summarized as follows:

- For each water sample (usually raw water) a number of beakers (jars) are filled with equal amounts of the water sample;
- Each beaker of the water sample is treated with a different dose of the chemical; other parameters may be altered besides dosage, including chemical types, mixing rate, time, etc.;
- By comparing the final water quality achieved in each beaker, the effect of the different treatment parameters can be determined; and
- Jar testing is normally carried out on several beakers at a time, with the results from the first test guiding the choice of parameter amounts in the later tests.

Jar testing should be done seasonally (temperature), monthly, weekly, daily, or whenever a chemical is being changed, or new pumps, rapid mix motors, new floc motors, or new chemical feeders are installed.

The following jar test procedure uses aluminium sulphate a chemical for coagulation/ flocculation in water treatment, and a typical six-gang jar tester. The results of this procedure can help optimize the performance of the plant.

First, using a 1,000 millilitre (ml) graduated cylinder, add 1,000 ml of raw water to each of the jar test beakers. Record the temperature, pH, turbidity, and alkalinity of the raw water before beginning.

Turn on the stirrers. This part of the procedure should reflect the actual conditions of the plant as much as possible.

- Operate the stirrers at a high RPM for 1 minute to simulate the static mixer. Then reduce the speed of the stirrers to match the conditions in the flocculator and allow them to operate for 30 minutes. Observe the floc formation periodically during the 30 minutes.
- At the end of the 30 minutes turn off the stirrers and allow settling. Most of the settling will be complete after one hour.
- Now, look at the beakers and determine which one has the best results (if any). If no results were noticeable, then increase the dosage for the next six jars. The best way to determine which sample is the clearest would be to check the turbidity of each beaker and record this information. Use a pipette to draw a portion from the top of each beaker one at a time not stirring or disturbing the sample.

(An underfeeding will cause the sample in the beaker to look cloudy with little or no floc and no settling or very little. An overfeeding will cause a dense fluffy floc to form and will not settle well, meaning it stays in suspension and floats)

Direct filtration jar testing

The objective of this test is to define the best dosage, eventually injection sequence of coagulant and/or polymer for direct filtration.

On conventional WTP, low coagulant or polymer dosages can be considered when raw water turbidity is very low (below 3 NTU). In this case effectiveness of the sedimentation units may seriously be compromised. Direct filtration has therefore to be considered.

Treated water quality shall definitely be ensured but small amount of flocs shall be produced to guarantee reasonable filter runs. The economics of the situation is also important. This would depend on the location of the plant and delivered cost of each coagulant / polymer.

The procedure is the following:

- Step 1 : Determine the raw water turbidity and record.
- Step 2 : Filter the raw water through Wattman #40 filter paper and record.
- Step 3 : Fill the six jars with raw water to the 1-liter (2-liter) mark and decide on coagulant and / or polymer dosages.
- Step 4 : Measure out the coagulant and polymer doses (syringes).
- Step 5 : With the Stirrer at maximum speed, pour in the coagulant and /or polymer (test to determine sequence); stir at maximum speed for 30 to 40 seconds.
- Step 6 : With stirring continuing at about 50 rpm take a 200 ml sample.
- Step 7 : Filter through Whatman #40 filter paper (discard paper).
- Step 8 : After 3 or 4 minutes of the stirring at 50 rpm take another 200 ml sample.
- Step 9 : Filter this later sample through Whatman #40 filter paper (discard paper).
- Step 10 : Read and record turbidity of all samples. Eventually plot data on arithmetic scale paper.

Strengthening Provision of Services
and Promoting Rural Sanitation Options in Qena, Egypt

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Water Treatment Plant
« O & M on the job » Training Session

