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

Verification report

Physical removal of microbiological and particulate contaminants

WATER • ENVIRONMENT • HEALTH

CoMeTas
July 2010

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AQS-144-800-(2*2) 3 micron
Verification report

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2 INTRODUCTION

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 quality assurance.

2.1 Name of product

The product is the CoMeTas AquaSolution Element AQS-144-800-(2*2) 3 micron, designed for removal of particulate contaminants from solutions by dead-end filtration. The membrane may be placed in housings (the equipment surrounding the filters) from different manufacturers. For that reason, the product verified is the membrane (AquaSolution Element) without the housing.

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
Homepage: www.cometas.dk

2.3 Name of Center/verification responsible

The Danish Center for Verification of Climate and Environmental Technologies (DANETV), DHI DANETV Water Center, DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark.

Verification responsible: Mette Tjener Andersson, e-mail mta@dhigroup.com Phone +45 4516 9148

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

2.4 Verification and test organization

The verification was conducted by the Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for the reduction of climate changes and pollution.

The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

The day-to-day operations of the verification and tests were coordinated and supervised by DHI personnel, with the participation of the vendor, CoMeTas. The testing was conducted in Gladsaxe Svømmehal (GS), Gladsaxe, Denmark. DHI operated the AquaSolution filter during the verification. CoMeTas provided AquaSolution filters and mounted them at the test site. Furthermore, CoMeTas provided user manuals and operation instructions, and participated in development of protocol and plans with DHI.

An internal and an external technical expert were assigned to provide independent review of the planning, conducting and reporting of the verification and tests.

The organization chart in Figure 2-1 identifies the relationships of the organization associated with this verification and tests.

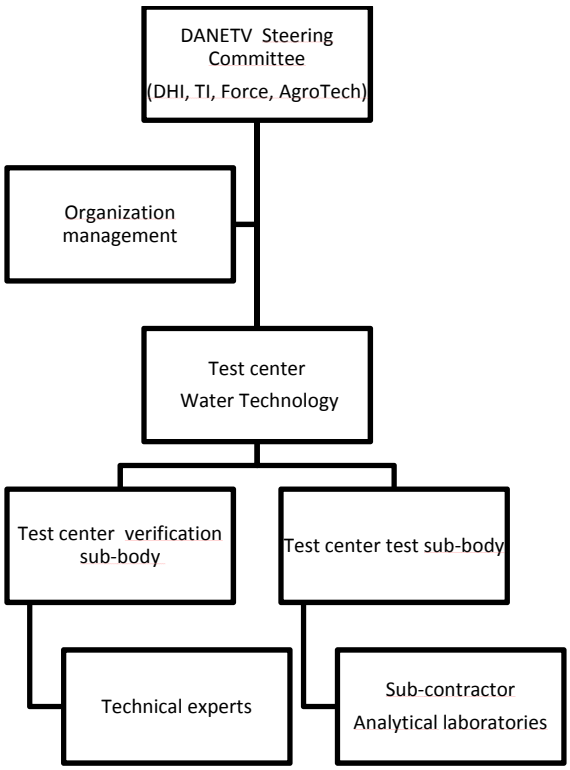

Figure 2-1 Organization of the verification and tests.

2.5 Technical experts

The technical experts assigned to this verification and responsible for review of the verification protocol, test plan and report documents include:

Gerald Heinicke (GHE) e-mail ghe@dhigroup.com, DHI, Agern Allé 5, 2970 Hørsholm, phone +45 4516 9268

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

2.6 Verification Process

Verification and tests were conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2-2.

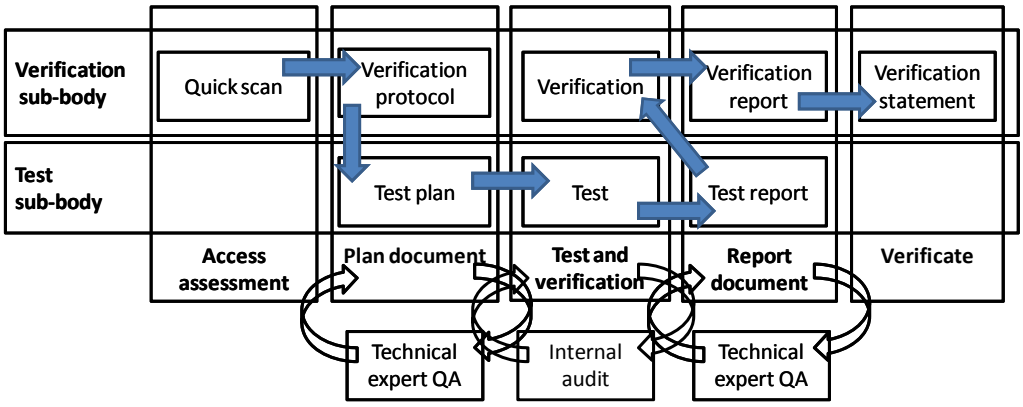

Figure 2-2 Verification steps.

References for the verification process are the Center Quality Manual – Water Technology for ETV Center and Test organization /1/.

A verification statement was issued by DANETV after completion of the verification. The verification statement, verification report and test report shall be seen as one consolidated verification description.

