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Report on:

Optimisation of Water Treatment Plants

By:

Eric Goessens

January 2010

gtz

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الشركة القابضة لمياه الشرب والصرف الصحى

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

Optimisation of Water Treatment Plants

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RODECO CONSULTING GMBH

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<u>Cover page picture</u>: Floc retention profile – rapid gravity filter – Assessment and "on the job" training in Queft

Acronyms and Abbreviations

?	Data not available
B/W	Back-Wash
DBP	Disinfection By-Product
E&M	Electro-Mechanical
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
STE	Short-Term Expert
TOC	Total Organic Carbon
ToR	Terms of Reference
WT	Water Treatment
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 STE in Water Treatment in his second assignment to Qena within the frame of the TC project "Strengthening Provision of Services in Qena and Promoting Appropriate Rural Sanitation Options" between November 2009 and January 2010, to communicate the main findings and results and to propose recommendations regarding the possible optimization of the WTP in Qena District.

During this assignment, the expert supported the development of an "optimisation" process at each plant by carrying out on-the-job training of plant personnel, mainly at laboratory level, while assessing and testing the WTP. 6 large Water Treatment Plants were assessed, including possible cost savings, plant output efficiency and water quality. The optimization process and on-the-job training sessions mainly focused on pre-chlorination and related chemical requirements, coagulation and related chemical / energy requirements and finally filter backwash and running period and related water and energy requirements.

Coagulation / flocculation and filtration are important unit processes that should further be scrutinized to mainly optimize the use of chemicals and water within the WTP. The reuse of back-wash water was not considered as a priority. Other priorities regarding plant process are definitely more urgent and it would moreover require major investments and definitely increase work load and costs at plant level.

This report considers optimization issues and proposes recommendations for individual process units. Some general recommendations are also made at a managerial level to support and institutionalize the "optimization" process:

1. Design issues: "Optimization" of the WTP starts at design level. Design "bugs" can hardly be corrected considering O&M practices only.
2. Commissioning of the works: Commissioning should be done respecting technical specifications. Infrastructure and equipment should be operable and in good condition. This should supersede all "other" constraints.
3. Detailed assessment of "existing" plant: There is need to assess infrastructure and equipment plant deficiencies and propose an investment plan including priorities. It should be remembered that replacing equipment should consider process constraints and optimization.
4. Facilitate optimization of the plants: An optimization facilitator should be identified at central level.
5. Optimize plant operation: Plant performances should be monitored and deficiencies identified:
    a. Avoid unnecessary waste (consumables, energy, water) by providing daily plant monitoring and appropriate maintenance.
    b. Identify "short term" and "long term" plant deficiencies, provide evidence, test and propose corrective measures.

Issues to be considered regarding the general infrastructure and asset renewal or refurbishment have also been discussed with plant personnel and with the Team Leader and are listed in chapter 8.

In the expert's recommendations, the following should be noted:

Effective optimization can only be considered if "normal" plant and process conditions are restored. A filter without sand, full of mud or without automation device can hardly be optimized.

Figures are presented throughout this report to illustrate the optimization process but should be used very carefully as evidence will require further testing. Potential "saving" issues definitely require evidence and therefore further experimentation and process follow up to avoid possible misunderstanding between plant and management staff.

It should be noted that water treatment plant optimization is a long and routine procedure requiring "available" data assessment and multiple field tests to provide evidence. It is and should be the result of long, conscientious and routine work. Short term expertise can only provide training, recommendations and guidelines for plant optimization.

2 INTRODUCTION

2.1 Background of the Assignment

The project "Strengthening Provision of Services in Qena and Promoting Appropriate Rural Sanitation Options" aims at supporting Qena Company for Water & Wastewater (QCWW) 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.

The purpose of this report is to communicate to the stakeholders the findings and the recommendations made by the international STE in Water Treatment during his second mission regarding the possible optimization of the WTP in Qena District. This assignment is the logic continuation of the first WTP field mission in 2007 which focussed on assessing the current operating practices, identifying and providing appropriate 'best practice' operating standards and proposing operating improvements of the Water Treatment Plants by carrying out direct "on the job" coaching of selected personnel.

The STE started conducted his assignment between November 2009 and February 2010, split in two site visits in November and January. During this time, the STE was to

1) Support the development of a 'Process Optimisation Team' for QCWW by carrying out 'on the job training' of team members when carrying out optimization surveys, studies, assessments and testing on site.
2) Carry out optimization assessments on 6 large Water Treatment Plants with a focus on cost savings, plant output efficiency and water quality in the following key areas: Chlorination - Filtration/backwash (b/w) including b/w water re-use if viable - Chemical dosing
3) Make general recommendations for each plant covering: General infrastructure renewal or refurbishment - Plant and Asset renewal or refurbishment
4) Deliver a short presentation on findings to the Chairman and O&M Managers, QCWW.

8 plants were initially foreseen in the ToR but at the beginning of January 2010, Armant and Esna WTP were transferred to the Luxor Water Company. Thus, the WTP considered during this field missions are Qena ("new" WTP – Salhayat and "old" WTP - Homaydat), Naga Hammadi, Deshna, Quous and Queft. The 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 & flocculation, sedimentation, rapid sand filtration and finally disinfection.

The target WTP are summarised in the table below.

Table 1 : WTP

WTP in Qena	WT line – date of operation	Nominal capacity (lps)
Qena WTP – Salhayat	New line 1998 Extension 2009	600 = 2 x 300 900 = 2 x 450
Qena WTP - Homaydat	2 New lines under construction / rehabilitation Direct filtration Conventional plant	 200 400
Naga Hammadi WTP	2 x 400 LPS – 1999/2007	800
Deshna WTP	2 x 200 LPS – 1998	400
Queft WTP	"OLD" - 2/4 filters operated – 1985 "NEW" - 1995	100 100
Quous WTP	"OLD" – 1981 "NEW" – 1998	100 200

Plants are generally operated at nominal flow : 880 lps – Naga Hammadi, 1050 lps – Salhayat, 400 lps - Deshna, 200 lps - Queft and 300 lps - Quous during day time and at ½ capacity at night.

The plants in Naga Hammadi, Deshna, Queft and Quous have not been rehabilitated since December 2007 (STE's first "Water Treatment" field expertise). Major process deficiencies have been noticed / confirmed. Although the plants are reasonably operated and maintained, the plants' general condition jeopardizes optimisation work.

The plant in Qena – Homaydat is currently rehabilitated / extended with the construction of a new 200 lps direct filtration unit – 8 filters, the rehabilitation of 3 lamellar clarifiers to a capacity of 440 lps and the construction of 5 new filters 400 lps. The capacity of the plant in Qena – Salhayat has been extended. A "mirror copy" of the existing unit has been recently built extending the capacity from 600 to 1500 lps (2 x 300 + 2 x 450 lps).

The following report outlines the main activities undertaken, discusses main findings and results, and proposes recommendations. A bullet point format is used to facilitate the follow-up by the WTP staff and local partners.

2.2 Site Activities

The mission started with a site visit of the treatment facilities and a discussion with the plant manager and the laboratory technicians. Subsequently, during approximately 1 week per plant, possible optimization was investigated and discussed with the plant staff based on field experiments and laboratory tests.

Issues discussed covered:

1. WTP design parameters and process limitations.
2. Design parameters were discussed with QCWW engineers mainly based on the Homaydat WTP available drawings (extension and rehabilitation). Basic calculations were made to identify process limitations. O&M constraints were discussed considering the proposed design.
3. Process parameters were discussed with the laboratory technicians. Field tests & laboratory analysis were performed to further identify bottle necks, limitations and optimization possibilities. Field visits to new direct filtration plants (Quena and Queft) and conventional WTP ("Sugar Factory" and industrial area of Queft) were organised to further discuss design and O&M parameters / constraints.
4. The new Salhayat plant was scrutinized regarding O&M constraints. The O&M staff has been involved in the field experiments and discussions.
5. Optimization process and "on the job" training sessions mainly focused on:
    a. Pre-chlorination and related chemical requirements.
    b. Coagulation and related chemical / energy requirements.
    c. Filter backwash and running period and related water and energy requirements.

The expert supported the development of an "Optimisation" process at each plant level by carrying out on-the-job training while assessing and testing the WTP. As listed above, 6 large Water Treatment Plants were assessed, including possible cost savings, plant output efficiency and water quality with a focus on chlorination - filtration/backwash (b/w) and chemical dosing.

