CoMeTas AquaSolution
AQS-144-800-(2'*2) 3 micron filter

Test plan

Physical removal of microbiological and particulate contaminants

WATER • ENVIRONMENT • HEALTH

CoMeTas
May 2010

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AQS-144-800-(2'*2) 3 micron filter

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1 CONTENTS

APPENDICES

2 INTRODUCTION

This test plan is the implementation of a test design developed for verification of the performance of an environmental technology following the DANETV Centre Quality Manual – Water Technology.

2.1 Verification protocol reference

This test plan is prepared in response to the test design established in the CoMeTas AquaSolution verification protocol, AQS-144-800-(2*2) 3 micron filter /1/.

2.2 Name and contact of vendor

CoMeTas A/S, Lerhøj 10, 2880 Bagsværd, Denmark, Phone +45 4498 6060

Contact: Kenneth H. Johansen e-mail khj@cometas.dk

Hompage: www.cometas.dk

The laboratory for responsible for the analysis of samples:

Particulates (size distribution): DHI

Total bacteria count (Total kimtal): DHI

Chemical analysis (TOC (DHI), total hardness, THM (Eurofins)

2.3 Name of centre/test responsible

DHI DANETV Water Centre, DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark

Verification responsible: Hans G. Enggrob, e-mail hge@dhigroup.com phone +45 4516 9127

Test responsible: Bodil Mose Pedersen, e-mail bop@dhigroup.com phone +45 4516 9433

2.4 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:

Head of Innovation Gert Holm Kristensen (GHK) e–mail ghk@dhigroup.com, DHI, Agern Allé 5, 2970 Hørsholm, phone +45 4516 9434

Professor Erik Arvin, Technical University of Denmark (DTU), DTU Environment, phone +45 4525 1472 era@env.dtu.dk

3 TEST DESIGN

The test design is applicable to any pressure driven membrane process. The total verification testing plan shall be performed over 30 days (not including time for system set-up and test run). At a minimum, 30 days of verification testing shall be conducted to provide equipment testing information. Task description is provided in Table 3-1.

Table 3-1 Task description.

Task	Issue	Test
1. Characterization of membrane flux and recovery	Rate of flux decline	Development of flux during specified operational conditions
2. Evaluation of back wash efficiency	Frequency, water consumption	Flux recovery of back wash
3. Evaluation of finished water quality	Produced water quality	Measurements of feed water quality and produced water quality
4. Membrane integrity testing	Removal of particles and total microbial count	Rejection capability of particles and evaluation of total microbial count in feed water, produced water and back wash water

3.1 Test site

The test will be conducted as a field test at Gladsaxe Svømmehal, Vandtårnsvej 55, DK-2860 Søborg, and the test plant is provided by Provital A/S and equipped with CoMeTas ceramic filters. Gladsaxe Svømmehal has two pool areas – one area equipped with one 50 m basin and a pool area equipped with a warm water pool and a paddling pool. The warm water pool, the paddling pool and the pipelines all together contain 50 m^3. The pool water from the warm water pools is re-circulated and passes sand filters designed for removal of suspended particles (Figure 3-1). The pool water to be used for the test is a side stream of re-circulated pool water from the warm water pool.

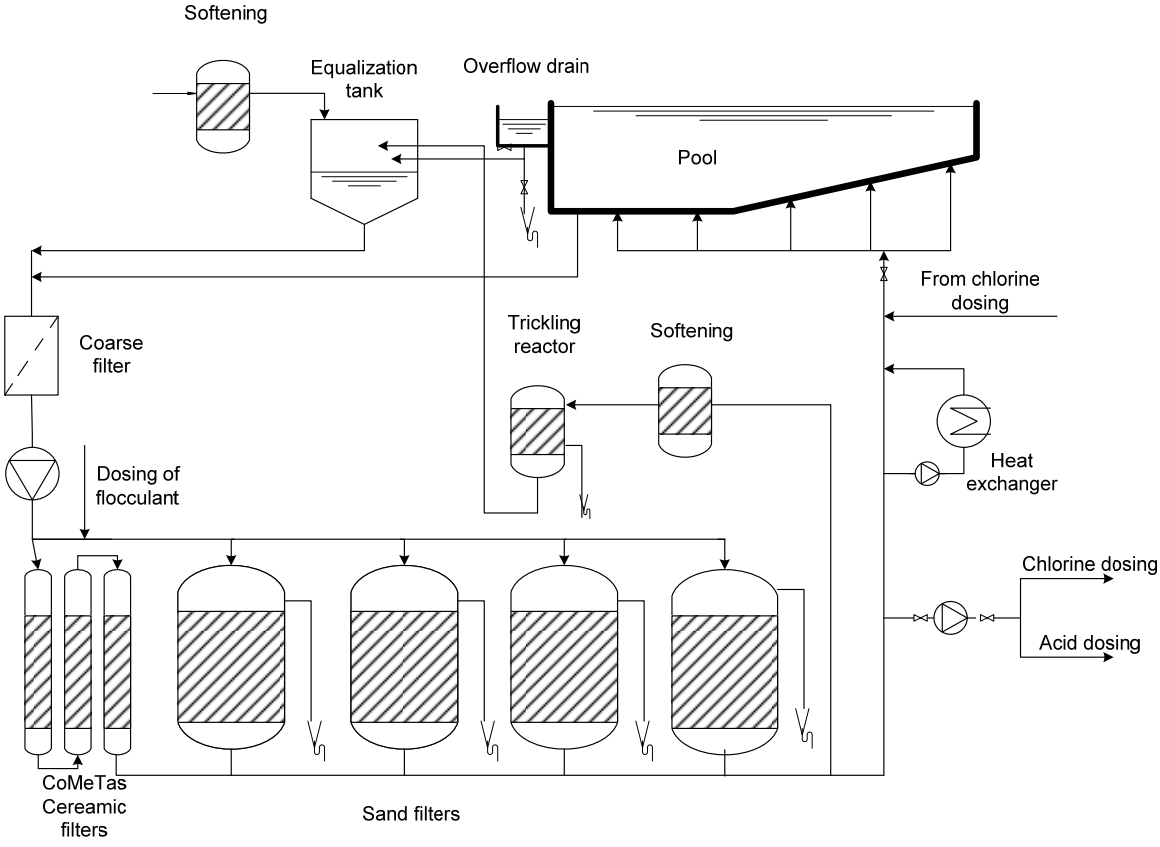

Figure 3-1 Flow diagram showing the re-circulation and treatment of pool water in sand filters.