3 DESCRIPTION OF THE TECHNOLOGY

Pressure-driven membrane processes are used for a broad number of water treatment applications ranging from removal of microbial contaminants to removal of natural organic matter contributing to disinfection by-products (DBP) formation. Typically, low pressure membrane processes such as microfiltration (MF) and ultra filtration (UF) are employed to provide a physical barrier for removal of microbial and particulate contaminants from drinking waters, pool water and process water. Furthermore, low pressure processes can be used as pre-treatment for Reverse Osmosis.

AquaSolution Elements are silicon carbide membrane with a pore size of either 0.04 µm, 1 µm or 3 µm. The filter elements are designed for dead-end operation and applicable to filtration of pool and spa water.

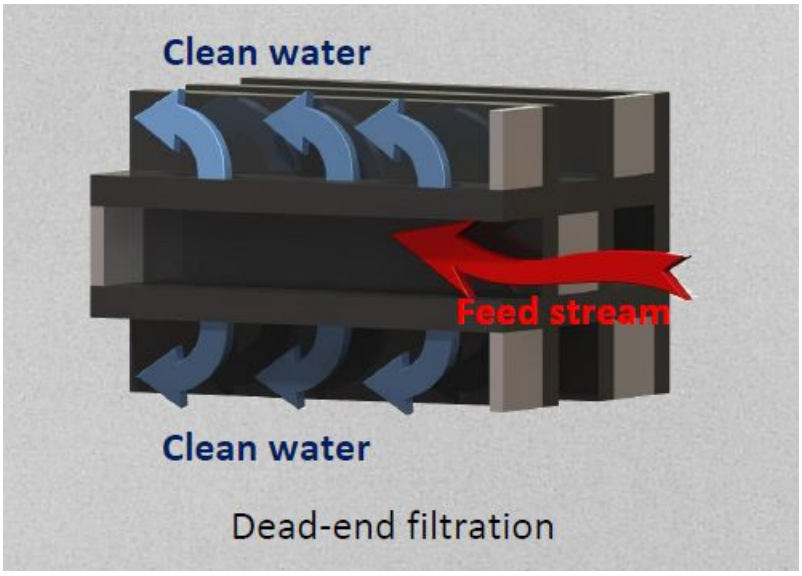

Figure 3-1 Illustration of dead-end operation.

4 DESCRIPTION OF THE PRODUCT

The product verified (one module) has a channel dimension of 2*2 mm, membrane area of 3.0 m^2, and dimension of 144 mm (diameter) times 800 mm (length). The typical specific water flux of the element is 40 $m^3/(m^2*h*bar)$. The information on the element was supplied by the vendor and does not represent verified information.

Equipment name: AquaSolution

Model: (AQS)-144-800-(2*2) Channel dimension 2*2 mm

Pore size: 3 µm

Dimension D=144 mm, L=800 mm

Typical water flux at *25ºC:* 40 $m^3/(m^2*h*bar)$

Warning and caution statements: Maximum operating pressure is 10 bar

Capacity per module: 40 m^3/h at 0.35 bar

Operation condition: Total Hardness of water less than dHº = 5

The high flux AquaSolution asymmetric silicon carbide (SiC) membrane is designed for removal of particulate contaminants from solution. The filtration equipment used for testing the membrane element was delivered by Provital Solution A/S (a joint venture between Cometas A/S and Løkken Spa og Pool A/S), and equipped with an automatic operation system. Three modules in parallel were tested. The flow and pressure at inlet and outlet were measured continuously (one-minute-intervals). The plant was designed for both automated (specific frequency) and manually backwash.

On a web based interface it was possible to follow the logged data concerning the temperature and pump operation (% performance of maximum). If an error arises an e-mail can be sent to the person responsible for the operation of the equipment. During the test, a side stream to the re-circulation of the whole water flow through the warm water pools in Gladsaxe Svømmehal was connected to the test plant.

Figure 4-1 shows a flow diagram of the re-circulation and treatment of the pool water in Gladsaxe Svømmehal.