The reuse of b/w water was not considered as a priority. Other priorities regarding the plant process are definitely more urgent and it would moreover require major investments and also increase work load and costs at plant level.

3 Approaches to Plant Optimization

Optimization is to be understood as:

- **Achieve high quality of finished water on a continuous basis.**
- **To attain the most efficient or effective used of the WTP.**

Remember:

Process units should be evaluated one by one but it is important to have an overall view on the plant performance. Optimization of certain components will have consequences on the others.

Water quality (laboratory issues) and O&M procedures and workload should be simultaneously considered.

Procedure / methodology to be followed:

- Common sense to be used.

Findings:

The best way to observe plant operation is to follow the same route as the water, start with the raw water intake and go through the plant to the treated water reservoir. The operation of each unit should be observed, noting obvious problems, and possible solutions should be studied and discussed.

The next step is routine measurements and sampling to assess the performance of each unit, together with bench scale testing if needed.

A study of the design of the plant is essential before making observations. Plant problems are often directly related to design issues.

Common sense should be used – a basic and simple approach is recommended.

Example : Modular prefabricated WTP in Queft – Aluminium dosing parameter

Monitor aluminium sulphate dosage parameters at WTP level:

(1) Measure the density of concentrated aluminium sulphate solution with a density meter and compare with a calibration curve – conclude. Prepare a calibration curve if not available yet. The calibration curve should be prepared considering the current "operation" parameters.

(2) Determine the dosing flow by dosing from a calibrated pot – conclude. The flow of a piston – diaphragm type pump is not influenced by reasonable manometric head differences.

(3) Examine coagulation – flocculation parameters on the plant – conclude.

Example : Quous WTP – Evaluation of total WTP flow and flow distribution between the WTP lines

Reasonable plug flow can be expected at hydraulic flocculation level.

*(1) Measure the raw water flow velocity by measuring the velocity of a floater (length travelled by unit of time), multiply by a 85 – 90 % factor to get the average velocity in m/h in the channel. Measure the average perpendicular surface (width of the flocculator channel in m * depth of water in m). Multiply the average velocity by this surface = flow in m^3/h, divided by 3.6 = flow in lps.*

(2) Proceed with the other hydraulic flocculators and conclude re: total flow & flow distribution and related process parameters.

- Participatory approach involving laboratory technicians, O&M staff.

Findings:

The optimization process has to be performed by a “multidisciplinary team” including laboratory and O&M technicians, and preferably WTP engineers under the leadership of a “polyvalent” water treatment engineer.

The participatory approach should also include QCWW staff involved in the planning, follow-up and commissioning of new WTP infrastructures and equipment. Optimization starts at design stage!

Recommendations:

Producing the best quality finished water and working at nominal / maximum capacity begins with the decision of water department managers to improve plant operation and provide the necessary resources.

Meeting the needs of required equipment, supplies and qualified personnel will require the authorisation and support of top management including the head of the water department, the engineers in charge of water treatment and those empowered to allocate funds and personnel.

Improved treatment plant operation does not just happen in response to these decisions; it is the action of many motivated people throughout the water department that makes it happen.

Optimising the performance of an existing water treatment plant must be done mainly by those who operate it, from managers of the water department to the operators and general workers in the plant itself.

Remember:

Competence and experience limitations of each team member should not be considered as a “weakness” but as a component of the optimization process.

Strong compartmentalized / hierarchic utility services definitely jeopardize the optimization process.

- Information gathering and processing:
  - Visual observations and data trending (daily – weekly and monthly reporting). Good plant records are extremely important to improve plant performance.
  - Check-up of plant design criteria against “current” situation.
  - Evaluation of performance such as chemical dosing – coagulation / flocculation – sedimentation – filtration and of course disinfection.
  - Supplementary field measurements related to the “assessment & optimization” process.
  - Experience exchange between WTP.

Findings:

The assessment and optimization process should be performed at WTP level by the plant personnel as it can vary from plant to plant.

Developing a specialized “Assessment & Optimization” mobile team at central level makes little sense. This process is recurrent; it directly benefits the plant and the plant’s personnel. It requires a good knowledge of the WTP and its history, including the history of the different optimization processes and should therefore be carried by the plant personnel itself.

Nevertheless, experience exchange is important and will maintain a dynamic as WTP optimization should be considered as a “recurrent” operation. A “mobile” person should therefore preferably be identified at central level to catalyse, encourage and monitor the optimization process at the level of the different WTP. This person should also form the link which is too often missing between O&M and Laboratory services at local level.

WTP management personnel should support and encourage the optimization process, and make sure that recommendations are implemented and respected once evidence is provided. WTP procedures should be adapted accordingly.

The reference “mobile” person should have the authority – in collaboration with each plant manager – to approve “optimization” experiments and tests, to validate results and authorize plant’s modifications.

Recommendations:

It is essential to have a technically trained person to be directly responsible, to lead work and to train the operators in the aspects of effective plant operation. Operators are rarely qualified for laboratory work, in the use of equipment such as jar-test stirrers, turbidimeters and pH meters, or qualified to make use of information from the laboratory to improve performance.

It is valuable to have an engineer as team leader, an engineer with relevant training who fully understands the physics and chemistry of treatment operations, follows manufacturers' instructions for equipment operation and maintenance and uses published material on plant operation and improvement.

Remember:

Optimization can easily be quantified. Direct benefits of the optimization process should partly return to the plant and its personnel.

- Decision making :
    - Optimization will require “authorization” for temporary modifications of the WTP process and further field testing before evidence is provided.
    - Optimization will require decision making afterwards.

4 OPERATION OF THE WTP FACILITIES

4.1 PRE-REQUISITES TO WTP OPTIMIZATION

Optimization of WTP requires the following:

1. Standard operating procedures: Standard operating procedures should be available and strictly respected by the operators, including nightshift operators. Respect of procedures should be encouraged and controlled by the management personnel.

   Standard procedures should be elaborated by the plant manager in cooperation with the laboratory and O&M staff. Procedures should be adapted after an optimization "campaign".

Findings:

All QCWW WTP are currently operated manually, some of them even "physically". The operation of raw water pumping, sludge removal, filter backwash, etc. facilities is left to the appreciation of the O&M staff. Automation systems of new plants are actually partly or totally by-passed due to conception problems (Salhayat WTP).

The laboratory staff focuses on dosing requirements and water quality monitoring only. The operation of the WTP is compartmentalized: The O&M staff is unable to perform simple laboratory tests, such as FRC and turbidity, while the laboratory staff has to call O&M staff to operate simple valves for water sampling.

Recommendations:

The optimization process should start with the modification of "habits" and "believes".

WTP management requires "technicians" with a polyvalent background making the link between the conventional laboratory and O&M departments.

Job descriptions should be elaborated to allow interaction between "O&M" and "Laboratory" procedures and encourage some degree of "polyvalence".

Training should be provided to encourage "interaction".

2. Adequate sampling and adequate process monitoring: Sampling of water at all process stages should be possible for laboratory analysis and process monitoring. The laboratory should be equipped with appropriate equipment for routine analysis at plant level and reference at central level.

Findings:

Adequate sampling is not possible at all process stages. Sampling of raw water requires sometimes unnecessary "travels" and related costs. When possible at all, sampling of individual filter effluent needs control valves to be shut off, a manipulation which requires the presence of the O&M staff and occasions shocks in the filtration process.

Portable laboratory equipment is not always available for simple "onsite" analysis. O&M staff is not involved in water quality monitoring. Online equipment is not available.

Recommendations:

The optimization process definitely requires:

Sampling facilities to be available and easily accessible at all process stages.

Reliable portable laboratory equipment to be available (FRC & TRC, NTU, Colour, Residual aluminium, pH, etc.); some of it should be used directly by the O&M staff on a routine basis.

Parameters (Oxydability $KMnO_4$, Colour, etc.) and equipment for process optimization should be made available at laboratory level.

The central laboratory with its "high tech" equipment should provide support to provide reference analysis and fine-tune the optimization process.

3. Rate changes monitoring and calibration: Operation of a WTP requires correct information on the different flows within the treatment plant, mainly the raw water, the treated water and the chemicals.