3.1.1 Types

The temperature of the pool water is 33°C. One of the sand filters which usually treat nearly one half of the re-circulated pool water will be replaced during the test period by the AquaSolution filtration plant. The exact ratio of sand filter treated water and AquaSolution treated water is measured during the preliminary characterization of the test site.

3.2 Tests

Sand filtration is currently in use for a broad number of water treatment applications. Filtration through ceramic membranes is an alternative to sand filtration, where the objective is removal of natural organic matter contributing to formation of disinfection by-products.

During the test, records are collected from the operation and the belonging sampling and analyses.

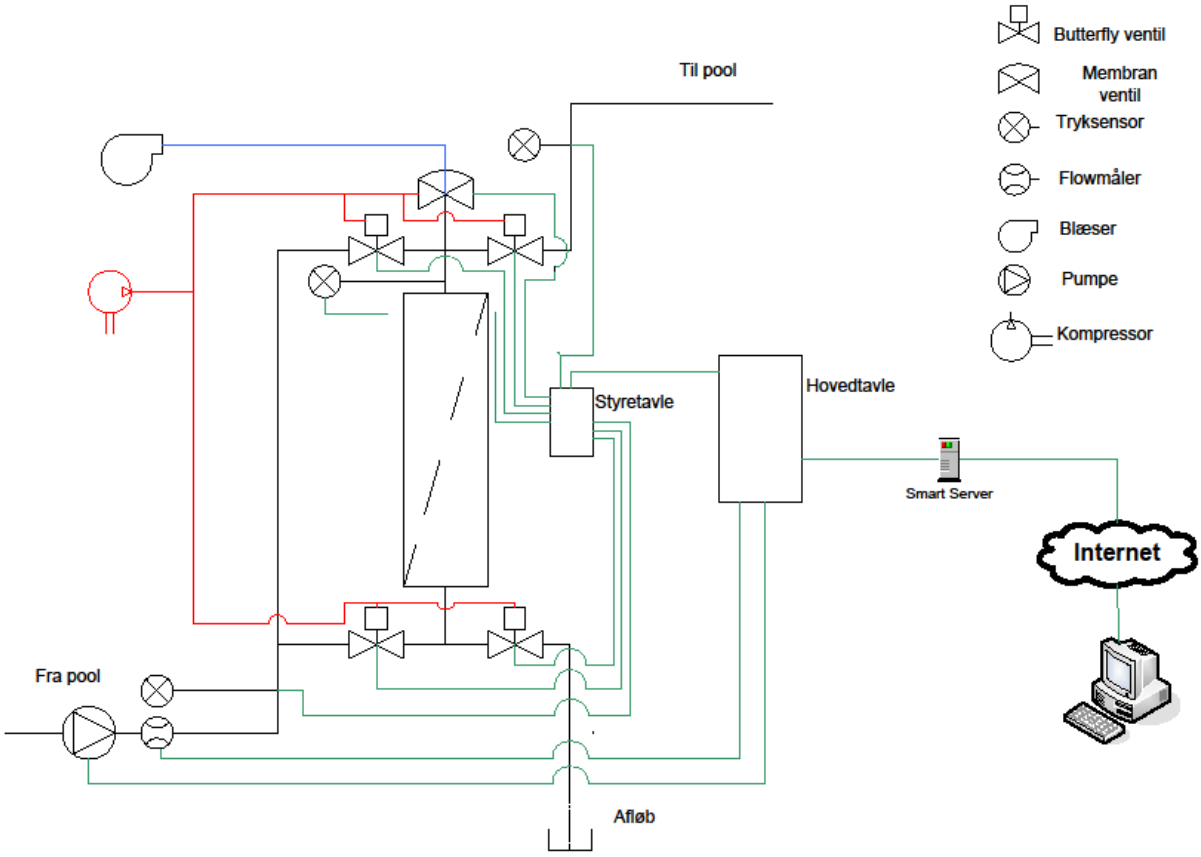

Figure 3-2 Overview of components and characteristics of membrane test unit (Pressure – Impulse diagram).

3.2.1 Characterization of the test site

The test site selected for the verification is characterized by three tasks: sampling and analyses, measurements and description of the test site.

Sampling and analyses

The numbers of samples to be taken during the initial runs are presented in Table 3-2. Sampling must take place during normal operation and preferably straight after a back wash cycle, half way between two back wash cycles and just before a back wash cycle. When sampling takes place on-line measuring and date and hour of the measurements are recorded. The on-line parameters to be collected are presented in Table 3-3.

Table 3-2 Number of samples to be analysed.

Parameter	Unit	Laboratory	Feed water	Treated water	Backwash water
Particle counting	Number/ml	DHI	3	3	3
Total microbial counting	Number/ml	DHI	3	3	-
TOC	µg/l	DHI	3	3	3
Total Hardness	°dH	Eurofins	3	3	-
THM	µg/l	Eurofins	2	2	-

Measurements and data logging carried out at test site
During 48 hours of normal operation on-line logging of data takes place. The data collected during the operation are evaluated and a graph is plotted showing the transmembrane pressure over time. One or more back wash cycles must be included in the logging period and the back wash must not be started by force. The flux is equally plotted against time and logging of back wash frequency takes place (the time when the back wash takes place is recorded).