December 2007 – Qena
Rodeco GmbH – GTZ

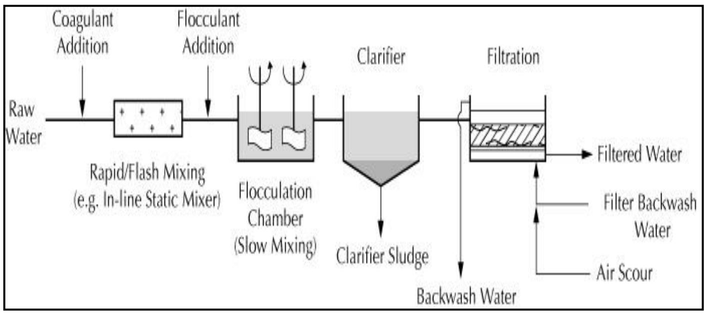
Table of contents

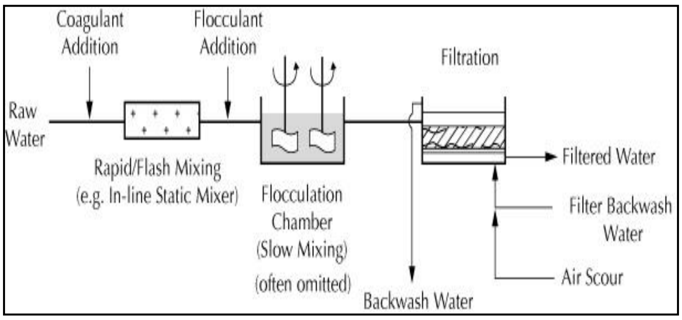
1 Objectives

- Outcome of site visits – 7 WTP - **WHAT & WHERE ?**
- Technical issues – background - **WHY ?**
- Further discussion on specific topics and recommendations - **HOW ?**

2 Water Treatment Plant

- Conventional WTP or Direct Filtration WTP ????

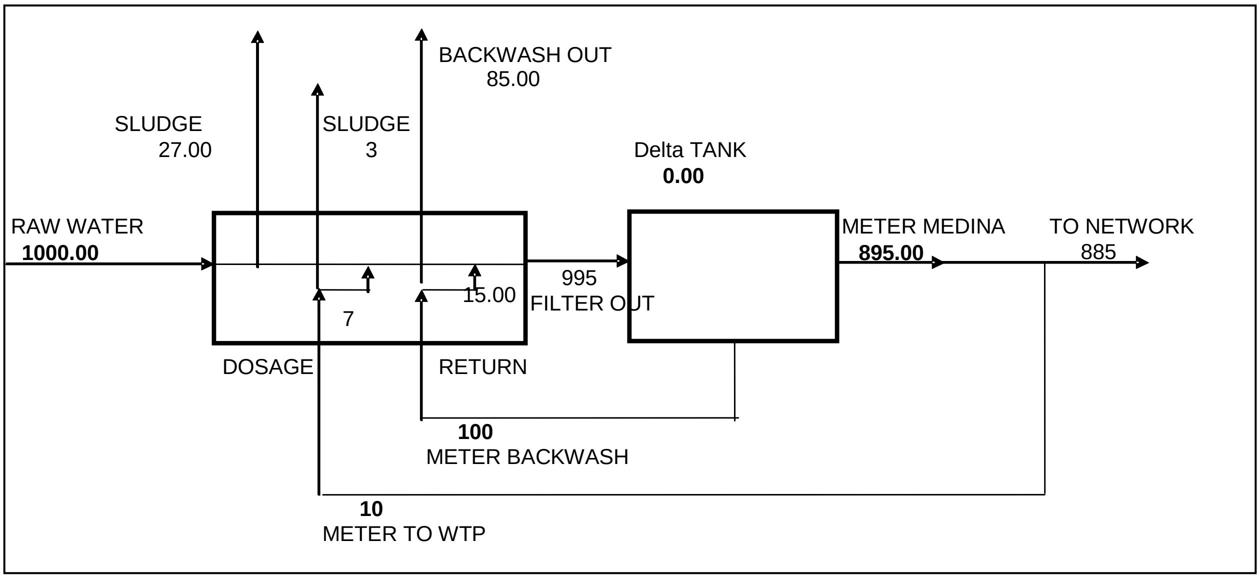




3 Water treatment process

3.1 Flow Metering

- **Follow-up of O&M of E&M equipment**
- **Dosage of chemicals**
- **WTP efficiency**
  - Conventional WTP η > **95%**
  - Direct filtration η > **90%**



3.2 Pre – chlorination

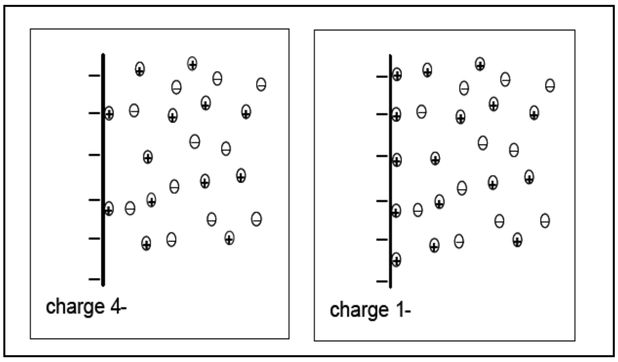
- ☺ **Biological growth control**
- ☺ Colour removal
- ☺ **Coagulation enhancement**
- ☺ *Metal precipitation*
- ☺ *Odour – taste – organic matter reduction*