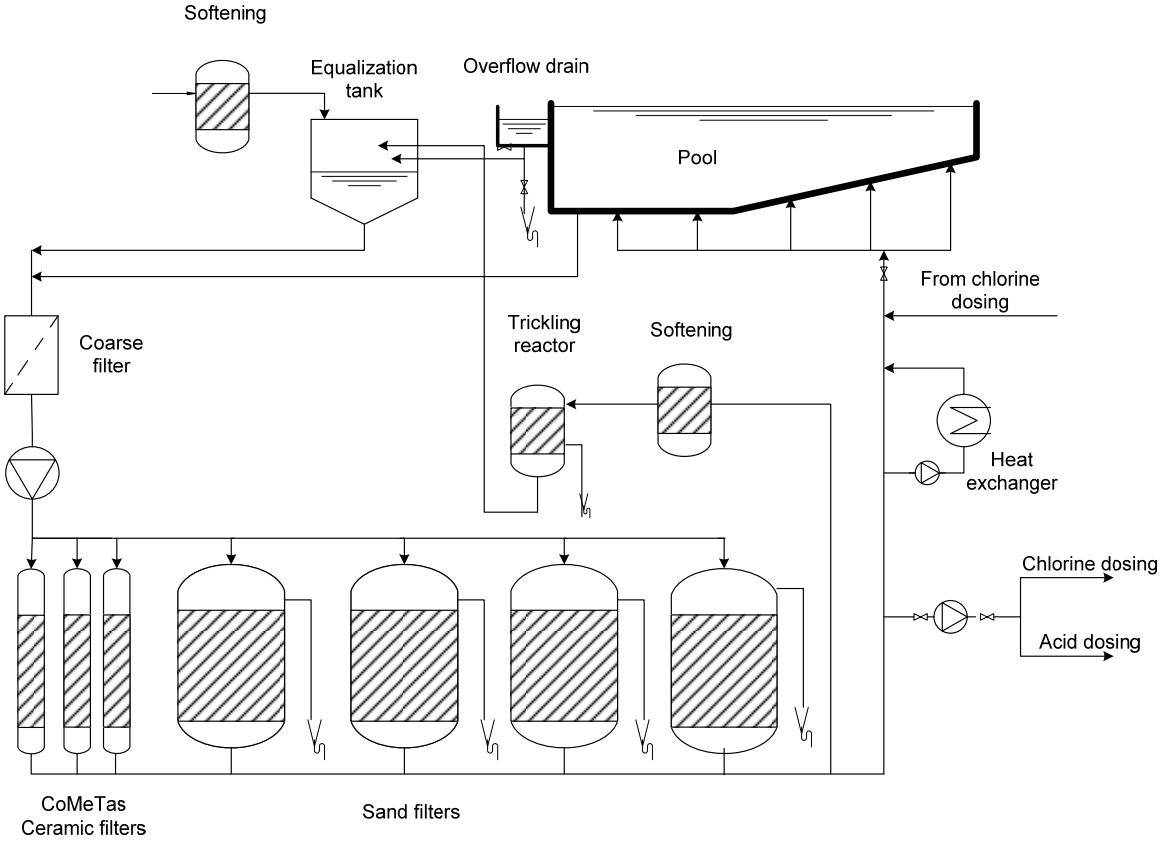

Figure 4-1 Flow diagram showing the re-circulation and treatment of pool water in sand filters.

The back wash procedure for the test plant was initiated daily. The back wash cycle consists of four phases:

1. The filtration is stopped and positions of valves are changed to back wash mode.
2. The blower is started, and the water inside pipes and modules is forced from the permeate side against the direction of filtration. The water is out of the system within seconds and the forced convection continues for a total of three minutes.
3. Tap water is flushed from the permeate side against the direction of filtration through the module to remove the loosened solids. The system is flushed for ten seconds.
4. The valves are changed to normal mode, and filtration continues.

5 APPLICATION AND PERFORMANCE PARAMETER DEFINITIONS

AquaSolution elements by CoMeTas were verified for treatment of re-circulated pool water at about 33ºC. The application is defined as detailed in the application definition appendix – Appendix 3 – in the terms of matrix/matrices for use and targets of removal of microbial and particulate contaminants from drinking waters, pool water and process water.

5.1 Application definition

For this verification, the matrix was re-circulated pool water from a paddling pool and a warm water pool in Gladsaxe Svømmehal. The main effect of the application evaluated was the removal of particles from the feed water. Because only a side stream was treated by the AquaSolution Elements it could not be verified if long term changes of the pool water quality happened. The operational conditions during the test were also reported.

5.2 Performance parameters for verification

The range of performance parameters relevant for the application as derived in Appendix 3 is presented in Table 5-1.

Table 5-1 Performance parameters for filters used for re-circulation of water in swimming pools. Total microbial count and TOC were measured but calculated percents of reductions are not performance parameters.

Parameter	Unit	Value	% removal
Rejection of particles 0.5-5 µm	number/ml		80
Rejection of particles 5-10 µm	number/ml		95
Rejection of particles 10-20 µm	number/ml		100
Total microbial count	number/100 ml	< 500	
TOC	mg/l	< 1	

TOC is measured in the pool water only in order to characterize the water. Most of the TOC is expected to consist of soluble organic matter which is not removed by the filter.

These performance parameters were verified under given operational conditions (Appendix 3 section 2.2) and it has been documented during the verification testing that the product was operated according to the stated operational conditions. The operational conditions linked to the above verification performance criteria are given in Appendix Table 5 (Appendix 3).

5.3 Additional parameters

No additional parameters were included in the verification.

6 EXISTING DATA

The vendor has provided some data from a test conducted at Skallerup Klit in Denmark. The system included two elements of AquaSolution OD144xL800 mm (2*2) 3 micron pore size. The modules were installed at a 5 m^3 spa (37°C). The system was operational from April 2008 and still operating in October 2009 when DHI received the data from the filter.

6.1 Summary of existing data

The following data were logged on-line: Transmembrane pressure, flow, Non-volatile Organic Carbon (NVOC), bound and free chlorine. The Danish Technological Institute concluded the following /2/:

- Permeate flux: 6 m^3/h at transmembrane pressure of 0.4 bar.
- Consumption of water for back wash: 0.05 m^3 water per element per day.

6.2 Quality of existing data

The documentation made available for the verification was not sufficient to allow for an assessment of the data quality.