Table 3-3 Measurements carried out at the test site and by the filtration plant.

Parameter	Unit	Gladsaxe Svømmehal	Provital plant
pH	-	On-line	
Free chlorine	mg/l	On-line	
Bound chlorine	mg/l	On-site	
Temperature	°C	On-line	
Redox (ORP)	mV	On-line	
THM	mg/l	2 samples per year	
Feed flow	m^3/h		On-line
Feed water pressure	bar		On-line
Produced water pressure	bar		On-line
Back wash cycle start	ss:mm:tt:dd:mm		On-line
Back wash cycle stop	ss:mm:tt:dd:mm		On-line

Description of test site
Information is collected concerning the test site address, contact and number of visitors per year in the swimming pools.

The physical characteristics of Gladsaxe Svømmehal will be reported. These characteristics include: Types of basins, temperature, volume of hot water pool, volume of make-up water used for back washing of sand filters and frequency of back washing.

Furthermore, specification of sand filters shall be given. Specifications include: Sand filter area and height, sand material and back wash velocity (air and water).

3.2.2 Initial operational runs
The initial test run comprises evaluation of the equipment operation and determination of the treatment conditions that cause efficient treatment of the feed water. The initial runs are shakedown testing and include the tasks described in Table 3-1, which consist of preliminary characterisation of feed water, produced water and back wash water, logging of on-line data from membrane filtration plant and description of test site.

Table 3-4 Test conditions for the initial operational runs.

Parameter	Unit	Interval
Feed flux (max. value)	$m^3/(m^2*h)$	50
Specific feed flux (max. value)	$m^3/(m^2*h)/bar$	12.5
Feed flow	m^3/h	20-60
Pressure feed water	Bar	0.6-0.75
Pressure produced water	Bar	0.5-0.6
Transmembrane pressure	bar	0.1-0.25
Number of backwashes	Number/day	1
Backwash cycle length	Minutes	10
Consumed water for back wash	L/back wash	75

3.2.3 Testing

The test equipment will be operated 24 hours a day, during 2½ half week. Duration of interruptions is recorded and must not exceed more than 30% of time. The tasks that will be performed are listed below:

Task 1: Characterisation of membrane flux and recovery
Task 2: Evaluation of back wash efficiency
Task 3: Evaluation of finished water quality
Task 4: Membrane integrity testing (particle counting and total microbial counting)
Task 5: Data management

Task 1: Characterisation of membrane flux and recovery
The objective of this task is to evaluate the membrane operational performance. Measurements of flow and pressure (in and out) are logged. Logging of pressure takes place every minute. The transmembrane pressure and flow are logged during operation. Transmembrane pressure-time curve, flux-time curve and flux-transmembrane pressure curve will be developed.

Task 2: Evaluation of back wash efficiency
An important aspect of membrane operation is the restoration of membrane productivity after (specific) flux decline has occurred. The objective of this task is to evaluate the effectiveness of the back wash. The recovery of (specific) flux will be determined after a back wash cycle has taken place.

The criterion for starting the back wash cycle is usually a trans membrane pressure higher than 0.25 bar. The back wash cycle is performed automatically and the criterion is set by the vendor to be once every 24 hours.

The flow in the whole re-circulating pool water system will vary depending on the development of clogging of the sand filters, and therefore it is not possible to obtain a constant water flow to the test plant. In fact this means that the back wash of the filter cannot be trigged based on the trans membrane pressure and this is why the back wash is started once every 24 hours.

To determine the effect of the back wash cycle flux-pressure profiles will be developed before and after back wash.

The immediate recovery of membrane productivity is expressed by the ratio between the final (specific) flux value of the current filtration run (J_{Sf}) [L/(h*m^2)/bar] and the initial (specific) flux (J_{Si}) measured for the subsequent filtration run.

Recovery of (specific) flux = 100 * [1- (J_{Sf}/ J_{Si})]

The loss of (specific) flux capabilities is expressed by the ratio between the initial specific flux for any given filtration run (J_{Si}) and the specific flux at time zero (J_{Sio}) as measured at the initiation of the first filtration run in a series.

Loss of original (specific) flux = 100* [(J_{Si}/J_{Sio})]

Task 3: Evaluation of finished water quality
The objective of this task is to evaluate the quality of water produced by the AquaSolution membrane. Some of the water quality parameters are measured on-line by Gladsaxe Svømmehal. Analyses of the water quality will be performed by an accredited laboratory). The analytical parameters to be determined are presented in Table 3-5. Optional analytical parameters are listed below the horizontal line. Table 3-6 includes methods of measurements to be used to document the operational conditions.

Table 3-5 Analytical parameters and analytical methods used for verification testing. Analyses on Pseudomonas, coli form bacteria and AOX are optional parameters.

Parameter	**Facility**	**Method**
pH	On-site	pH-meter, Gladsaxe Svømmehal
Temperature	On-site	Grundfos RPS Temperature sensor
Hardness	Laboratory	DS 250:1973
Particle count	On-site	AccuSizer AD
Total microbial count	Laboratory	Reasoner and Geldrich /18/
THM	Laboratory	GC-ECD
Free chlorine	On-site	Chlorine sensor
Bound chlorine (Chloro amines)	On-site	Gladsaxe Svømmehal (method)
TOC	Laboratory	DHI method
Pseudomonas	Laboratory	DS/EN ISO 16266:2000
Enumeration of coli form bacteria	Laboratory	DS 2255:2001
AOX	Laboratory	DS/EN ISO 9562:2005

Table 3-6 Operational parameters – methods of measurements.