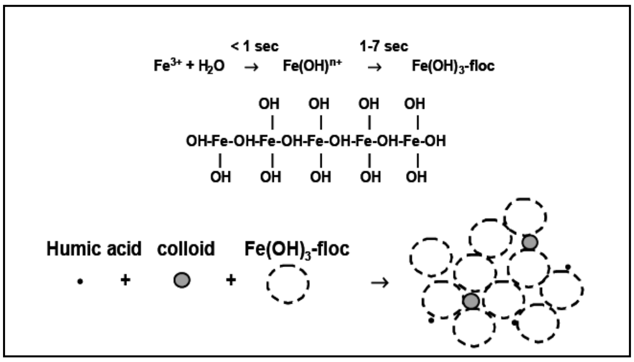
- 😐 **Min. Chlorine at outlet filter – Acceptable chlorine after sedimentation**
- 😐 **Avoid losses of chlorine in atmosphere**
- 😐 **Contact time required** – Jar tests (> 30 min in some applications)
- 😐 **Flash mixing required**

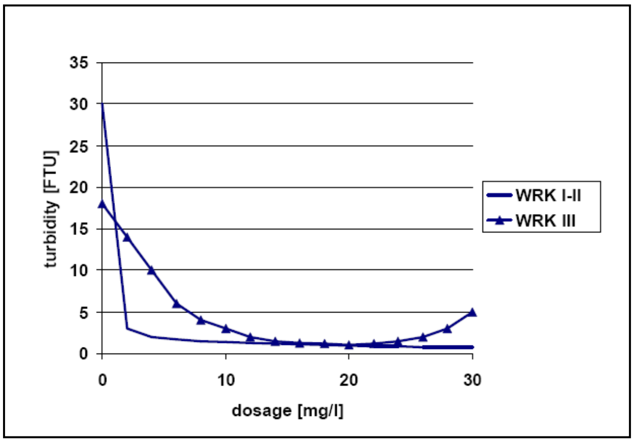
- ☹ Disinfection By - Products

3.3 Coagulation

- Mechanism
  - Electrostatic coagulation & Precipitation

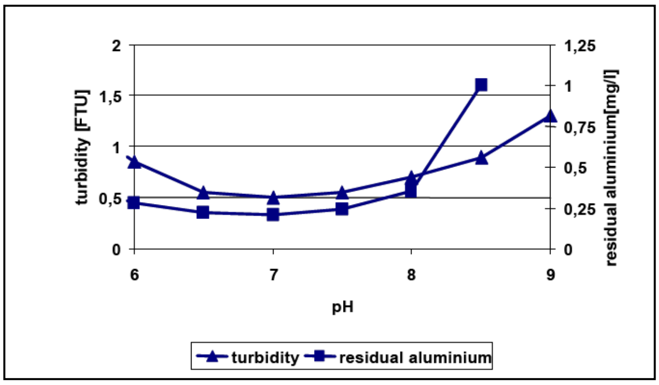




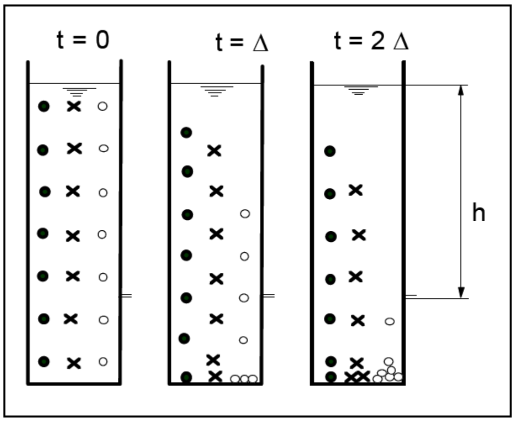


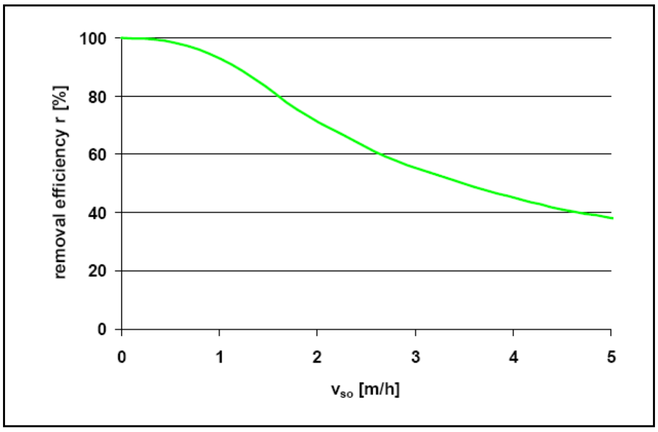
3.4 Jar test

- Coagulant type
- **Coagulant dosage**
- Injection sequence
  - Pre-chlorination
  - **Polymer**
- Mixing process
  - Coagulation
  - Flocculation
- **NTU** - Al residual – **pH**
  - For aluminium sulphate usually 5.5 to 7.5
  - Aluminium guide-line is 0.1 mg/L as Al
  - 1 mg/L of alum (as Al2(SO4)3.14H2O) will consume 0.5 mg/L of alkalinity (as CaCO3).