Findings:

Raw and treated water meters are either not existing or not working. The WTP are operated based on the operators' experience. Chemicals calibration devices / columns are not installed.

Recommendations:

The optimization process definitely requires the monitoring of the different WTP flows. Calibration and cross-check should be done on a routine basis.

The settings of the WTP parameters should consider "real" flows. Evolution of the flows should be recorded to evaluate possible problems or deterioration of equipment.

On a long term basis, water meters should be installed for proper monitoring of the plant performance.

Remember:

Should water meters not be available, simple flow measurements and calibration can be made considering - portable ultrasonic flow metering – volume versus time in empty reservoirs after maintenance (raw water pumps), in filters (backwash pumps), in preparation tanks or at the outlet of pipes (dosing pumps), etc.

Example : Quous – estimation of the total WTP flow and the flow distribution by measuring surface velocity in the plug flow hydraulic flocculators with a floater, a watch and a measuring tape.

7 m travelled in 25 sec – flocculator width is 0.455 m and the depth of water is 0.89 m.

*7 / 25 * 3600 m/h * 0.455 m * 0.89 m * 90 % = 367 m³/h /3.6 = 102 lps (expected 100 lps)*

4. <u>“As per design, possible operation” and “As per optimum operation, design” :</u>

<u>Findings:</u>

The WTP process should be understood and modelled in laboratory “optimization” experiments (jar test).
The plant should be “operable” as per design, mainly at filtration level (constant flow / constant level filters) with a minimum of automation equipment. Deficient material / equipment (no sand in the filter, no control valve and level control, damaged under-drains, etc.) should be rehabilitated.
Identified O&M constraints should be reported and considered for modifications of existing WTP and certainly during the design and construction of new plants: sludge removal, automation regulation of the filtration units, systematic filter to waste to be installed, etc.
Designers have apparently limited experience of water treatment plant operation and operators do not have any input into the conceptual or final design of their plant. Involving operators at design stage could eliminate or at least greatly alleviate many problems, but this is currently not the case and probably will not be for some time to come. Operators, therefore, must do the best with what they have.

<u>Remember:</u>

Design acceptance and work commissioning should respect basic principles: “Plant design considering plant operation” and “Plant commissioning if plant operable”.
Keep in mind that the “best designer” is an engineer with an “operator” background / experience.

<u>Recommendations:</u>

As per design operation should definitely be restored. This mainly concerns the filters: constant flow, constant level systems, filtration and backwash capacity and efficiency, etc.
Modifications of existing plants and construction of new plants should consider O&M experience and constraints.

<u>Development of an “ASSET PROCUREMENT” plan at managerial level:</u>

This plan should be a sub-plan of the TMP (Total Management Plan). This plan should give the guideline to establish and implement effective infrastructure procurement and procedures, and to develop associated documentation. Asset procurement involves infrastructure project delivery and covers the design, construction and asset handover phases. It concerns new and rehabilitated infrastructure.
The outcomes from effective asset procurement include the delivery of infrastructure at the lowest life cycle cost and just in time delivery, within quality and budgetary specifications to meet the requirements of the utility and the customers.
Internal policies should be developed regarding purchasing, infrastructure delivery method for individual and group of projects (D&C – BTO – BOOT), design standards (concept and detailed design) and construction and rehabilitation standards, including the supervision of works, commission and handing over of assets and evaluation of projects.

5. Operator application of concepts:

Recommendations:

Optimization concepts should be elaborated considering a participatory approach including all plant personnel. Once evidence is provided, optimization concepts should be applied, respected and controlled by the plant personnel, mainly the operators.

Plant operators and laboratory staff should be trained in the fundamentals of water treatment plant operation – in the operation of their specific plant – and understand raw water characteristics at their plant and the quality standards to be met, but mainly know their own specific job, know what they are supposed to do and which information is to be collected or calculated and recorded.

Plant operators and laboratory staff should receive proper supervision.

The above pre-requisites should be reinforced at utility level. Laboratory, O&M and managerial staff are concerned. Such pre-requisites will require minimum "investment".

4.2 VISUAL OBSERVATION AND DATA TRENDING

1. Data to be collected and presented in spreadsheets to ease analysis. Computers have been made available at laboratory level.
   a. Turbidimeters and instruments / process equipment (dosing pumps) to be calibrated and cross-checked.
   b. Water quality trends - Raw water parameters versus treated water parameters (NTU – pH – etc.)
   c. Pre-chlorination trends:
      i. Raw water turbidity versus pre-chlorine dosage.
      ii. Calibration of chemical feeders.
   d. Chemical dosing trends :
      i. Raw water turbidity versus coagulant dosage.
      ii. Clarified water turbidity versus coagulant dosage.
      iii. Calibration of chemical feeders.
   e. Increase performance monitoring such as turbidity (Raw – Settled - Individual filter) and complementary tests.
2. Laboratory - O&M and financial parameters to be correlated.

Recommendations:

Provide daily, weekly and monthly reports to include results and trends and related comments.

Provide specific reports detailing the optimization process. These reports can consider a process unit only or preferably the entire WTP. These reports will be required as "evidence" to support decision making.

Remember:
Correlate process "optimization" and financial issues. This will help the management personnel in their decision making.

4.3 PRE-CHLORINATION – CHEMICAL DOSING & COAGULATION

1. Pre-oxidation parameters to be controlled
   a. Dosage
      i. Accurate dosage
      ii. Immediate reaction to water quality and quantity variation
   b. Feed location(s)
   c. Flash and rapid mixing intensity
   d. Detention time
   e. pH (aluminium residual problematic)
2. Chemistry of coagulation to be evaluated:
   a. Type of coagulant / coagulant aid – pre-evaluation at jar-test level.
   b. Sequence of dosing – pre-evaluation at jar-test level.
      i. Better sequence can improve the performance.
      ii. Mixing too many chemicals can cause side reactions (fouling or clogging of injectors, etc.)
   c. Appropriate coagulant dosage – jar testing.
   d. Coagulant dosage versus WTP process (conventional plant versus direct filtration plant).

Recommendations:
Jar testing should consider "real" plant parameters (G-velocity gradient and T- Contact Time). Calculate plant parameters for different flows and adapt jar test procedure accordingly. Use chemical of the WTP as the operators do.
Jar test parameters should be adapted considering plant "reality" (refer to annex) for routine check-ups. Other jar tests should be performed to evaluate possible plant modifications for evidence.
Routine comparison of plant results and jar test results (pH, dosage, floc formation, sedimentation, etc.) should be performed.
Should aluminium residual be a problem, perform conventional jar test at different aluminium sulphate dosage – at different pH – followed by Whatman paper filtration. Analyse the residual aluminium versus coagulation pH and conclude.
The jar test procedure should indeed consider "optimum coagulation – flocculation" (size, formation, sedimentation, etc. of flocs) but also the "coagulation pH" and related "residual aluminium" problematic.

Perform routine analysis of FRC/TRC at plant level and at the inlet and outlet of the sedimentation tank and identify possible short-circuiting – at the outlet of each filter and identify possible abnormal chlorine consumption.

Avoid in any case waste of chemicals (leakages, etc.)

Remember:

Jar testing considering optimal parameters generally under-estimates the dosage required at plant level.

Chlorine demand on raw water should be established in jar tests to define operational dosage.

For jar testing purposes use the concentrated solutions from the plant and cross-check. Concentrated solutions can vary from time to time – the density value can be "disturbed" by the presence sludge, etc.

Examples : Pre-chlorination

Example: Salhayat – dosage parameters at plant level to be optimized considering intermittent booster pre-chlorine dosage (high algae concentration).

*As per plant information : 5 kg/h (dosing of pre-chlorine) / 600 lps (plant) / 3.6 = 2.31 mg/l with a FRC at the outlet of the sedimentation tank of 2.0 mg/l. Total consumption of chlorine is 5 kg * 24 = 120 kg/day.*

Possible reduction: 16 hours at 2 kg/hour and 2 x 4 hours at 6.5 kg/h = 92 kg/day.

*Correction possible: (120-92) kg/day * 365 * 1.5 Egyptian £/kg = 15,330 Egyptian £/year*

Example: Naga Hammadi – dosage parameters at plant level to be optimized considering low and high pre-chlorine dosage linked to the over-evaluation of the break point.