Parameter	Facility	Method	Precision	Range of application
Flow	On-line	Krohne Optiflux 2000	± 0.5%[1)]	0-150 m^3/h
Flux		Calculated	-	-
Pressure	On-line	Jumo MIDAS	≤0.5 of scale max.	0-1.6 bar
Pressure	On-line	Grundfos RPS	± 1.5 % of scale max.	0-2.5 bar
Total microbial count	Laboratory	Reasoner and Geldrich /18/		>5
Particle count	On-site	AccuSizer AD	5%	1.5-400 µm
Temperature	On line	Grundfos RTS	± 1 °C [2)]	0-100°C

[1)] Velocity ≥ 0.4 m/s.
[2)] ± 1°C at temperatures between 25 and 80°C.

Task 4: Membrane integrity testing (particle counting)
The particle removal efficiency of the membrane filtration process is established by indirect particle counting. The removal efficiency value is demonstrated and monitored during 30 days of operation and focus on the removal efficiency of particles within defined particle size intervals 1.3-4.99, 5-10.32 and 10.33-20.39 µm.

The methods to be used for determination of the particle size distribution shall preferably be accredited, however, this is not practically possible and therefore the size distribution is performed by using the equipment AccuSizer 780/SIS which is based on the method of single-particle optical sensing (SPOS) also called optical particle counting. The particle sensor will be calibrated by using a set of certified particle standards of narrow size distribution having well defined diameters.

It is expected that the membrane also provides a constant barrier to microbial contaminants, but the microbial contaminants in the pool water is affected by the chlorination and therefore it is not possible in this on-site test to verify, if the membrane provides a barrier to the microorganisms. However, present microorganisms are quantified in samples from the feed water and the produced water in order to get an indication if the membrane works as a microbial barrier. The method used for enumeration of the total microbial count is adjusted to chlorinated pool water. The method include incubation for 7 days and application of a medium which improves the possibilities for growth of microorganisms that have been exposed to chlorination /18/.

Although the removal of microorganisms is affected by chlorination of the pool water the number of present microorganisms is quantified by sampling and analysing water from the inlet and the outlet of the filter.

Task 5 Data management
Data management including manual recording and handling of logged data is described in Chapter 5.

3.2.4 Test methods
No standard method exists for testing filters intended for treatment of pool water. The test methods have accordingly been prepared for the purpose with reference to the EPA/NSF ETV Equipment verification Testing Plan for Removal of microbiological and particulate contaminants by membrane filtration /15/.

3.2.5 Test staff

The test staff, which are test responsible: B.Sc. Eng. Bodil Mose Pedersen (BOP) and test technician Susanne Klem (SEK).

3.2.6 Test schedule

The test schedule is given in Table 3-7.

Table 3-7 Test schedule.

Task	Week 2009/2010												
	45	46	47	48	49	50	51	52	01	02	03	04	05
Characterization of test site	x												
Initial operation runs		x											
Characterization of membrane flux and recovery			x	x	x	x							
Evaluation of back wash efficiency			x	x	x	x							
Evaluation of finished water quality			x	x	x	x							
Membrane integrity testing			x	x	x	x							
Test report draft												x	
Test report QA													x
Test report											x	x	x

3.2.7 Test equipment

The high flux AquaSolution asymmetric silicium carbide (SiC) membrane is designed for removal of particulates from a water matrix. The membrane also rejects bacteria – depending on the pore size in the filter of interest. However, in the present test particle removal is the primary objective.

The AquaSolution filter elements (three units) are placed in a housing delivered by Provital A/S. Depending on the water flow several filtration modules might be installed in parallel. Currently, 3 filters in parallel are tested corresponding to a water flow of 20-60 m^3/h.

The current filtration unit is equipped with an automatic operation system. The flow and pressure at inlet and outlet are measured continuously and the back wash cycle is controlled by these parameters. A forced back wash cycle can be started.

Description of the test equipment delivered by Provital is given in Appendix 4 and includes construction, operation, data logging and monitoring equipment.

3.2.8 Type and number of samples

The types and numbers of samples to be taken are summarized in Table 3-8 and Table 3-9. During 30 days of operation sampling takes place once a week. The week days where sampling takes place must not be the same during the test period. Immediately after spot samples have been taken the on-line instruments, which measure pH, temperature, free chlorine and bound chlorine in the re-circulated pool water, are read. The spot samples which are taken from the feed water and the produced water are sent to an accredited laboratory to be analyzed. The laboratory delivers appropriate bottles for storage of samples until analysis.

The back wash water should be sampled and analyzed concerning TOC and particle counting. Sampling takes place 6 times with equal time intervals during the 2½-week testing period.

Table 3-8 Sampling during 2½ weeks of operation. Spot samples should be taken from the feed water and the produced water.

Parameter	Sampling/Reading
pH	Read on-line instrument
Temperature	Read on-line instrument
Free chlorine	Read on-line instrument
Bound chlorine (Chloro amines)	Analysed by Gladsaxe Svømmehal
Hardness	10 – 5 samples from inlet and outlet
THM	10 – 5 samples from inlet and outlet

Particle concentrations are measured in samples taken from the feed water and the produced water. Sampling takes place 6 times (6 events) with equal times during the test period (2½ weeks). The intervals between the spot samples representing one event appear from Table 3-9. Total microbial count is included in the program, but microbial counting is only performed to characterize the pool water before and after treatment. Samples from 3 events are included.

Table 3-9 Sampling, particle counting (p) and total microbial counting (m) within the following ranges: 1.5-4.99 µm, 5-10.32 µm and 10.33-20.34 µm.

Water	Hours after back wash					
	0.5	1	2	4	22	23.5
Feed water	pm	p	p	p	p	pm
Produced water	pm	p	p	p	p	pm

Particle size analyses are carried out on 36 samples from the feed water and on 36 samples from the produced water. Replicates will be carried out. The time is recorded when the sampling is carried out.

Total microbial count is analyzed in 6 samples from the feed water and 6 samples from the produced water.

3.2.9 Operation conditions

The operational conditions applied during verification of the product appear from Table 3-10.