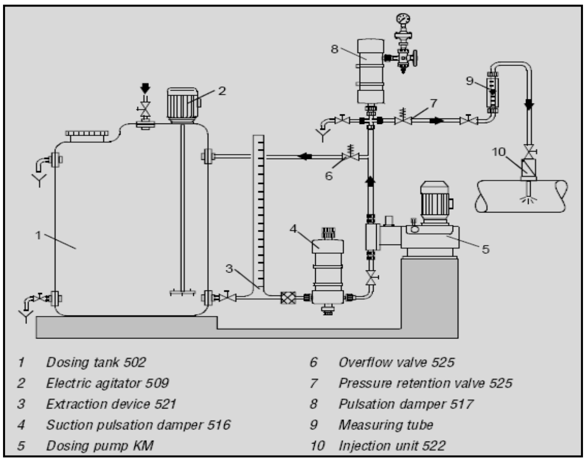
- Settling velocity & Removal efficiency (design – follow-up)





3.5 Dosage

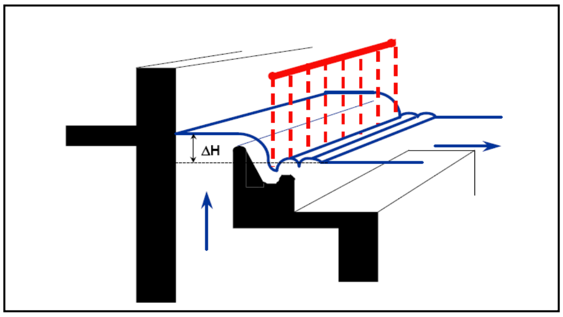
$$\frac{30\ (g/m^3)\ \times\ 200\ (l/s)\ \times 3.6}{10\ (g/l)} = 2160\ l/h$$

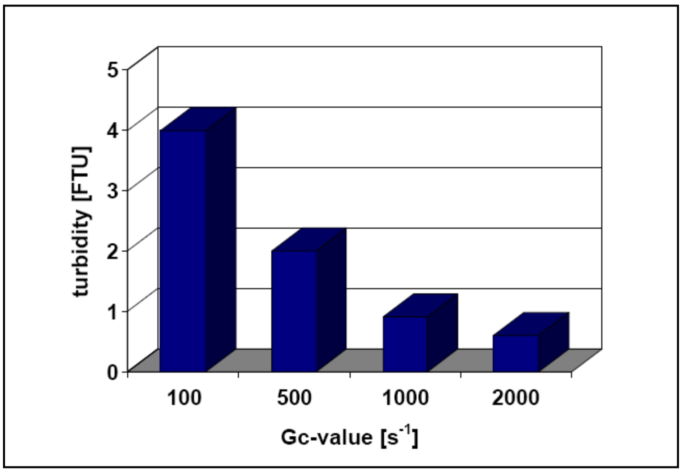


- Operation
  - **Jar test – optimal dosage**
  - **Flow raw water control**
  - **Concentrate solution control**
  - **Flow of dosage pumps**
  - **Lab. Parameters (pH, jar test, etc.)**

3.6 Coagulation & Flash mixing

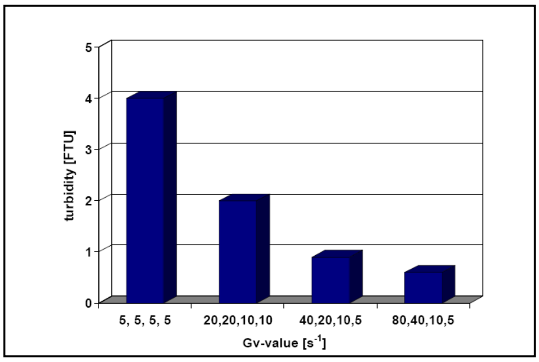
- **Velocity gradient (G) – 1500 s-1**
- **Time (< 1 sec)**