*As per plant information: 12 kg/h (dosing of pre-chlorine) / 880 lps (plant) / 3.6 = 3.78 mg/l. Total consumption of chlorine is 12 kg * 24 = 288 kg/day. Post-chlorination is at 4kg/day with a total*

*possible reduction : 12 hours at 12 + 4 kg/h and 12 hours at 3 + 5 kg/h, difference is 8 kg * 12 hours per day is 96 kg/day = 35,000 kg/year * 1.5 Egyptian£/kg = 52,000 Egyptian £/year*

Example: All WTP – avoid losses of chlorine throughout the process.

Possible reduction – assumption 0.5 mg/l per plant.

*Correction possible: 0.5 mg/l /1000 * (880 – Naga Hammadi + 1050 Salhayat) lps * 3.6 *24 * 365 * 1.5 Egyptian £/kg = 46,000 Egyptian £/year*

Examples: Aluminium sulphate

Example: Salhayat – dosage parameters at plant level differing from laboratory optimum.

*At Plant level: 1125 l/h (dosing) * 60 g/l (6% solution) / 600 lps (old plant only) / 3.6 = 31.25 mg/l while optimum is at 20 mg/l.*

*Correction possible: (31.25 – 20) mg/l /1000 * 600 lps (old plant only) * 3.6 *24 * 365 * 2 Egyptian £/kg /1000 = 425,000 Egyptian £/year*

<u>Example</u>: Naga Hammadi – dosage parameters at plant level differing from laboratory optimum.

*As per laboratory information: 1140 l/h (dosing) * 50 g/l (5% solution) / 880 lps (plant) / 3.6 = 17.9 mg/l while optimum is at 12 mg/l.*

*At Plant level: 654 l/h * 60 g/l / 880 lps / 3.6 = 12.4 mg/l as per optimum.*

*Correction possible: (17.9 – 12) mg/l /1000 * 880 lps * 3.6 *24 * 365 * 2 Egyptian £/kg = <u>320,000 Egyptian £/year</u>*

<u>Example</u>: Salhayat – over-estimation of the raw water: 600 lps instead of 540 lps

*In theory: 720 l/h (dosing) * 60 g/l (6% solution) / 600 lps (old plant only) / 3.6 = 20 mg/l required as per laboratory optimum is at 20 mg/l.*

*In practice: dosing pump should be at 648 l/h (dosing) * 60 g/l (6% solution) / 540 lps (old plant only) / 3.6 = 20 mg/l required as per laboratory optimum is at 20 mg/l.*

*Correction possible: (720 – 648) l/h (over-dosage due to raw water over-estimation) * 60 g/l (6% solution) /1000 *24 * 365 * 2 Egyptian £/kg = <u>75,000 Egyptian £/year</u>*

<u>Example</u> : Salhayat – jar test performed with plant concentrated solution.

At laboratory level: A jar test performed with plant concentrated solution reveals on optimum at 4 ml/l of concentrated solution.

*4 ml/l of a 10% dilution, means 0.4 ml * 600 lps (old plant only) * 3.6 = 864 l/h*

At Plant level: 1125 l/h (dosing) for the old line.

*Correction possible: (1125 - 864)l/h * 24 * 365 * 60 g/l (6% solution) /1000 * 2 Egyptian £/kg = <u>275,000 Egyptian £/year</u>*

<u>Example</u> : Salhayat – identification of leak on the dosing line dosage

*As per laboratory information: 62 l/h (leak) * 60 g/l (6% solution) /1000 *24 * 365 * 2 Egyptian£/kg = <u>65,000 Egyptian £/year</u>*

<u>Example: Queft- gravity supply of aluminium sulphate by-passing the existing (poor condition) dosing pumps.</u>

*0.55 kWh * 1 dosing pump * 24 * 365 *0.25 Egyptian £/kWh = <u>1,250 Egyptian £ / year</u>*

e. Assess Alkalinity & pH versus coagulant dosage
    i. "Every mg/l of Alum requires 0.45 mg/l of alkalinity as $CaCO_3$ and related impact on pH" & "Optimal coagulation may not occur without sufficient residual alkalinity (10 mg/l $CaCO_3$)"
    ii. Aluminium residual follow-up in correlation with coagulation pH. Evaluate coagulation pH versus aluminium residual.
    iii. Water equilibrium and corrosion indexes.

f. Match the laboratory test with the WTP parameters. Jar testing should reflect plant reality.

Recommendations:

Perform routine determination of corrosion and equilibrium indexes and report. Freeware has been made available to plant personnel.

Perform routine determination of aluminium residual and report. Correlate aluminium residual and pH, correlate aluminium residual and filter "breakthrough" turbidity, etc. and comment.

3. Dosing:
   a. Uniformity of coagulant flow – avoid or limit pulsation – use gravity constant level flow if possible.
   b. Pre-dilution of coagulant to improve mixing is not recommended and can only be considered to a certain extent and to match low dosing rates and pump characteristics.
4. Mixing:
   a. Assess injection point - mixing methods and results:
      i. Flash – rapid mixing is critical as coagulation reaction takes a fraction of a second to max. 7 seconds.
      ii. Avoid under- and overdosing coagulant due to poor mixing.
      iii. Poor mixing at injection can cause fouling or clogging of the injectors.
      iv. Static mixers loose efficiency at lower flow.
      v. Excessive flash mixing is energy waste.
   b. Assess pumping methods
5. Distribution:
   a. Assess proportional flow distribution between the different process units. This is important at the inlet of the WTP but should be considered for all process units.
   b. Avoid surge effects due to hydraulic siphoning (air trap and release phenomenon, etc.). Surge effects can disturb dosing, clarification, and filtration processes to a large extent.

Remember :

Flash – rapid mixing is a key element in the treatment process. Basic modifications can lead to great improvements.

Lower flow = lower mixing energy (static mixing) = poor flash mixing.

Unnecessary flash mixing is a waste of energy.

Rapid mixing can serve other purposes (air stripping).

Sequence between the chemicals can be modelled in the laboratory and provide evidence for plant modifications.

Water "falls" (hydraulic jumps, etc.) can occasion losses of chlorine and will require higher dosage – corrective measures should be proposed.

Example: Flash mixing and energy

Example 1: Salhayat – 4 rapid mixers with questionable impact on water quality requiring

*3 kWh * 4 mixers * 24 * 365 *0.25 Egyptian £/kWh = 53,000 Egyptian £ / year*

Example 2: Naga Hammadi – 4 rapid mixers with "air stripping" action in the afternoon and evening only –

*3 kWh * 4 mixers * 12 * 365 *0.25 Egyptian £/kWh = 27,000 Egyptian £ / year*

Example 3: Queft – 1 rapid miser with questionable impact on water quality requiring

*4 kWh * 1 mixers * 24 * 365 *0.25 Egyptian £/kWh = 8.750 Egyptian £ / year*

4.4 FLOCCULATION

1. Good practices: Flocculation for improved sedimentation:
   a. 20 to 30 min – tapered G = 70 to 20 s^{-1} (speed drives to be considered for optimal performance) – perforated intra-cell to minimize short-circuiting.
   b. Maximum blade speed 2 to 3 m/s for vertical turbine flocculators to avoid damage to flocs.
   c. Transition to the sedimentation basin with low inlet velocities – even distribution requiring head losses without flocs damages. Balance to be evaluated.
2. Evaluation:
   a. Flocculation stages
   b. Detention time
   c. Mixing intensity
   d. Short circuiting

4.5 CLARIFICATION

1. Good practices:
   a. Less than 2 NTU when the raw water turbidity is > 10 NTU and preferably 1 NTU when the raw water turbidity is <10 NTU. Attention should nevertheless focus on the final water quality of individual filters.
   b. Stable even when rapid changing conditions.
   c. Sludge of consistent quality – up to 1% TS.
2. Poor performance to be assessed:
   a. Inlet flow distribution between the different tanks and within the same tank (uneven inlet weir, etc.)
   b. Excessive loading rate – design loading rate to be determined.
   c. Density currents due to temperature variations are generally worst in large sedimentation units due to surface warming with localized higher velocities and floc carryover at the bottom.

d. Incidental flotation due to entrained air (clarifiers performing well early morning and starting to deteriorate at the beginning of the afternoon).
e. Sudden changes in raw water conditions.
f. Chemical under- or overdosing.
g. Inappropriate sludge removal with localized high velocities / anaerobic gas production / etc.
h. Although it generally requires specific design consideration and equipment, evaluate "fresh" sludge recirculation potential. It can help the clarification process for low dosage and low turbidity and reduce aluminium sulphate dosage. Avoid in this case shocks in the sedimentation process due to an intermittent recirculation flow – constant flow is much preferred. Evaluate aluminium residual problematic and possible build-up of bacterial population.