Table 3-10 Operational conditions during the test period.

Parameter	Unit	Test value minimum	Test value maximum
Feed flux	$m^3/(m^2*h*bar)$	N/A	50
Feed flow	m^3/h	20	60
Transmembrane pressure	bar	0.1	0.25
Time between back washes	hours	23.5	24.5
Backwash cycle length	minutes	9	11
Consumed water for back wash	L/back wash	70	80
Temperature	°C	32	34
Water volume (pools and pipes)	m^3	50	50
Re-circulation flow	m^3/h	60	80

3.2.10 Operation measurements

During operation, the logging of operational conditions will take place on the FTP-server connected to the filtration plant. Logging of pressure (in and out) takes place every minute. Parameters and units are summarized in Table 3-11.

Table 3-11 Operational data to be recorded.

Parameter	Unit
Feed flux	$m^3/(m^2*h*bar)$
Feed flow	m^3/h
Feed flow pressure	bar
Produced water pressure	bar
Transmembrane pressure	bar
Time between back washes	hours
Backwash cycle length	minutes
Consumed water for back wash	L/back wash

3.2.11 Product maintenance

Product maintenance described by Provital is given in Appendix 4.

3.2.12 Health, safety and wastes

Work at the test site will be done according to DHI rules for safe field work included in the DHI safety rules.

Back wash water is discharged to the sewer system in the same way as the back wash water from the existing sand filters in Gladsaxe Svømmehal.

4 REFERENCE ANALYSIS

Reference analyses are not performed.

The date is recorded concerning The latest calibration of the flow meter and the pressure meter shall be recorded.

The particle counter is calibrated using a set of particle standards of narrow size distribution having well defined diameters (typically polystyrene latex) (see section 6.2).

4.1 Analytical laboratory

Water quality of feed water and produced water to be carried out by Eurofins Miljø A/S, Ladelundvej 85, 6600 Vejen is a part of this test plan. Eurofins Miljø has a DANAK accreditation. The total microbial count is performed by DHI, Department of Environmental Risk Assessment. The analyses to be carried out appear from Table 4-1.

4.2 Analytical parameters

The analytical parameters appear from Table 4-1.

4.3 Analytical methods

The analytical methods are given in Table 4-1.

Table 4-1 Parameters and total number of samples to be analysed (6 feed water and produced water).

Parameter	Method	Samples	Limit of detection	% RSD
TOC	Sievers 800 TOC analyzer	12[1)]	1 µg/l	
THM	GC-ECD	10	0.1 – 0.5 µg/l	2-5
Hardness	SM 3120 ICP	4	0.5 °dH	4.3
Particle analysis	Accusizer 780/SIS	12	1.3 -400 µm	5
Total microbial count	SF 30/816:02	12	5 counts/ml	-

[1)] 12 samples = 3 days (one sample of feed water and produced water immediately after back wash and immediately before back wash).

SF 30/816:02 DHI method based on /18/.

4.4 Analytical performance requirements

The limit of detection and uncertainty is given in Table 4-1.

4.5 Preservation and storage of samples

All water samples are sampled in glass bottles and the secondary samples are put into bottles delivered by the laboratories. The samples are preserved as prescribed by the laboratory if needed and as minimum stored cold (1-5ºC) and dark until delivered to the laboratory within maximum 3 days.

5 DATA MANAGEMENT

In general the data filing and archiving procedures of DHI Quality System Manual will be followed.

The data management involves manual recording of operational data and handling of operational data which has been logged on the FTP- server. Data from the FTP- server will be transferred to DHI. Add to this, transfer of analytical results from accredited/qualified laboratories.

5.1 Data storage, transfer and control

Data handling will consist of collection and writing into custom designed Excel spread sheets (Appendix 5).The spread sheets will be used for calculation and storage of data concerning water quality. Operational parameters are transferred from the smart server, operational data collected from Gladsaxe Svømmehal's monitoring of the pool water quality and data on sampling (time and location). The Excel spread sheet will be available on a lab-top PC provided by the test centre. Action and events with relevance to the test plan will be written into a log book including date and time. Samples to be sent for analyses by an external laboratory are labelled with the pre-defined label in order to ensure correct transfer of analytical data. Data received from the FTP- server will be reviewed by the test-site test responsible.

Data to be compiled and stored are summarized in Table 5-1.

Table 5-1 Data compilation and storage summary.

Data type	Data media	Data recorder	Data record timing	Data storage
Test plan and report	Protected pdf files	Test responsible	When approved	Files and archives at DHI
Test details at test site	Log book and pre-prepared forms	Test technician, DHI	During collection	Files and archives at DHI
Operational data	FTP- Server	CoMeTas	During operation	Transferred data - files and archives at DHI
Calculations	Excel files	Test responsible, DHI	During calculation	Files and archives at DHI
Analytical reports	Paper	Test responsible, DHI	When received	Files and archives at DHI

6 QUALITY ASSURANCE

The tests are performed under the Centre Quality Manual - Water Technology which is ISO 9001 compliant, but not certified /16/. The DHI laboratories have ISO 17025 accreditations /16/ and OECD GLP approvals /17/ for a range of tests and ISO 17025 for sampling of drinking water. As part of the ISO 17025 and GLP inspections, the procedures for general laboratory processes, quality assurance and documentation/archiving are assessed.

6.1 Test plan review

The test plan will be subject to internal review by the internal expert from DHI, Head of Innovation: Gert Holm Kristensen.

External review of the test plan will be done by the technical expert assigned to this verification.

6.2 Performance control – Sensor calibration

The sensor in the AccuSizer 780/SIS can be calibrated using a set of particle standards of narrow size distribution having well defined diameters (typically polystyrene latex).

The sensor calibration is performed once every month with a single point standard reference material used in the calibration of the system. The standard should be in the centre range of system (10 µm). The population-weighted distribution of the standard is compared with the reported size. The values should be within 5% of each other. If the values deviate by more than 5% the procedure for recalibrating the system should be followed for the entire range of standards. A printout of the sensor Calibration Curve is generated.