6.3 Accepted existing data

Data generated during the above-mentioned test was not included in this verification.

7 TEST PLAN REQUIREMENTS

Based on the application and performance parameters identified in section 5.4, the requirements for the test design were set. A detailed test plan was prepared separately, based on the specification of the test requirements presented below.

7.1 Test design

The test design was partly based on the EPA/NFS ETV Equipment Verification Test Plan /3/.

The outline of the required tests is shown in Table 7-1. The principle behind the test design was the following four overall tasks:

A. Characterization of the test site.

B. Initial operational runs.

C. Verification testing.

D. Documentation.

Each task was subdivided and they are described briefly in the following sections.

Table 7-1 Test design of the verification.

Characterization of test site **A**	**Initial operation runs** **B**	**Verification testing during 18 days (24 hours a day)** **C**	**Documentation of verification** **D**
• Sampling and analyses of feed water (Laboratory analyses) • On-line measurements (CoMeTas/Provital/-Gladsaxe Svømmehal) Frequency of logging • Description of test site and description of the housing	• Operational conditions • Back wash • Logging of on-line data during 24 hours and during one week	Task 1 Characterization of membrane flux and recovery after back wash. Operational conditions and performance: flow (flux), pressure, and temperature	• Data management • Data quality
		Task 2 Back wash: Duration (water and air), volume of water, composition of back wash water	
		Task 3 Evaluation of feed water quality: Sampling and external analyses	
		Task 4 Membrane integrity. Removal of particles and (total microbial count)	

7.1.1 Task A: Characterization of the test site

Objectives

The objective of this task was to describe the test site and to obtain preliminary information about the composition of the feed water relevant for the operation of the AquaSolution filtration unit, which removes particulate contaminants and microorganisms from the pool water by passage through the micro-porous silicon carbide membrane.

Work plan
The initial characterization of the test site consisted of three tasks:

- Characterization based on existing analyses and new analyses.
- On-line data collected during daily operation of the re-circulation plant.
- Description of the test site.

The description of the test site included a schematic diagram and a list of equipment available at the test comprising on-line measurements for monitoring of the water quality in the warm water pool in Gladsaxe Svømmehal.

7.1.2 Task B: Initial operation runs

Objective
The objective of the initial runs was to identify and read/log the proper operating parameters for treatment of feed water during the final verification testing. The ability of the AquaSolution plant to effectively reduce the content of particles and microorganisms will vary depending on the flux, transmembrane pressure and the back wash frequency and back wash efficiency. Therefore it was important to have experiences about the operation of the plant before the verification test took place.

Work plan
The initial operation runs task was performed as three separate tasks compromising:

- Operational conditions.
- Back wash.
- Logging of on-line data.

During initial operation runs, the equipment operation was evaluated by determining flow and the accumulation of material on the membrane surface, which gradually increase the pressure required to force the water through the membrane pores. Back wash was initiated at a regular time during a 24 hours period. The operational parameters and the frequency for monitoring are presented in Table 7-2.

Table 7-2 Operational parameters and frequency for monitoring during test.

Parameter	Unit	Frequency	Logging
Feed flux	$m^3/(m^2*h)$	continuous	CoMeTas
Specific feed flux	$m^3/(m^2*h)/bar$	calculated	-
Feed flow	m^3/h	continuous	CoMeTas
Pressure in	bar	continuous	CoMeTas
Pressure out	bar	continuous	CoMeTas
Transmembrane pressure	bar	continuous	CoMeTas
Frequency of back washes	time	24 hours	-
Back wash cycle start	time	-	CoMeTas
Consumed water for back wash	L/back wash	5 times	-

CoMeTas A/S and the DHI DANETV Water Center evaluated the data produced during the initial runs, to determine if the filtration equipment performed in a manner that met or exceeded the statement of performance objectives.

The initial runs followed a schedule for sampling and analysis similar to the set up for the verification testing.

7.1.3 Task C: Verification testing

Objectives
The objective of this task was to evaluate the capacity of particle removal within the particle size ranges of 1.5-4.99 µm, 5.00-10.32 µm and 10.33-20.39 µm. Because the presence of micro-organisms is influenced by the chlorination of the pool water the removal capacity of total microbial count was not verified, but the number of total microbial count was analysed (number per 100 ml). The particle removal effect was given for a system operated at a flow between 20 and 60 m^3/h and back wash once every 24 hours.

Work plan
The verification test was conducted over a period of 18 days, and divided into four separate tasks:

Task 1: Characterization of membrane flux and recovery.

Task 2: Evaluation of back wash efficiency.

Task 3: Evaluation of water quality.

Task 4: Membrane integrity testing (particle counting).

Task 1: Characterization of membrane flux and recovery
The objective of this task was to evaluate the membrane operational performance. Measurements of flow and pressure (in and out) were logged every 60 seconds. Transmembrane pressure time curves and flow-time curves were 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 was to evaluate the effectiveness of the back wash. The restoration of specific flux was determined before and after back wash cycles had taken place. To determine the effect of the back wash cycle, flux-pressure profiles were developed before and after back wash.