Recommendations:

Perform temperature profiles and cross-sections. Water analysis (TRC/FRC) at inlet, outlet and different locations on the sedimentation tank where localized "plugs" can form. Assessm the "plug" extent.

Perform tracer test (salt). Determine the real retention time (T_{10}).

Increase and determine coagulant dosage effects on the sedimentation tank (heavier flocs) or run (if possible) the plant as a direct filtration plant by reducing the aluminium sulphate dosage – conclude. Run direct filtration jar test before.

Remember:

Poor performances are difficult to rectify as design related and would require evidence before modifications.

Conventional sedimentation is not ideal for highly coloured (high algae load) low turbidity water.

Example : Desha – dosage parameters at plant for a conventional (17 mg/l) versus a direct filtration process (5 to 8 mg/l).

*Correction possible: (17 – 8) mg/l /1000 * 400 lps * 3.6 *24 * 365 * 2 Egyptian £/kg = 230,000 Egyptian £/year*

4.6 FILTRATION

1. Guide values are for instance:
   a. Less than 0.5 NTU at start-up and after backwash – no longer than 15 minutes, 0.3 NTU on a 95% basis.
   b. Filter to waste (if possible!) until < 0.3 NTU.
   c. Largest spike = 1 NTU.
   d. Long and predictable filter runs (24 hours or plus) equivalent for each filter. If not it implies:
      i. Problems with time for backwash purposes and related waste of water.
      ii. Low net filter production.

   e. Maximum of 72 hours. If not there is risk of:
      i. Air binding.
      ii. Media compaction.
      iii. Bacterial growth.
   f. Typical filter run from the end of the backwash procedure when re-starting the filtration process should be as follows:
      i. Clean backwash water below the media – outlet turbidity increases but below the threshold.
      ii. Backwash remnant and influent water within and above the media – outlet turbidity increases above the threshold.
      iii. Influent only to re-condition the media – outlet turbidity decreases to reach the threshold.
      iv. Filtration can start up to breakthrough is observed – outlet turbidity increasing above threshold. Backwash is then initiated.
   g. Minimal filter ripening (ii and iii above).
   h. Minimal premature breakthrough (iv above).
   i. Provide filter history.
      i. As-Built drawings.
      ii. Specifications.
      iii. Vendor or design O&M manuals.
      iv. Operating records.
      v. Maintenance records.
      vi. Filter assessment records.
2. Good “conventional” filter design:
   a. Reasonable uniformity coefficient < 1.6 to avoid fine particles at the top of the filter.
   b. Conventional loading rates 6 to 7 m/h.
   c. Media depth < 1 m.
   d. Backwash.
      i. Air scour of 0.9 to 1.5 $m^3/min/m^2$
      ii. Water wash – 20 to 25 m/h.
3. Poor performance:
   a. Poor clarifier performance – excessive solid loading (refer to clarification section).
   b. Excessive operational loading rate. Verify loading rate with 1 filter in stand-by and 1 filter in backwash.
   c. Backwash re-classifies filter bed to place the finest particles at the surface. Surface filtration to be assessed. If needed:
      i. Use 110% backwash capacity if possible and skim repeatedly.

    ii. Ensures entire bed fluidizes at the selected backwash rate. Measure expansion rate if needed.
  d. Filter media characteristics can change over time (encrustations, depositions, physical degradation). Measure E.S. and U.C. if needed.
  e. Filter media losses: Replacement of lost media with same E.S. as original and lower U.C. (to avoid fines and shorter filter runs)
  f. Filter under-drain damages or failure.
  g. Poor cleaning effectiveness – mud-balling and short circuiting.

4. Common problems:
   a. Valve "hunting" – turbidity spikes.
   b. Initial turbidity spike once filter online.
   c. Turbidity "creep" – rapid and constant increase of effluent turbidity.
   d. Spiking during filter run with major and minor concern.
      i. Spiking during backwash of other filters increasing the flow to remaining filters.
      ii. Short term hydraulic shocks, multiple spikes due to hydraulic surge as a result of variable raw water rates or one or more filters taken out of service.
   e. Hydraulic shocks (OFF / ON line – variation of inlet flow).
5. Evaluation:
   a. Visual inspection
      i. Filter general conditions: Levelness of troughs and hydraulic loading, Freeboard, Media level and loss (original specs versus probing), Condition of concrete/steel, Flow rate through filter and flow distribution, Condition of under-drains (if possible), Condition of piping, Condition of valves and controls.
      ii. Filter media:
         a. Filter fines at surface, moundings (high localised flows – disturbed gravel layer - damaged filter floor), media boiling during wash uneven wash distribution, backwash boils, uneven overflow into BW troughs, cratering in media surface (damage of filter drain), mud-balls (insufficient wash velocities, blocks of filter areas, etc.), filter media in troughs.
         b. Algae grow.
         c. Media depth uniformity, scaling or fouling.
   b. Filter surveying
      i. Filter indices
         a. L/d_{10} ratio > 1000 for conventional filter (filter bed depth to media nominal diameter – E.S.).
         b. $FPI = (NTU_{in} - NTU_{ex}) / NTU_{ex} \times Q_{prod}$
      ii. Unit filter run volume = filter run (hr) x filter rate (m/h) – 300 to 500 $m^3/m^2/h$ is desirable.

iii. Filter efficiency accounts for losses – 2 to 4% waste production. Performance can vary with the period considering temperature, floc formation and settling.
   a. <3% is “normal”
   b. <2% is “very good”
   c. >4% is “poor”
   d. >5% is “very poor”

iv. Filtration rate checking.

v. Filter head loss and filter run follow-up.
   a. Make the difference between “constant flow – constant level filters” and “constant flow – variable level filters”
   b. Causes for short filter runs can be (1) fines at the surface, (2) E.S. is too “small” or/and U.C. too high for filtration rate, (3) too much floc in influent, (4) dirty filter bed, (5) filter-clogging algae, (6) air-binding (supersaturated water).
   c. Monitor clean bed head loss and evolution after backwash and return to service. This is a good indicator after change in BW procedure.

vi. Monitoring backwash pressure:
   a. To assess the condition of the filter under-drain at maximum flow for each filter – measure after the flow control valve.
   b. To assess the condition of the BW pumps at a given flow – measure before the flow control valve.

vii. Floc retention profile to determine removal versus depth of the filter (refer to annex) - >102 NTU is dirty - >300 NTU is indicative of mud balls.

viii. Backwash waste characterization to assess the right duration to reduce water wastage and residuals volumes. Collect samples of backwash water every minute and plot the results.

ix. Bed fluidization checking and comparison of backwash rate and fluidization.

x. Gravel layer profiling during backwash – Support gravel mapping.

c. Filter sampling.
   a. Sieve testing for the filter media.

d. Backwash trough level check.

6. Optimization:
   a. Adjust effluent control valves as they adjust according to level fall / rise.
   b. Filter to waste addition - Filter to waste until < 0.30 NTU (at least 0.5 NTU) after backwash and upon start-up.
      i. This can be done at normal rate or at rates much lower than normal.
      ii. This should preferably be done based on NTU outlet basis and not on time.
      iii. Transition between filter to waste and filtration should be done smoothly with no rate change through the filter.

c. Delayed start (resting)
d. Slow start - Reduce raw water inlet.
e. Do not re-start dirty (> 50 % head losses) filters.
f. Optimal cleaning.
    i. Multiple air scours followed by water wash.
    ii. Selection of wash rates and duration.
    iii. Backwash before breakthrough occurs.
    iv. Avoid consecutive backwash of all filters.
    v. Increase treated water storage if needed – Buffer the demand instead of changing production rate.
    vi. Provide if possible idle (stand-by) filter.
g. Avoid spiking
    i. Avoid risk periods for backwashing other filters / manage backwash periods - more risk during final hours of filter run (higher head loss)
    ii. Filter aid chemicals (polymers).
h. Even distribution of flows.
    i. Inlet distributors
    ii. Levelling wash trough.