3.7 Flocculation

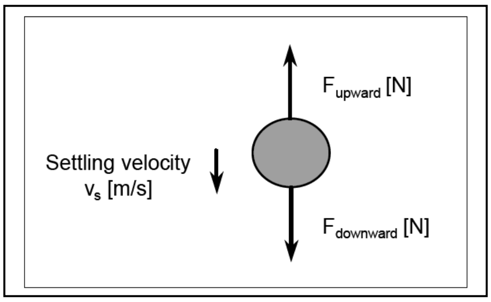
- Commonly 20 - 30 minutes for conventional clarifier
- 3 - 6 minutes if further flocculation continues in the clarifier
- 3 steps recommended (velocity gradient 100 – 50 – 10 s-1 / 3 – 3 – 10 or more minutes)

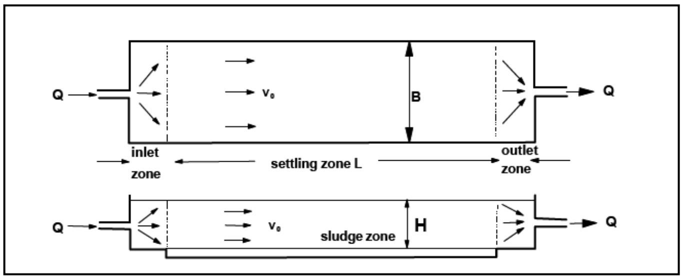


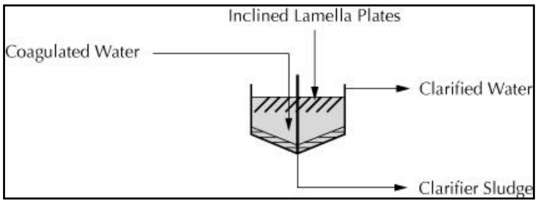
3.8 Sedimentation

- Conventional Clarifiers
  - Surface loading rate – 1 to max. 2 m/h (VS0)
  - Up to 5 m/h with polymers

Diameter [m]	type of particles	Settling time over30 cm	
$1\text{-}10^{-2}$	Gravel	0,3	seconds
$1\text{-}10^{-3}$	Coarse sand	3	seconds
$1\text{-}10^{-4}$	Fine sand	38	seconds
$1\text{-}10^{-5}$	Silt	33	minutes
$1\text{-}10^{-6}$	Bacteria	35	hours
$1\text{-}10^{-7}$	Clay	230	days
$1\text{-}10^{-8}$	Colloids	63	years