Task 3: Evaluation of water quality
The objective of this task was to evaluate the quality of water used as feed water for the filtration by the AquaSolution element. Some of the water quality parameters were measured on-line by Gladsaxe Svømmehal. Other parameters were performed by accredited laboratories.

Task 4: Membrane integrity testing (particle counting and total microbial counting)
The objective was to evaluate the removal of particles within defined particle size intervals 1.5-4.99 µm, 5.00-10.32 µm and 10.33-20.39 µm.

The removal of microorganisms was monitored by sampling and analysing water from the inlet and the outlet of the filter. Bacteria removal cannot be expected by a membrane with 3 µm nominal pore size.

7.1.4 Task D: Documentation of verification and operational conditions

Objectives
The objective was to establish the protocol for the management of all data produced during testing.

Work plan
Documentation of the verification and the operational conditions was performed through on-line measurements, data logging, log-book notes and putting data into excel spread sheets. Deviations were stated.

7.2 Analytical methods

The analytical methods consisted of on-line measurements at the test site (Table 7-3) and the methods for the analyses of samples sent to analytical laboratories (Table 7-4).

Table 7-3 On-line measurement at the test site.

Parameter	Facility	Method	Precision[1)] %	Range of application
Flow	on-line	Magnetic inductive	± 0.5%	0-150 m^3/h
Pressure – feed water	on-site	Pressure transmitter	± 1.5%	0-1.6 bar
Pressure – produced water	on-site	Pressure transmitter	± 1.5%	0-1.6 bar
Temperature	on site	Grundfos RPS Temperature sensor	±1°C	0-100°C
Free chlorine	on-site	Chlorine sensor, Gladsaxe Svømmehal	n.d.	n.d.
pH	on site	pH-meter, Gladsaxe Svømmehal	n.d.	n.d.

[1)] Standard deviation specified by supplier or through traceable calibration.
n.d. = no data

Table 7-4 Analytical methods.

Parameter	Detection limit	Method
Particle count	1.5 µm	AccuSizer 780/SIS
Total microbial count	1 per 1 ml	Reasoner and Geldrich /4/
TOC	0.5 µg/l	Sievers 800 TOC analyzer
Hardness	0.5 °H	SM 3120 – ICP
THM	1 µg/l	GC-ECD

7.3 Data management

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

Data from the on-line measurements at the filtration plant were stored on a data logger and retrieved by the test personnel via GSM modem. The data were then transferred to Excel files and evaluated.

7.4 Quality Assurance

The quality assurance of the tests included control of the test system (filtration plant), the on-line measurement equipment and the control of data quality and integrity.

The test plan and the test report were subject to review by an internal and an external expert as part of the review of the verification protocol and this verification report.

7.5 Test report

The test report follows the principles of template of the Center Quality Manual – Water Technology with data and records from the tests presented.

8 EVALUATION

The evaluation of the test results focused on the performance parameters. The efficiency of the filtration process for particle removal depends among other things indirectly on the flux, clogging and back wash. These parameters are stated in the test report except for the clogging (or fouling). The test period was too short to evaluate the fouling of the membranes.

8.1 Calculation of performance parameters

The performance parameters (removal of particles within defined sizes) were verified. Furthermore, the characterization of the pool water was documented by sampling and analysing at the inlet and the outlet of the filtration plant. The operational conditions linked to the verification performance parameters are given as an overview in section 8.2.

Calculations were done according to generally accepted statistical principles. For all relevant parameters, minimum, average and maximum values are stated. Logged on-line measurements of the flow were read 3 minutes before and after back wash and represent the flow used for calculation of flux.

Calculated data based on logged on-line parameters (flow, pressure in, pressure out and transmembrane pressure) are shown Table 8-1.

The removal of particles (see Table 8-2) was presented as percentage of particles removed by filtration of the feed water and related to 3 sizes of particles: 1.5-4.99 µm. 5.00- 10.32 µm and 10.33-20.39 µm.

8.2 Performance parameter summary

Table 8-1 shows the operational parameters for the verification of CoMeTas AquaSolution filters. The parameters will in the same way be presented in the verification statement. The information is given on the planned ranges for the test and the measured mean values during the test. The specific flux of the feed water is based on the mean values of the flow measured 3 minutes before/after back wash took place. The planned values represent the typical flux defined by CoMeTas A/S on the datasheet about the filter element AQS-144-800-(2*2) 3 micron. The flow through the filter was in the lower part of the planned range, due to the low feed pressure at the site. The available feed pressure was limited by the sand filters operated in parallel with the tested filtration plant and it was not possible to regulate the pressure of the feed water to a realistic level compared to the pressure that matches the pressure on a plant, which treat the entire recirculated water flow over a swimming pool.

The back wash did not start automatically, and this implied some extra checks of the back wash procedure. Therefore the number of back washes was higher than planned. In preparation of measuring the volume of back wash water some of the back washes were started manually several times consecutively. The back wash procedure of three filters used on average 241 L.

Table 8-1 Operating parameters during test period.