Remember:

Poor performance is difficult to rectify as it is design related but simple fixes can improve the situation.

Avoid unnecessary long air wash. Consider splitting the “air” and “water” backwash processes to provide better efficiency.

Avoid unnecessary long water backwash. It can create long ripening process, does not improve the filtration run, wastes treated water and reduces the time for filtration.

Analyse sand size if needed (d10 = E.S. and U.C.) and perform regular sand profile analysis.

Example: Backwash profile

Example : Naga Hammadi – 1 to 2 minutes per backwash possible “waste for water”

*1.5 minutes / 60 * 2 backwash/day * 10 filters * 60 m² per filter * (25 m/h backwash + 5 m/h filtration) * 365 * 0.25 Egyptian £/m³ at consumer level = 80,000 Egyptian £ / year*

Example : Salhayat – 4 to 5 minutes per backwash possible “waste for water”

*4.5 minutes / 60 * 2 backwash/day * 14 filters * 60 m² per filter * (25 m/h backwash + 5 m/h filtration) * 365 * 0.25 Egyptian £/m³ at consumer level = 345,000 Egyptian £ / year*

5 WATER QUALITY ISSUES

5.1 Taste and Odour

- Change intake level if possible.
- Use $KMnO_4$, chlorine dioxide or pre-chlorination.
- Use combinations of the above.
- Cap filters with GAC – use PAC.

Remember:

Tastes and odours are quite common. Naturally occurring tastes and odours are often attributable to algae and cyanobacteria (blue-green algae) and/or to petrochemical industries.

The problems are often produced when chlorine is applied to organic matter (pre-chlorination and post-chlorination).

The best approach is to eliminate causes of taste and odour before they reach the treatment plant.

When prevention at source is not feasible, treatment is necessary: oxidation (chlorine, permanganate, ozone or chlorine dioxide) and adsorption (activated carbon) are the two methods the most often used.

5.2 High Colour/TOC

- Change intake level if possible.
- Use enhanced coagulation - Lower pH.
- Use ozone or other chemical such as $KMnO_4$. Consider increased dosage.
- Use Powdered – Granulated Activated Carbon.

Remember:

The design of a WTP must pay attention to several points when colour of the raw water is high – large capacity for coagulant storage, supply and dosing & very good initial mixing.

Highly coloured waters generally require large amounts of coagulant to ensure coagulation and floc formation (up to 100 mg l-1 of coagulant when colour range is 200-300 TCU - true colour units). The floc, formed mainly from organic colour with little turbidity, is light and fragile. This situation then requires a well-controlled flocculation system and careful transport of flocculated water into settling basins. The floc going over to the filters is very gelatinous and quickly clogs sand filters.

5.3 Algae

- Change intake depth if possible.
- Change coagulant dose.
- Consider lowering pH of coagulation – enhanced coagulation.
- Use copper sulphate.

Remember:

Raw water with high algae content should be monitored regularly and measures should be taken to control or eliminate the algal blooms and to prevent them from reaching the treatment plant.

If control is not feasible, problems can generally be anticipated because algae thrive in seasonal cycles.

The water treatment process removes algae mainly by coagulation, flocculation and settling. Nevertheless sufficient numbers may reach the filter system to cause serious problems.

Growth should be controlled in the treatment plant by using high shock doses of chlorine during times of algal abundance. Continuous pre-chlorination reduces all microbiological contaminants and keeps the treatment plant practically free of algae, but may cause a potentially problem of tri-halomethane formation – taste and odour. In this case periodic shock chlorination can, however, be carried out safely.

The algae of most concern in water treatment are those that cause tastes and odours (Asterionella, Ceratium, Dinobryon, Peridinium, Stephanodiscus, Synedra, Synura, Tabellaria and Uroglenopsis) and those that clog filters (Asterionella, Fragillaria, Synedra, Tabellaria and Tribonema). All need to be identified and controlled.

6 "ON THE JOB" TRAINING

The STE's on-the-job training conducted during the assignmemt had three main objectives:

- Impart a better understanding of how WTP works by identifying common problems and browsing technical solutions.
- Provide information on worthwhile monitoring to feel more comfortable in assessing and upgrading WTP.
- Provide support to diagnose problems and identify possible solutions.

Three categories are directly concerned by the "optimization" process:

- Administration
  - Establishment of goals to define and communicate water quality goals, and provide support to ensure goals are met.
  - Standard operating procedures.
  - Training.
  - Improved communication.
  - Resources
    - Personnel
    - Funding, eventually generated by the optimization process itself.

- Design
  - Upgrade or replace equipment such as pumps and related piping / accessories, filter media, under-drains and valves, etc.
  - Provide automation.
- Operation and Maintenance (Maintenance is not covered under this assignment).

Discussions and tests performed during the “on the job” training sessions are summarized below.

Tests performed at plant level are:

- Naga Hammadi (Calculation notes, Back-wash profile, pH and residual aluminium in jar testing, Filtration follow-up, Break point curve)
- Salhayat (Back-wash follow-up before and after optimization, Filtration follow-up, Break point curve)
- Homaydat (Calculation notes rehabilitation and extension Homaydat)
- Deshna (Calculation notes, Temperature profile of a sedimentation tank, Sand sieve analysis, curve and parameters for Deshna, Quous and Queft WTP)
- Queft (Calculation notes, Free residual chlorine profile of a sedimentation tank, Filter backwash follow-up, Total flow and flow distribution assessment, Sand profile analysis)
- Quous (Calculation notes, Filter backwash follow-up, Sand size analysis)

Issues discussed to be controlled at design / supervision level are:

- Coagulation: Water metering – flash-mixing (velocity gradient) – retention time – flow distribution
- Chemicals: calibration – concentration – sequence – flow and continuity of flow
- Flocculation: flow distribution – tapered flow – velocities – velocity gradient – retention time
- Sedimentation: flow distribution – inlet velocity – outlet loading rate – surface loading rate – retention time – sludge removal facilities.
- Filtration: flow distribution – inlet velocity – backwash loading rate – surface loading rate – backwash rates (Air – Water) – d_{10} – d_{60} – U.C. – sand bed depth – supporting layer / bottom - automation/regulation.
- Disinfection: sequence – injection point – rate – contact time - safety measures.

7 RECOMMENDATIONS & CONCLUSIONS – OPTIMIZATION PROCESS

Recommendations and "technical" conclusions are progressively proposed in the previous chapters. General recommendations are:

6. Design issues: "Optimization" of the WTP starts at design level. Design "bugs" can hardly be corrected considering O&M practices only.
   a. "Modern" design should be considered to limit the required investment, provide modern process and ease O&M.
   b. "Old" design, including "copy and paste" technique, should be scrutinized before approval. "Copy and paste" should consider at least O&M experience and recommendations.
   c. Multidisciplinary QCWW experts team to comment, modify and upgrade proposed designs and related tender dossiers, follow up work implementation and finally participate in the initial operation and commissioning of the plant.
7. Commissioning of the works: Commissioning should be done respecting technical specifications. Infrastructure and equipment should be operable and in good condition. This should supersede all "other" constraints.
8. Detailed assessment of "existing" plant: Assess infrastructure and equipment plant deficiencies and propose an investment plan including priorities. Remember that replacing equipment should consider process constraints and optimization.
9. Facilitate optimization of the plants: Identify an optimization facilitator at central level
10. Optimize plant operation: Monitor plant performances and identify deficiencies
    c. Avoid unnecessary waste (consumables, energy, water) by providing daily plant monitoring and appropriate maintenance.
    d. Identify "short term" plant deficiencies, provide evidence, test and propose corrective measures.
    e. Identify "long term" plant deficiencies, provide evidence, test and propose corrective measures.

IMPORTANT:

Water treatment plant optimization is a long and routine procedure requiring "available" data assessment and multiple field tests to provide evidence. It is and should be the result of long and conscientious work. Short term expertise can only provide recommendations and guidelines for plant optimization.

Coagulation / flocculation and filtration are important processes that should further be scrutinized to optimize the use of chemicals and water within the WTP.

Effective optimization can only be considered if "normal" plant and process conditions are restored. A filter without sand, full of mud or without automation device can hardly be optimized.