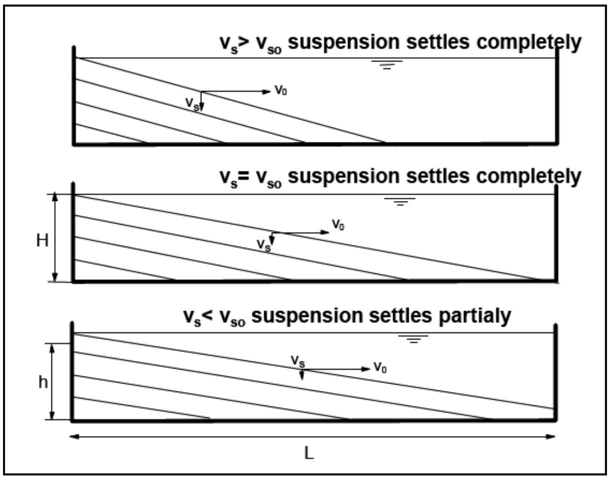




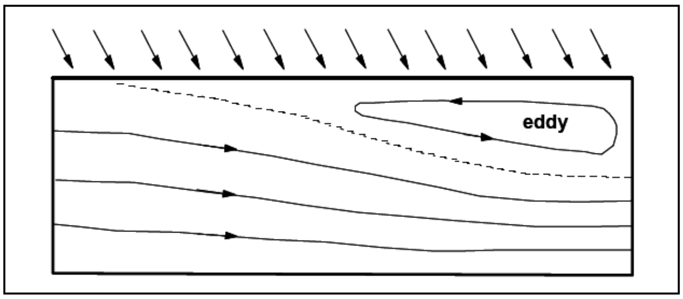


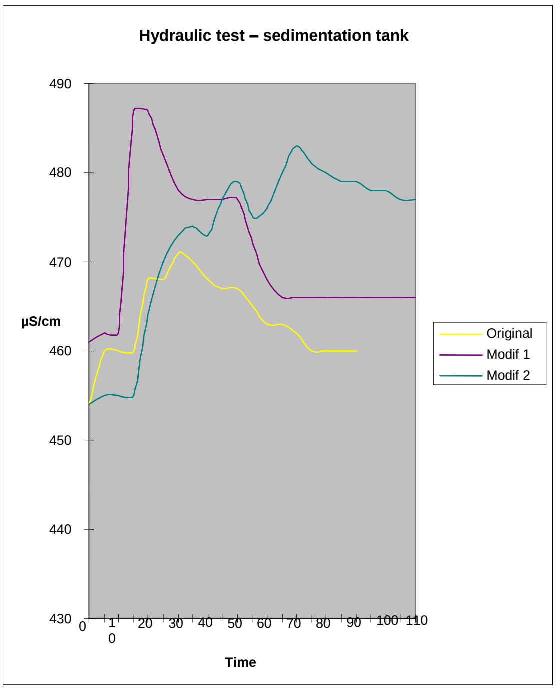
- Follow-up
  - **Less than 1.0 NTU 95% time - raw water less than 10 NTU, and**
  - **Less than 2.0 NTU 95% time - raw water more than 10 NTU.**

  - Surface loading rate

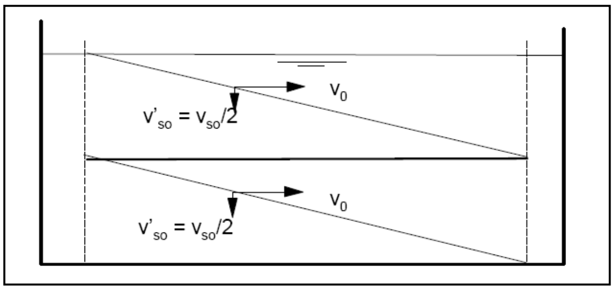


- Short circuiting
  - **Design / Wind & Temperature negative impact**



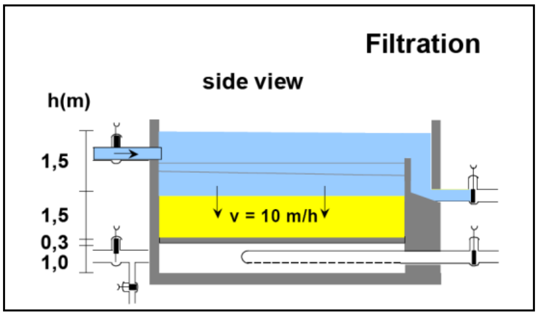


- Plate – Tube settlers
  - Surface loading rate – 5 to 20 m/h



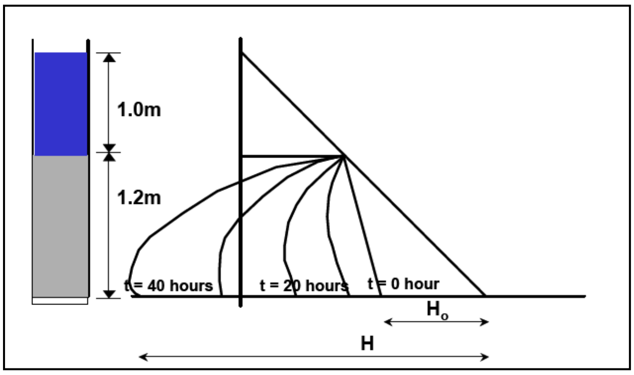
3.9 *Rapid Filtration*

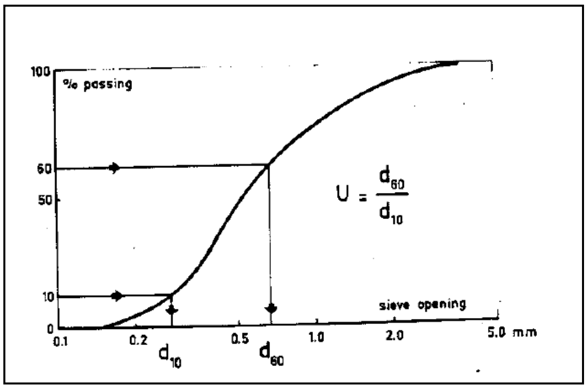
- Filter type
  - **Constant Flow & Level**
  - **Constant Flow – Variable Level**



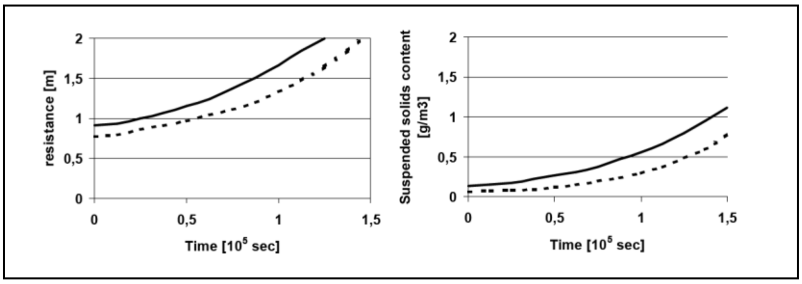
- Q = K and H= K … Why ? / Q ~ and H ~ … Risk !!!
- Q = K and H ~ … How ?