Operational parameters	Unit	Planned operational range	Verified mean values
Run length	day:hours	18:00	17:16
Temperature	°C	32-33	32.9
Flow on-line	m^3/h	20-60	27
Specific flux (before bw)	$m^3/h \cdot m^2 \cdot bar$	10	10.1
Specific flux (after bw)	$m^3/h \cdot m^2 \cdot bar$	10	16.0
Flow ratio Provital/GS	%	50	34.2
Back washes	Number/day	1	1.6
Back wash duration	minutes	7-9	7
Back wash volume	l	70-80	240
Transmembrane pressure	bar	0.3	0.12

bw= back wash.
GS = Gladsaxe Svømmehal.

The performance of the particle removal efficiency appears From Table 8-2. Within the particle size interval 1.5-4.99 µm 64% of the particles were removed. The filter was more efficient concerning removal of larger particles and within the size range 5.00-10.32 µm and 10.33- 20.39 µm 79% and 89% were removed respectively. Generally the main part (about 70% /5/) of the particles in pool water was found in the size range between 10 and 20 µm and within this range the tested filter removes 89%, but that does not mean that those sizes of particles are the particles which most often form disinfection by-products (DBP). It is necessary to make a filtration test on the whole recirculated water flow – not only a side stream – if an evaluation of particle removal on the formation of DBP is needed.

Table 8-2 Summarized particle count data within different particle size intervals (1.5-4.99 µm, 5.00-10.32 µm and 10.33-20.39 µm).

	Feed water			Produced water		
	1.5-4.99 µm	5.00-10.32 µm	10.33-20.39 µm	1.5-4.99 µm	5.00-10.32 µm	10.33-20.39 µm
Number of counting	66	66	66	65	65	65
Average Number/ml	116	17	26	42	3.6	2.8
Std.dev.	80	12	18	27	3.2	3.3
Min. Number/ml	43	4	4	17	0	0
Max. Number/ml	540	81	103	206	24	25
95% lower conf.	96	14	22	35	2.9	2.0
95% upper conf.	136	20	31	48	4.4	3.6
Verified performance (% removed)				64	79	89

The sum of THM varied between 25 and 30 µg/L and the legislative requirement /6/ says less than 50 µg/L.

The hardness of the pool water was on average 2.6 °dH during the verification test and the operation of the plant was apparently not effected by fouling of the membrane.

The concentrations of TOC in the feed water and the produced water were less than 4 µg/L, which is far less than the expected recommended limit on 1 mg/l stated in the draft Danish announcement on water quality in swimming pools /7/.

The total microbial count is influenced by the chlorination of the pool water. Therefore it is not possible to verify the membrane filtration's effect on removal of total microbial count.

8.3 Evaluation of test quality

The information of the test report and the test system together with data quality and integrity control were evaluated against the requirements set in the protocol and the objectives set in the test plan.

The spread sheet used for calculation was subject to control on a sample basis (spot validation of at least 5% of the data).

8.3.1 Audits

No external or internal audits were undertaken for this verification task.

8.3.2 Deviations

The test plan included automatic start of the back wash procedure every 24 hours, but that did not work and during the verification testing, the back wash procedure had to be started manually. Moreover, the back wash of the second and the third filter did not start automatically and this meant that the whole back wash cycle was delayed and had to be operated manually.

8.4 Additional parameters

No additional parameters were included in the verification.

8.5 Operational parameters

Section 8.2 and Table 8-1 include the operational parameters measured during the verification testing.

8.6 Recommendations for verification statement

It is recommended to issue a verification statement based on the performance described in section 8.2.

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
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
Housing	The equipment that surrounds the filters
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
NSF	NSF International (Public Health and Safety Company)

Word	Explanation
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 a laboratory under accreditation (ISO 17025)
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)
TOC	Total organic carbon
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

A P P E N D I X 2

References

/1/ DanETV Centre Quality Manual – Water Technology; version 2 October 2009 www.etv-denmark.com

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/3/ DANETV: CoMeTas AquaSolution AQS-144-800-(2*2) 3 micron. Verification Test Plan May 2010 www.etv-denmark.com

/4/ 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

/5/ Meike Kramer; Iris Hübner; Klaus Hagen and Lothar Erdinger "Particle Analysis in Swimming Pool Water". Poster Presentation; 2nd International Conference Swimming Pool and Spa Munich 2007

/6/ Announcement on swimming pools etc. and these qualities. (in Danish) Bekendtgørelse nr. 288 af 14/04/2005: Bekendtgørelse om svømmebassiner m.v. og disses kvalitet

/7/ Draft Announcement on swimming pools etc. and *these* qualities. (in Danish) Udkast til Bekendtgørelse om svømmebadsanlæg m.v. og disses kvalitet; May 2008

/8/ DS 477:1996: Code of practice for swimming pools (will be replaced by DS/EN 15288-2)

/9/ DIN 19643: Treatment of water of swimming pools and baths

/10/ NSF International; Environmental Technology Verification Report; Physical Removal of Microbiological & Particulate Contaminants in Drinking Water; US filter 3M10C Microfiltration Membrane system Chula Vista, California May 2003; http://www.nsf.org/business/drinking_water_systems_center/dws_project_docs.asp?program=DrinkingWatSysCen

A P P E N D I X 3

Application and performance parameter definitions

This appendix defines the application and the relevant performance parameter applications as input for the verification and test of an environmental technology following the DANETV method.