Figures are presented in this report to illustrate the optimization process but should be used carefully as evidence will require further testing.

Potential "saving" issues definitely require evidence and therefore further experimentation and process follow-up to avoid any misunderstanding between plant and management staff.

Recommendations

- Design issues: Create a multidisciplinary team controlling design, implementation and commissioning.

- Detailed Process expertise – Investment plant – Prioritization issues: Define an investment plan and prioritization considering process issues and their optimization.

- Optimization issues: Organise routine "optimization" check-ups to identify deficiency "symptoms" and remedy. Identify "Optimization" facilitator at central level.

8 RECOMMENDATIONS & CONCLUSIONS – INFRASTRUCTURE RENEWAL OR / AND REFURBISHMENT

Competent, well-informed and motivated plant operators can improve the performance of existing plants. The actions are directly related to operation but can also include simple structural or hydraulic changes. Such activities include:

- Control the level of the intake structure from which raw water is drawn and the measurement of raw water flow into the plant.
- Control the concentration of the coagulant solution in the solution tanks and control of the coagulant dilution, dosage and injection for the best application of the coagulant.
- Control the raw water flow distribution.
- Improve the hydraulic flocculation basins / the energy input of mechanical flocculation basins.
- Monitor the sedimentation process.
- Monitor the head loss through the filter, water quality and calculate the maximum filter rate.
- Verify the filter and backwash rates and results.
- Remove, clean and replace filter sand and support gravel and filter bottom where it may be damaged.
- Control the dosage of chlorine(s).

With technical assistance from the water department engineers and some financial support, competent operators can also:

- Accurately measure the intake of raw water.
- Construct and install a diffuser and piping to apply dilute coagulant.
- Redesign and modify a flow distributor, if needed to distribute water between basins.

- Provide proper energy input to flocculation basins by appropriate design. Design and build compartments for flocculation basins which use mechanical mixing, or modified baffling for those basins which use hydraulic mixing.
- Design and build a perforated baffle for the entrance into the settling basins.
- Design and install a more efficient system of settled water removal.
- Modify filter bottom and outlet piping.

8.1 RAW WATER INTAKE

Intake location will provide a benefit for the life of the water treatment plant as the quality of raw water, for instance, may vary greatly with location and depth below the surface in large rivers. If the structure is in a « wrong » location, consideration can be given to changes (Quous WTP).

8.2 RAW WATER METERING

It is important that operators know the rate of raw water intake because chemical dosing is directly related to the raw water flow. Most plants do not have satisfactory measurement of the raw water flow. Operators rely on the number and capacity of raw water pumps in operation. This approach is a useful method if pumps are calibrated at least annually, using one of the flocculation or settling basins to determine the actual volume of raw water entering the plant. This exercise should be repeated for each pump and pipe combination possible in operation. Ultrasonic portable flow-meter or any other “simpler” method can be used for such calibration.

8.3 COAGULATION

The correct dose should be applied to the raw water as effectively as possible. Certain information should be known accurately, such as the dose required, the amount of coagulant per unit of volume in each batch, the amount of dilution water and the applied dose all time.

The most effective coagulant or any possible combination should be determined in the laboratory. Jar testing should be used to determine the best coagulant, combination and sequence, and the most effective and economical dosing.

Solid aluminium sulphate is actually put into solution in batches. This method of preparation should be closely supervised to make sure that the amount of dry aluminium sulphate and water is carefully respected for each batch. Efforts to control amounts of water and aluminium sulphate should be made to make sure that concentrations are exact (+/- 1 % of the target).

The application of the coagulant to the raw water is most of the time deficient. Uneven dosing results in a small amount of raw water receiving far too much coagulant, while most of the raw water receives far too little. Concentration of the coagulant from the batch tanks (5% and below for some plants) is acceptable. Raw water and coagulant should be mixed in less than 1 second. This requirement for application at a point of high turbulence (velocity gradient of at least 1,000 s^{-1}) is not met.

Coagulant can be applied at a concentration of around 0.5 %, and certainly less than 1 %. This provides a maximum volume of coagulant. Inline dilution of the coagulant can be considered. Rapid mixing and coagulant dispersion should be improved considering preferably hydraulic methods.

8.4 FLOCCULATION

At this stage an equal distribution among the flocculation basins should be ensured and an excessive head loss avoided. Water is generally distributed to a series of transverse pipes or channels from a common header (coagulation). Hydraulic factors have not been understood and taken into account during plant design. Head loss and velocities in the transport system are sometimes high. Overloaded basins cannot function properly, mainly at sedimentation level when high turbidity water is sent on to the filters.

Trouble in the distributing and in the filter backwash systems has been noticed as well. Poor distribution of wash water causes uneven washing and leads to problems in the filter bed.

The flocculation systems have not been designed with sufficient consideration to optimum velocity gradients and optimum energy input (in hydraulic systems, the velocity gradient around the ends of baffles is high while between bends it is low, vertical rotary systems are poorly located, tapered input of energy is not systematically provided, flexibility to increase and decrease the agitation is not provided at equipment level, etc.). Over-flocculation and under-flocculation often occur in the same basin. High and low energy input can be very detrimental to optimum or even good floc formation.

Flocculation time is generally good enough. Short-circuiting and dead space are under control. Sufficient compartments have been provided (mechanical flocculation units).

Non-ionic / cationic polymers can be used to accelerate settling.

8.5 SEDIMENTATION

The efficiency of settling basins is questionable. The entrance to the settling basin is poorly designed, forming currents, short-circuits and dead spaces resulting in poor clarification and too many flocs going to the filters.

Temperature differences have been noticed between the water in the basin and the water entering the plant. Incoming water is colder and short-circuits along the bottom of the basin.

Proper design of the entrance to the settling basin can partly solve these problems. "Plug flow" should be restored. The settled water removal system should reduce the exit velocity with the longest possible weirs or launders. Weirs or launders of rectangular settling basins should preferably extend through the final third of the basin length. An outlet weir as long as the basin width (modular prefabricated plant) is not acceptable.

8.6 FILTRATION

All filters are single medium filters with sand depths up to 60-70 cm and even more, and with effective grain size from 0.6 mm to 0.8-0.9 and sometimes even above 1.0 mm. Filter performance with good design and operation should be able to produce a consistent supply of filtered water of less than 0.5 NTU.

The floc load that reaches the filter requires measures as it can make a significant difference. The first place to look for causes of poor-quality filtered water is not necessarily the filter itself but in pre-treatment prior to filtration.

Relatively high-turbidity settled water applied to the filter for a long period can result in clogging, formation of mud balls, and possible breakthroughs in the filter beds (Quous, Queft, Naga Hammadi). Improvements to pre-treatment are necessary before attending to the filter itself. There is no point in replacing filter sand if operation will continue with poorly pre-treated water.

The sand in the filter is often supported by a gravel bed with an under-drain system to remove filtered water. The same system is used for backwash purposes. This system may be the origin of many filter problems (upset beds, breakthroughs in the beds, and poor distribution of backwash water). Part of the bed is under-washed and eventually becomes clogged and the other part which is over-washed receives backwash water at very high velocities causing an upset of the bed. Uneven backwash occurs because of the elevation differences between wash-water troughs.

The backwash rate should provide sufficient bed expansion. Air entrainment in the backwash water or excessive air flow may disrupt filter bottoms and media.