- Sand specifications
  - **$d_{10} = d_{eff}$**
  - d_{60}
  - Cu = d_{60}/d_{10}



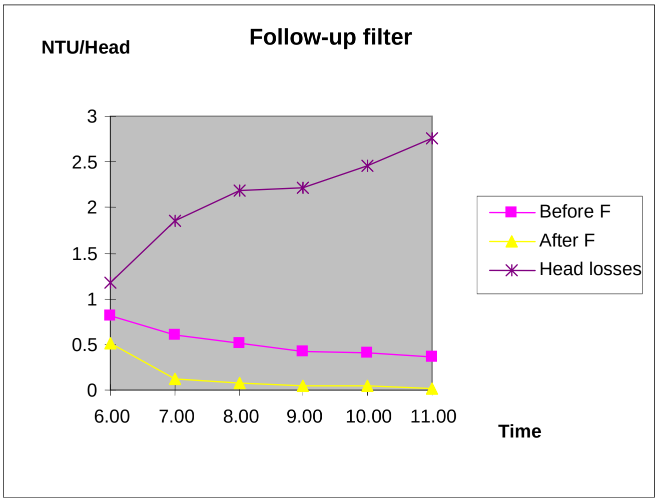


- Filtration - Design Parameters for Conventional filters – Uniform media
  - H = 0.6 to 0.8 m
  - Sand d10 = 0.5 to 0.7 mm – Cu = 1.3 to 1.6
  - H/d10 > 1000
  - **Filtration velocity**
    - **Nominal = Q / S = 5 to 7 m/h**
    - **Maximal = 1 filter out of use & 1 filter backwashing**
- Filtration Follow-up
  - **Each filter must be < 0.30 NTU for at least 95 percent of the time**
  - **“Goal” - < 0.10 NTU**

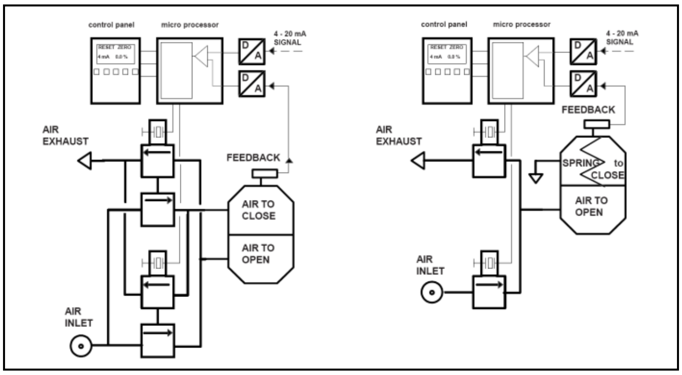


- Filtration & Backwash
  - Backwash conventional
    - 1) Air only 18 – 36 m/h – 3 to 5 min.
    - 2) H20 only 12 to 25 m/h (expansion 0 %) – up to 20 min.

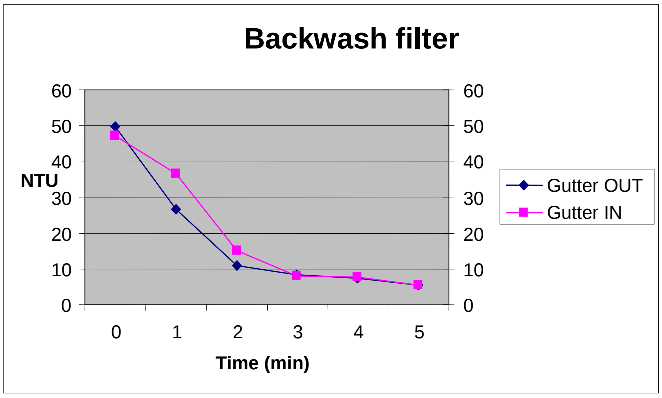
  - Modern practices
    - 1) Air only 18 – 36 m/h – 3 min.
    - 2) Air + H20 up to 25 m/h – up to 10 min.
    - 3) H2O only 35 to 55 m/h (expansion 20 %) – up to 10 min.