The latest calibration performed by the manufacture is stated in a certificate which will be included in the test report.

6.3 Test system control

The stability of the test equipment will be controlled continuously by supervision and recording of data in the log book and by logging of operational data on the FTP-server. The data to be recorded is feed flow, inlet/outlet pressure, transmembrane pressure, temperature, the frequency of back washing, disposal of back wash water, particle analysis.

The control of the particle analysis is done by using analysis of reference samples and field blank samples.

6.4 Data integrity check procedures

Data storage, transfer and control is done in accordance with the requirements of the Centre Quality Manual – Water Technology enabling full control and retrieval of documents and records. The filing and archiving requirements of the DHI Quality System Manual is followed (10 years archiving).

6.5 Test system audits

Internal audit from DHI following GLP audit procedure by a trained auditor is done.

6.6 Test report review

The test report will be subject to internal review by internal expert Head of Innovation Gert Holm Kristensen.

External review of the test report will be done by the external expert as part of the review of the verification report.

7 TEST REPORT

The test report will follow the template of the Centre Quality Manual - Water Technology /1/ and will be included as an appendix in the verification report. The test report will contain the test plan, except for this Chapter 7 on the test report format with data and records from the tests to be inserted as a new chapter 7.

7.1 Test site report

The test site report will include: PI-diagram and operational data as outlined in Section 6.

7.2 Test data report

The test data will include all data recorded during the test and the data reported by the analytical laboratories.

7.3 Amendment report

The report section on deviations will compile all changes of the test plan occurring before testing with justification of deviations and evaluation of any consequences for the test data quality.

7.4 Deviations report

The report section on deviations will compile all deviations from this test plan occurring during testing with justification of deviations and evaluation of any consequences for the test data quality.

A P P E N D I C E S

A P P E N D I X 1

Terms and definitions used in the test plan

Word	Explanation
Analytical laboratory	Independent analytical laboratory used to analyze reference samples
Application	The use of a product specified with respect to matrix, target, effect and limitations
AQS	Trademark - AquaSolution
Back washing	Periodic mode which the filter is cleaned by sending pressurized water/air in the reverse direction of filtration
BEK	Bekendtgørelse = Announcement
Cross flow filtration	Filtration mode where membrane flow is re-circulated. The feed passes through a membrane and the solids are trapped in the filter
Dead end filtration	Filtration mode where there is no circulation and the only flow inside the membrane is the feed flow
DBP	Desinfection by-products
DIN	Deutches Institut für Normung
DS	Danish Standard
Feed water	Water introduced to the membrane module
Feed water recovery	Filtrate flow rate divided by the feed water flow rate
Filtrate	Water produced by the membrane filtration process
Flux (water flux)	Rate of product water (flow) through a pressure-driven membrane divided by the total filtration surface area
FPT-server	File transfer Protocol (client server protocol)
Fouling	Deposition of organic matter on the membrane surface, which cause inefficiency
Effect	The way the target is affected, in this verification the way the target compounds are measured
EN	European standard
EPA	U.S. Environmental Protection Agency
ETV	Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and adequate quality assurance
EU	European Union
Evaluation	Evaluation of test data for a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification or on verification as a process
HAA	Halogen Acetic Acid
HAN	Halo Aceto Nitriles
Hardness (water) ºdH	One degree German (ºdH) is defined as 10 milligrams of calcium oxide per liter of water. This is equivalent to 17.848 milligrams of calcium carbonate per litre of water, or 17.848 ppm
ISO	International Standardization Organization
Matrix	The type of material that the product is intended for
Membrane fouling	A reduction of filtrate flux that can be restored by mechanical or chemical means is teemed “reversible” fouling. In contrast “irreversible” fouling is defined as a permanent loss in filtrate flux capacity that cannot be restored. The fouling of membranes designed for particle or microbial removal is primarily attributed to deposition of material on the membrane surface and/or in the membrane pores
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
MF	Membrane filtration

Word	Explanation
NSF	NSF International (Public Health and Safety Company)
NVOC	Non Volatile Organic Carbon
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of intended use
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product
Pool water control	Control of pool water quality against pool water maximum concentrations
Precision	The standard deviation obtained from replicate measurements, here measured under repeatability or reproducibility conditions
(Environmental) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology
QA	Quality assurance
Range of application	The range from the LoD to the highest concentration with linear response
Reference analyses	Analysis by a specified reference method in an accredited (ISO 17025) laboratory
Repeatability	The precision obtained under repeatability conditions, that is with the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time
Reproducibility	The precision obtained under reproducibility conditions, that is with measurements that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects
Robustness	% variation in measurements resulting from defined changes in matrix properties
RSD	Relative standard deviation in %
Scaling	The precipitate that forms on surfaces in contact with water as the result of a physical or chemical change
SM	Standard Methods for the Examination of Water and Wastewater, latest edition
SiC	Siliceous carbide
Specific flux (permeability)	Flux divided by transmembrane pressure
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product, in this verification the target compounds measured
(Environmental) technology	The practical application of knowledge in the environmental area
Test/testing	Determination of the performance of a product by parameters defined for the application
THM	Tri Halo Methan
Transmembrane pressure	Feed stream (average feed/concentrate) pressure (cross flow operating mode) or feed pressure (dead-end operating mode) minus the permeate (product)
UF	Ultrafiltration
Vendor	The party delivering the product or service to the customer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

Word	Explanation
TOC	Total organic carbon

A P P E N D I X 2

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/18/ Reasoner, D.J. og Geldreich, E.E. 1985. A new medium for the enumeration and subculture of bacteria. A&EM, 1985, Jan p 1-7.