8.7 DISINFECTION

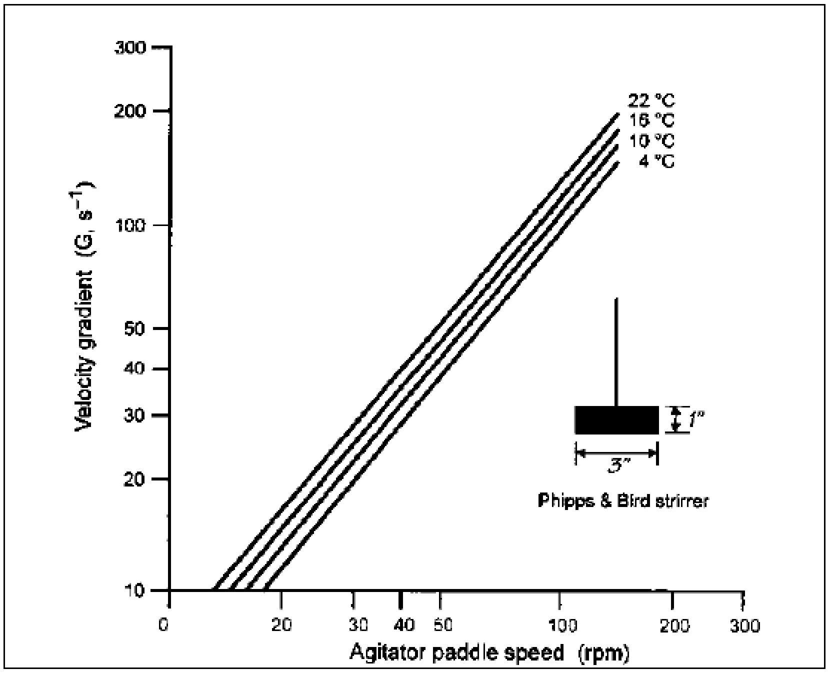
Filtered water is disinfected with chlorine. Contact time is often short and the chlorine dosage must be high to safeguard the health of consumers. The WTP is usually the only chlorine dosage location and should provide a chlorine remainder through a quite long water distribution system.

Chlorination equipment must be maintained in good condition to avoid the danger of a serious chlorine leak and to guarantee the safety of the finished water. The effectiveness of the chlorine as a sterilising agent is related to water pH. The pH of filtered water should be optimized.

The clear well should be designed and operated so that the chlorinated water will remain in the basin for at least 30 minutes and preferably longer.

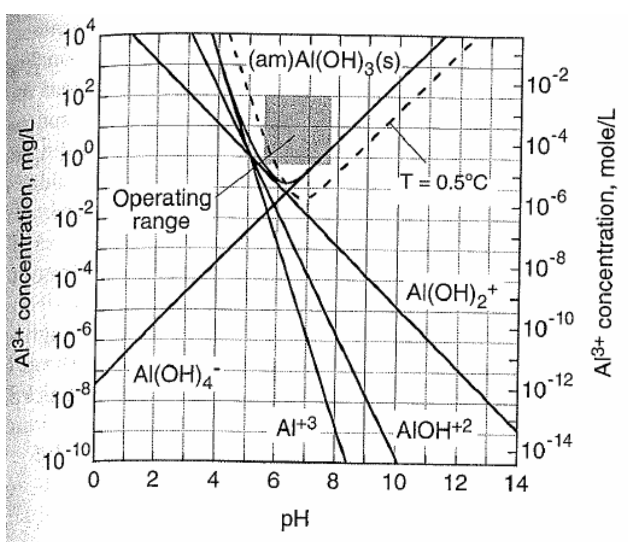
9 SPECIFIC PROCEDURES

9.1 JAR TEST PARAMETERS



9.2 ALUMINIUM RESIDUAL PROBLEMATIC

The pH has a significant influence on the reaction of coagulants with the raw water: amounts of Al2(SO4)3 required to reduce turbidity vary with pH. For maximum effectiveness of alum as a coagulant, the pH range is quite narrow. In treatment plants using alum as the coagulant, the optimum pH is particularly important, or coagulant is wasted and residual aluminium becomes problematic.



9.3 SAND SIZE ANALYSIS

9.3.1 Apparatus

- Scale (or balance) - 0.1 g accuracy
- A set of sieves, lid, and receiver (Select suitable sieve sizes (table) to obtain the required information as specified).
- Drying oven 110 +/- 5°C
- Metal pans – one for each sieve size, plus one for sample
- Mechanical sieve shaker preferably

9.3.2 Method

- Label with sieve number or size and weigh metal sample pans, and set aside.
- Begin with about a 100-gram sample of sand. Fill the pan and sand sample with tap water, shake and decant wash water. Repeat several times until wash water is clear. Dry the sample again in 105–115°C oven for two hours. Weigh dry washed sand with pan.
- Arrange a set of sieves from largest opening to smallest with the pan below the bottom sieve.

No.	Mesh Size (mm)	No.	Mesh Size (mm)	No.	Mesh Size (mm)	No.	Mesh Size (mm)
1"	25.0	7	2.80	20	0.85	60	0.250
3/4"	19.0	8	2.36	25	0.71	80	0.180
1/2"	12.5	10	2.00	30	0.60	100	0.150
3/8"	9.5	12	1.70	35	0.50	120	0.125
4	4.75	14	1.40	40	0.425	140	0.106
5	4.00	16	1.18	45	0.355	170	0.090
6	3.35	18	1.00	50	0.300	200	0.075

- Place the sample on the top sieve. Place lid over top sieve.
- Shake stacked sieves, vibrating, jogging, and jolting them by hand or by mechanical apparatus. Keep the sand in continuous motion for a sufficient period such that not more than 1% by weight of the residue on any individual sieve will pass that sieve during 1 minute of additional hand sieving. Five to ten minutes of original sieving will usually accomplish this criterion.
- Pour the sand off each sieve into labelled, weighed pans. Weigh and determine the sample weight by subtracting the weight of the pan

9.3.3 Record and Calculation

- Record all the weights in the “Report” sheet and determine the percent passing for each sieve:
- Graph the percent passing result for each sieve on semi-log paper
- Find the Effective Size as d_{10}, where only 10% of the sample is a smaller size.
- Also from the graph, find d_{60}, where 60% of the sample is a smaller size. The Uniformity Coefficient is d_{60}/d_{10}.

Project: Sample Material:			Date: Sample I.D. : Total dry sand with pan, W0 (g): Total dry sand, WDS (g):				
Sieve No.	Sieve Size (mm)	Pan W p (g)	Sample + Pan W(g)	Sample Weight WS (g) = W – Wp	% retained = WS × 100 / WDS	% passing last larger size	% passing = % passing last larger size – % re-tained
						100	

9.4 STEPS OF FLOC RETENTION ANALYSIS

9.4.1 Sampling

1) Drain filter
2) Collect samples in 5 locations
    a. 0-5 cm
    b. 5-15 cm
    c. 15 - 30 cm
    d. 30 - 45 cm
    e. 45 – 60 cm
    f. 60 – 75 cm
    g. 75 and more
3) Place media samples in marked baggies
4) Wash the filter
5) Drain filter
6) Repeat step 2
7) Repeat step 3

9.4.2 Analysis

1) Prepare a 50 mL test sample from each bag
2) Place media sample in wide-mouth 500 mL flask
3) Add 100 mL of tap water and shake for 30 seconds
4) Drain water into a 1-L beaker
5) Repeat washing procedure 4 more times
6) Measure and record turbidity of wash water
7) Multiply results by 2 for turbidity of 100 mL media sample
8) Plot the results

9.4.3 Results after backwash

Turbidity, NTU	Filter Media Condition
0 - 30 NTU	Clean - Unripened filter – Long ripening time
30 - 60 NTU	Clean - Ripened Filter
60 - 120 NTU	Slightly dirty, Still OK
120 - 300 NTU	Dirty - Re-Evaluate Backwashing
> 300 NTU	Mudball Problems

9.5 DIRECT FILTRATION JAR TESTS

The potential economy both in capital outlay and operating costs makes direct filtration an attractive treatment process. Although the decreased costs associated with reduced chemical consumption and reduced sludge load have been emphasized less than the initial capital economy in plant construction, they represent on-going savings that continue for the life of the plant. Pilot plant investigations are required in order to establish the design criteria for a direct filtration plant. However, pilot plant investigations should not be undertaken unless the raw water can be treated by direct filtration.

The procedure is the following:

1. Determine the raw water turbidity and record.
2. Filter the raw water through Whatman #40 filter paper and record.
3. Fill the four to six jars with raw water to the 1 to 2-liter mark and decide on dosages.
4. Measure out the coagulant (eventually polymer) doses.
5. With the stirrer at maximum speed, pour in the coagulant (eventually polymer); stir at maximum speed for 30 to 40 seconds.
6. With stirring continuing at about 50 rpm take a 100 to 200ml sample.
7. Filter through Whatman #40 filter paper (discard paper).
8. After 3 or 4 minutes of the stirring at 50 rpm take another 100 to 200 ml sample.
9. Filter this later sample through Whatman #40 filter paper (discard paper).
10. Read and record turbidities of all samples.
11. Plot data on arithmetic scale paper.