1. Applications

The intended application of the product for verification is defined in terms of the matrix, the target and the effect of the product.

The AquaSolution filters are placed in a fully automatic filtration plant which is controlled electronically and monitored by a build-in web-server. The filter elements to be verified are provided by CoMeTas and the plant (housing) containing the filter modules is provided by Provital Solutions A/S.

1.1 Matrix/matrices

The matrix of the application is re-circulated pool water and the field of application is removal of particulates and microorganisms. The concentration of particulates and microorganisms in the pool water will vary depending on the number of guests, the re-circulation and the operational conditions of the filter elements and the operation of the existing sand filters treating a side stream of the re-circulated flow in Gladsaxe Svømmehal.

1.2 Targets

The targets of the filtration elements are particle concentration in various particle size ranges. Total microbial count in the pool water (DS/EN ISO 6222:2000) /10/ is influenced by the chlorination and therefore reduction of total microbial count is not a target in this test, but the concentration will be measured in the inlet and the outlet.

While the size of microorganisms is within the particle intervals that are removed by the filter, the removal of micro organisms is a secondary effect (see Appendix Table 1). Most bacteria will be removed and virus will pass the filter.

Present particulate organic carbon might be precursors of unwanted disinfection by-products formed during chlorination. Some of these particles might also be removed during filtration.

Appendix Table 1 Size of microorganism.

Microorganisms	Size diameter µm
Virus	0.02-0.3
Bacteria	0.1-5
Parasites	4-6

According to the Danish announcement /6/ on swimming pools enumeration of *E. Coli* and coliform bacteria (DS/EN ISO 9308-1:2001) and pseudomonas (ISO 16266:2006) must take place if the total microbial count are larger than 500 per 100 ml.

The removal capacity of total microbial count can be estimated by using a low nutrient medium and then the incubation is carried out at 21 or 33°C for one or two weeks /4/.

1.3 Effects

The effect for the application is in terms of removal capacity of particles within the range of 0.5-3 µm, 3-10 µm, and 10-20 µm. The effect is given for a system operated at a flow between 20 and 60 m^3/h and back washed once every 24 hours.

The effect for application is set in terms of average, standard deviation, 95% confidence interval, minimum and maximum (range of application).

1.4 Exclusions

The verification test will be performed in Gladsaxe Svømmehal where the temperature of the pool water is about 33°C. The requirements concerning pool water quality (concerning trihalomethanes, free chlorine and re-circulation rate) linked to such a pool are different from requirements linked to pools larger than 25 m.

Due to the fact that only a side stream of re-circulated pool water is treated in the AquaSolution elements, it is not possible to evaluate long term changes of the pool water quality followed by the microfiltration. The quality of the pool water is influenced by the operation of the sand filters treating the other part of the side stream re-circulating over the warm water basin.

Depending on the pore size the membranes are capable of rejecting bacteria. The pore sizes in the membranes that are going to be tested are larger than the size of the bacteria that might be present in the pool water. Add to this the prescribed chlorination of the re-circulated pool water reduces the possibilities for detecting the bacteria.

2. General performance requirements

The AquaSolution is an alternative to sand filtration and therefore the performance parameters will be linked to the required performance of sand filters, which are set up for re-circulation of pool water.

Two standards exist concerning construction of sand filters. In Denmark DS 477 /8/ is used and DIN 19643 /9/ is used in Germany and some countries close to Germany. The main performance parameters contained in the standards are shown in Appendix Table 2.

One of the disadvantages linked to the sand filters are accumulation of organic matter that might increase the risk for development of DBP (disinfection by-products). Therefore it is important to control the back wash parameters among these durations and frequency of back wash together with air and energy consumption.

Appendix Table 2 Sand filter specifications included in the Danish standard (DS 477) and the German standard (DIN 19643).

	DS 477	**DIN 19643**
Filter high	900 mm	1,200 mm
Filter material	sand (0.4- 0,7 mm ;50 % and 0.7- 1.2 mm; 50%)	sand 0.7-1.2 mm
Back wash velocity – water	minimum 40 m/h	minimum 60 m/h
Back wash velocity – air	about 60 m/h	about 60 m/h
Duration of back wash – water	5-10 minutes	6-8 minutes
Duration of back wash – air	3-5 minutes	5 minutes
Frequency of back wash	when needed	minimum twice per week

2.1 Regulatory requirements

Within the EU, swimming pools are not currently subject to any hygienic or water quality requirements. But national guidelines and announcements are implemented in several of the member states. In Appendix Table 3 is presented the requirement in four EU Member States related to chosen parameters. The Danish announcement about "Swimming pools, etc. and the water quality" (BEK nr 288 af 14/04/2005) set quality requirements for swimming pools with re-circulation of water. It is the local authorities, which carry out inspection of the public swimming pools. A new draft announcement about "Swimming pools, etc. and the water quality" has been developed (May 2008). The draft announcement does not include quality requirements concerning the permanganate index. Prospective, the final announcement will include recommendations concerning the TOC-level. The recommendation is expected to say 1 mg/l.