/19/ AccuSizer 780/SIS User Manual 08/2006

A P P E N D I X 3

In-house test methods and analytical methods

Particle count
The AccuSizer 780/SIS used for the particle counting is an instrument based optical particle counting (OPC). Particles in gas or liquid suspensions flow through a small "photo zone" – a narrow, slap-like region of uniform illumination, produced by light from a laser diode or incandescent bulb. The particle suspension is sufficient dilute when the particles pass one a time, through the illuminated region, avoiding coincidence.

Particle sizing instruments based on ensemble techniques are inherently limited in accuracy and resolution. The raw detected signal must mathematically "inverted" using an appropriated analysis algorithm in order to estimate the particle size distribution. In effect, these instruments must assume a shape, for the particle size distribution, using a small number of parameter and then minimizing the error between the measured data and a calculated fit by adjusting the parameters /19/.

TOC
The Sievers 800 Series Total Organic Carbon Analyzer is a high-sensivity analyzer to measure total organic carbon (TOC), total inorganic carbon (TIC) and total carbon (TC = TOC+TIC) in water samples.

The analyzer is based on oxidation of organic compounds to form carbon dioxide using UV radiation and chemical oxidizing agent (ammonium persulfate). Carbon dioxide is measured using a selective membrane-based conductometric detection technique. For each TOC measurement, the concentration of inorganic carbon species (CO_2, $HCO_3^-$and CO_2^{2-}) is determined and after oxidation of the organic compounds, the total carbon content of the sample is measured. The concentration of the organic compounds is then calculated from the difference between total carbon and total inorganic carbon concentrations: TOC=TC-TIC.

The analyzer can monitor water samples ranging from 0.5 ppb to 50 ppb TOC. The analyzer is calibrated at the factory with calibration stable for one year. Recalibration and validation is performed at DHI.

A P P E N D I X 4

Information about the test plant

Information til DHI vedr. testanlæg hos Gladsaxe Svømmehal

1 Contents

2 Beskrivelse af testsystem

2.1 Systemet indeholder:

- 3 stk. SiC membraner, Ø144x800, 2x2, 3 µm
- 1 stk. Komplet PolyPropylen system inkl. filterhuse
- 12 stk. Pneumatiske butterfly ventiler, inkl. pilotventiler og tilbagemelder
- 3 stk. Pneumatiske membranventiler inkl. pilotventiler
- 1 stk. Ringkammerblæser, 3.4 kW, 380V
- 1 stk. Kompressor, 1,86 kW (2,5 HP), 230 V
- 1 stk. Hovedtavle inkl. Smart Server, software, motorværn og softstarter
- 2 stk. Styrekasser inkl. kontrollere
- 1 stk. Flowmåler

- 5 stk. Tryksensorer

2.2 Driftsmanual:

Da filtersystemet er installeret med et fuldautomatisk styresystem, vil der ikke være nogen manuelle driftsfunktioner. Styresystemet er programmeret til kontinuerligt at måle og logge flow igennem systemet samt trykket på ind- og udgangen af systemet, og ud fra disse data og den til systemet specielt udviklede algoritme bestemme tidspunktet for bagskylning af filterne.

Det er muligt at påbegynde en tvungen bagskyl af systemet, ved at aktivere kontakten på hovedtavlen. Endvidere er det muligt via hovedtavlen at tænde og slukke systemet.

Ligeledes er det muligt via den internetbaserede brugerflade, som medfølger systemet. På brugerfladen er det muligt at se de loggede data fra flow, tryk, bagskyl og alarmer. Det er muligt selv at bestemme tidsperiode for de loggede data. Ved fejl på systemet genereres en fejlmeddelelse som sendes til de ansvarlige personer via e-mail.

Brugerfladen viser aktuelle data på temperatur og pumpens procentvis ydelse. Det er ikke muligt for brugeren at se andre ting eller ændre på noget i systemet. Ønskes der ændringer i systemet, skal Provital kontaktes.

2.3 Driftsinformation:

2.3.1 IP adresse på brugerflade

- 80.251.198.150 (HTTP)
- 80.251.198.150 (FTP)
- Login: ilon
- Password: ilon

2.3.2 Returskylle tid

- Det tager ca. 10 minutter at returskylle alle membraner.

2.3.3 Logning af data

- Interval: 15 min.
- Modtager af data
    - Provital
    - DHI
- Datalogning:
    - Flow
    - Tryk på ind- og udgang
    - Antal tilbageskyl
    - Alarm
    - Temperatur

3 Driftforhold

- Udgangstryk 0,5-0,6 bar
- Indgangstryk 0,6-0,75 bar
- Transmembrantryk 0,1-0,25 bar
- Flow 20-60 m^3/h

4 Instrumenter

4.1 Flowsensor, Krohne Optiflux 2000 med IFC 100D signalkonverter

- Måleområde: 0-150 m3/h
- Udgang/signal: 4-20 mA
- Nøjagtighed: ± 0,5 % af målt værdi ved hastighed ≥ 0,4 m/s
- Spændingsforsyning: 230 V

4.2 Jumo MIDAS tryktransmitter

- Måleområde: 0-2,5 bar
- Udgang/signal: 0-10 V, 3-leder
- Procestilslutning: G ½ iht. DIN 3852 T11
- Materiale: Rustfrit stål
- Spændingsforsyning: 24 VDC
- Beskyttelsesklasse: IP65 med kabeldåse
- Karakteristikafvigelse: ≤ 0,5 % af skala max.
- Hysterese: ≤ 0,2 % af skala max.
- Indstillingstid: ≤ 3 ms max.

4.3 Grundfos RPS tryktransmitter

- Måleområde: 0-1,6 bar
- Udgang/signal: 0,5-3,5 V
- Materiale, housing: EPDM og PPS
- Materiale, sensor: Silicon-based MEMS sensor
- Spændingsforsyning: 5 VDC
- Beskyttelsesklasse: IP44
- Nøjagtighed: ± 1,5 % skala max.
- Indstillingstid: < 0,5 s.