- Filtration Follow-up
  - Q = K & H ~



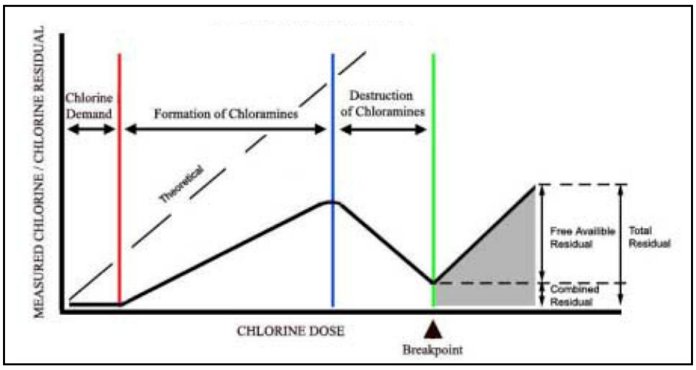
- **Optimisation**



- **Follow-up**
  (Sludge retention profile)
    - Before and after
      BW % BW Optimisation
    - Long term follow-up

3.10 Disinfection

- **Minimum free available chlorine (FAC) residual of 0.2 mg/L after 20 min. of contact time.**
- **No more than 1.5 mg/L**



- **C x t = constant (mg.min/L)**
  - Summary of C.t values for 99 percent (2 log) inactivation of various micro-organisms by disinfectants at 5oC
  - Surface Water Treatment Rule Requirements (90% = 1 log, 99% = 2 log, 99.9 % = 3 log, 99.99% = 4 log)

Micro-organism	Free Chlorine pH 6-7	Pre-formed Chloramine pH 8-9	Chlorine dioxide pH 6-7	Ozone pH 6-7
E. coli	0.034 - 0.05	95 - 180	0.4 - 0.75	0.02
polio 1	1.1 - 2.5	768 - 3740	0.2 - 6.7	0.1 - 0.2
rotavirus	0.01 - 0.05	3806 - 6470	0.2 - 2.2	0.006 - 0.6
G. intestinalis cysts	47 - >150	-	-	0.5 - 0.6
G. muris cysts	30 - 630	-	7.2 - 18.5	1.8 - 2.0

Free Chlorine concentration	Log removal of Giardia cysts ✓ ph = 7 ✓ T° = 20°C		
	1 log	2 log	3 log
< 0.4 mg/l	17	35	52
1 mg/l	19	37	56
1.2 mg/l	19	38	57
2 mg/l	21	41	62
2.4 mg/l	22	43	65

	Log removal	
WTP Process	**Giardia cysts**	**Viruses**
Minimum log removal inactivation	3	4
Conventional WTP credit	2.5	2
Remaining for desinfection	0.5	2
Direct filtration credit	2	1
Remaining for desinfection	1	3

- Retention time (t) = theoretical detention time x baffle factor
  - Baffle factors for use in measuring detention time

Condition	Factor	Description
Un-baffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.
Poor	0.3	Single or multiple un-baffled inlets and outlets, no intra-basin baffles.
Average	0.5	Baffled inlet or outlet with some intra-basin baffles.
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

3.11 Monitoring of WTP

- **Monitoring by treatment stage in a conventional process**

Parameter	Stage of Treatment				
	Raw Water	Coagulation	Clarification	Filtration	Disinfection & Supply
turbidity	X	X	X	X	X
temperature	X		X		X
pH	X	X	X		X
dissolved oxygen	X				
colour	X				X
organic carbon	X		X		X
conductivity	X				
aluminium			X	X	
alkalinity	X	X	X		
chemical dose		X			X
flow rate	X	X	X	X	X
head loss				X	
disinfectant C.t					X
disinfectant residual					X
pressure					X

- Monitoring WTP / Network
  - Surface Water Turbidity Performance Standards

Contaminant	Filtration type	Performance standard[1]	Determination of treatment technique violation	
Filtered water turbidity	Conventional filtration and Direct Filtration	0.3 NTU[2,4,5]	A treatment technique violation occurs if more than five percent of the composite filter effluent measurements taken each month exceed the performance standard values.	The turbidity level of representative samples of the filtered water must at no time exceed 1 NTU.[4,5]
	Slow sand filtration	1.0 NTU[2]	A treatment technique violation occurs if more than five percent of the composite filter effluent measurements taken each month exceed the performance standard values.	The turbidity level of representative samples of the filtered water must at no time exceed 5 NTU.
	Diatomaceous earth filtration	1.0 NTU[2]		
	Alternative filtration	1.0 NTU[2,3]		

■ Entry Point Turbidity Maximum Contaminant Level Determination

Contaminant	MCL	Determination of MCL violation
Entry point turbidity (surface water and groundwater directly influenced by surface water)	1 NTU [2,4] (Monthly Average) 5 NTU [3,4]	A violation occurs when the average of all daily entry point analyses for the month exceeds the MCL rounded off to the nearest whole number. A violation occurs when the average of two consecutive daily entry point analyses exceeds the MCL rounded off to the nearest whole number.

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