The announcement specifies the quality requirements for pool water control and monitoring of temperature, pH, organic matter (permanganate number), free chlorine, trihalomethane (THM), total microbial count, *E. Coli*, and pseudomonas bacteria. The quality requirements are specified as minimum values and recommended intervals. The quality control is specified as maximum values.

Indirectly the regulatory requirements concerning THM and organic matter influence relevant verification criteria related to removal capacity of particles. Relevant verification performance ranges concerning total microbial count and TOC set in Appendix Table 3 are based upon expected future requirements and/or recommendations related to pool water. An indirect method of monitoring membrane integrity is particle counting in size ranges 0.5-3 µm, 3-10 µm and 10-20 µm, which are the most frequent particle size ranges in pool water /5/. Moreover microfiltration membranes have been tested within ETV programs and the particle removals were monitored in similar particle size intervals (2-15 µm) /10/.

When adding free chlorine to swimming pool water, a very large number of different unwanted chlorine disinfection by-products (DBP) are formed during chlorine reaction with contamination deriving from bathers and from substances leaching from material in contact with the pool water. The best known DBP's are chloramines, trihalomethane (THM), halogen acetic acid (HAA) and haloacetonitriles (HAN). THM includes trichloromethane, dibromochloromethane, bromodichloromethane and trichlormethane.

Appendix Table 3 Requirements for microbial and chemical parameters in chosen European countries.

	Unit	Austria	Denmark[1)]	Germany	Holland
Total microbial count 36±1°C	cfu/ml	≤100	<5-10	≤100	≤100
pH		6.5-7.8	(7.2-7.6) 7-8	6.5-7.6	6.8-7.8
Free chlorine	mg/l	0.3-1.2	1-5[2)]	0.3-0.6	0.5
Permanganate index	mg/l	<4	[3)]	≤3	[4)]
THM	µg/l	-	50-100[2)]	≤20	-

[1)] Draft announcement May 2008 /7/.

[2)] Indoor basins <25 m.

[3)] <1 mg TOC is recommended.

[4)] 70% of consumed potassium permanganate + 6 mg/l.

2.2 Application based requirements

The application of the AquaSolution filter for treatment of re-circulated pool water defines the performance requirements in terms of particle size distribution before and after treatment.

If the efficiency of the AquaSolution filter is to be compared with the efficiency of a sand filter then the relevant particle size range should be 0.5-30 µm. In the lower range the conventional sand filter is expected to be less efficient than microfiltration membranes /5/. Particle analyses in swimming pool water have demonstrated that the concentration of particles depends on water treatment techniques, treatment performance and bathing load.

If the membrane filters are going to replace a sand filter, which are the most frequent used techniques of pool water then back wash frequency, duration and the discharged amount of back wash water become essential performance parameters. Furthermore the flux decline and transmembrane pressure, which are linked to the energy consumption, become important. During a 30-days test the transmembrane pressure is plotted against time of operation, the flux is equally plotted against time and logging of back wash frequency takes place.

3. State-of-the-art performance

Presently most swimming pools use sand filtration when re-circulating the pool water. An alternative to sand filtration could be membrane filtration.

Microfiltration is a filtration process which removes contaminants from a fluid (liquid and gas) by passage through a micro-porous membrane. A typical microfiltration membrane pore size is 0.1 to 10 µm.

Ceramic membranes are produced from inorganic materials such as aluminium oxides, silicon carbide and zirconium oxide. Ceramic membranes are resistant to the action of aggressive media. They are marketed to be stable chemically, thermally, mechanically and biologically inert. On the whole ceramic membranes have high weight and they are expensive to produce but have long working life.

There are two main configurations of membrane processes: cross-flow and dead-end filtration. In the cross-flow filtration the feed flow is tangential to the surface of the membrane, retentate is removed from the same side further down-stream, whereas the permeate flow is tracked on the other side. In dead-end filtration the direction of the fluid flow is normal to the membrane surface. Dead-end filtration may be applied in purification of pool water and surface water, but is considerable more susceptible to fouling than cross-flow filtration.

4. Performance parameter definitions

The performance parameters in Appendix Table 4 shall be verified under given operational conditions and it shall be documented during the verification that the product is operated according to the stated operational conditions. Furthermore, the characterization of the pool water will be documented by sampling and analysing at the inlet and the outlet. The operational conditions linked to the above verification performance criteria are given in Appendix Table 5.

Appendix Table 4 Performance parameters for AquaSolution elements. TOC and total microbial count will be measured at inlet and outlet, but they are not performance parameters.

Parameter	Unit	Value	Removal %
Rejection of particles 0.5-3 µm	number/ml		80
Rejection of particles 3-10 µm	number/ml		95
Rejection of particles 10-20 µm	number/ml		100
Total microbial count	number/100 ml	< 500	
TOC	mg/l	< 1	

Appendix Table 5 Operational parameters for the AquaSolution during verification.

Parameter	Unit	Test value
Feed flux (typical)	$m^3/(m^2*h*bar)$	10
Feed flow	m^3/h	20-60
Pressure – Feed flow	bar	0.6-0.75
Pressure – produced water	bar	0.5-0.6
Number of backwash cycles	number/day	1
Backwash cycle length	maximum	10 minutes
Temperature	°C	33
Basin volume	m^3	50
Re-circulation ratio	hour	0.5