4.4 Grundfos RPS tryktransmitter

- Måleområde: 0-2,5 bar
- Udgang/signal: 0,5-3,5 V
- Materiale, housing: EPDM og PPS
- Materiale, sensor: Silicon-based MEMS sensor
- Spændingsforsyning: 5 VDC
- Beskyttelsesklasse: IP44
- Nøjagtighed: ± 1,5 % skala max.
- Indstillingstid: < 0,5 s.

4.5 Grundfos RPS Temperatursensor

- Måleområde: 0-100 °C
- Udgang/signal: 0,5-3,5 V, 3-leder
- Materiale, housing: EPDM og PPS
- Materiale, sensor: Silicon-based MEMS sensor
- Spændingsforsyning: 5 VDC
- Beskyttelsesklasse: IP44

- Nøjagtighed: ± 1 °C (temp. mellem 25-80 °C)
- Indstillingstid: < 1,5 s.

5 Konstruktion

5.1 Rør materiale:

- PP (polypropylen)
- Temperatur: 0 - + 80 °C
- Længdeudvidelses-koefficient: 0,16mm/m°C
- Bestandig overfor:
  - Syre, base, svage opløsningsmidler, deioniseret vand
  - Bestandig overfor natriumhypoklorit v. 2 % aktiv klor og 20-40 °C
  - Bestandig overfor saltsyre v. > 30 % koncentration ved 20-40 °C
- Densitet: 0,91 g/cm3

5.2 Ventiler:

- Butterfly ventil: DN100
- Pakning: EPDM
- Aktuator:
  - PP20
  - Lukketid: 0,58 sek. ved 5,9 bar tryk
  - Styring:Magnetventil – 24 VDC

5.3 Membranventil:

- Membran: EPDM
- O-ring: Vitron

6 Drift

6.1 Normal drift mode

Ved normal drift forstås kontinuerlig rensning af svømmebadsvandet og filtreringsanlægget kører i systemets normal mode. Systemet har to hoved-modes, som systemet agere ud fra, normal-mode og returskylle-mode.

Normal-mode er i systemet defineret som den indstilling, hvor svømmebadsvandet filtreres gennem membranerne og returneres til bassinet. Denne indstilling er aktiv indtil systemet initiere et returskyl via systemets interne ur ellers via manuel aktivering vha. returskylleknappen på styrekassens front.

- Tidsindstilling
- Manuelt returskyl

Returskyl initieres primært af en i styresystemet indstillelig tid, som tvinger systemet til returskyl. Denne tid er ”default” indstilling til at foregå kl. 00.00 hver dag.

Et returskyl kan dog også påtvinges systemet via returskylle-knappen, som er placeret på hovedtavlens front. Denne holdes inde i 2 sek. hvorefter returskylle-mode initieres.

6.2 Returskylle mode

Som beskrevet i 6.1 vil et returskyl initieres automatisk eller manuelt. Som beskrevet initieres returskyl hver dag kl. 00.00.

Når systemet aktivere et returskyl, lukkes for tilgangen og afgangen på den pågældende membran, og tilgangen til kloakken åbnes. Samtidig startes blæseren og herefter ventilen for lufttilførsel.

7 Vedligeholdelse

Systemet er som udgangspunkt vedligeholdelses frit. Der vil ikke være nogen daglig vedligeholdelse på systemet, da systemet er fuldautomatisk og returskyller sig selv. Hvis der sker en fejl på systemet, således systemet ikke længere drifter optimalt, vil systemet give en alarm i form af en email eller sms, der automatisk genereres af systemet.

Det er vigtig for optimal drift af systemet at pumpe, blæser og kompresser efterses i overensstemmelse med disses vejledning. Ligeledes kan et årligt eftersyn af ventiler og aktuatorer være nødvendigt for sikker drift.

Hvis systemet ikke formår selv at regenerere membraner vha. returskyl kan det være nødvendigt at rense membranerne kemisk. Herved kan de regenereres 100 %.

Yderligere er det vigtigt at der hele tiden er salt på blødgøringsanlægget, da det kan være belastende for membranerne, hvis vandpåfyldningsvandet ikke er blødgjort.

A P P E N D I X 5

Templates for data tables

Flow read on the flow meters measuring the flow passing the filter plant (filter) and the flow that re-circulates over the warm water pool (GS)

Week day	Date	Time	Flow filter m^3/h	Flow GS m^3/h	Ratio %	Comment

Manual started back washes and measured water volume for back wash of the three filter

Day	Date	Time	Volume	Comment

Summary of back washes during the test and duration of the back wash process or processes

Week day	Date	Back wash Start Time	Back wash Stop Time	Duration Back wash minutes	Comment	Supervision by DHI
Sunday						
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						
Monday						
Tuesday						

Overview of samples taken for particle counting during the test

Hours after back wash	Monday file	file	Tuesday file	file	Thursday file	file	Friday file	file
in								
0.5								
1								
2								
4								
22								
23.5								
out								
0.5								
1								
2								
4								
22								
23.5								
	Tuesday file	file	Wednesday file	file	Wednesday file	file	Thursday file	file
in								
0.5								
1								
2								
4								
22								
23.5								
out								
0.5								
1								
2								
4								
22								
23.5								
	Monday file	file	Tuesday file	file	Tuesday file	file	Wednesday file	file
in								
0.5								
1								
2								
4								
22								
23.5								
out								
0.5								
1								
2								
4								
22								
23.5								

Read of online meters measuring pH, ORP (oxidation reduction potential), temperature and free chlorine In Gladsaxe Svømmehal

Day	Date	Time	pH	Redox mV	Temperature °C	Free Chlorine mg/l
Requirement			6.7-7.4			0,5-2,0
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						
Monday						
Number Average Minimum Maximum Std.dev.						