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Test Report

Determination of the adsorption capacity of ceramic filter membranes, Article Code: WS10042CH, WaterShield W.P.M. Brouwer, NL-1383 JB Weesp, referenced to microbiological and chemical parameter (heavy metals, organic contaminants) under maximum load as well as in a realistic application test.

1. Introduction:

The scope of this investigation comprises the determination of the absorption capacity of ceramic filter membranes, No. WS10042CH supplied by the Water Shield company, with reference to microbiological and chemical parameters.

The investigated ceramic filter membranes are used for different methods of drinking water treatment, among them their use as terminal filters in water treatment plants and as hand showers.

Almost every country in the world has legislation for drinking water in place, which defines limit values. If these limit values for certain microbiological and chemical parameters are not exceeded the water is regarded as safe and fit for human consumption.

However, the composition of potable water in stagnant conditions, for example in supply pipes in house installations, can become adversely affected. Growth of micro-organisms will occur while heavy metals may become mobilised from metallic materials.

Furthermore, there are often (and this includes the Federal Republic of Germany) no limit values for certain contaminants, such as endocrine disruptors (ovulation inhibitors).

Therefore the focus and core question of this investigation is on the reduction of adverse contaminants in potable water.

For this purpose, two tests are performed:

- Stress test with high microbiological and chemical load
- Practical application test with real concentration levels of microbiological and chemical loads

1.1 Load test with high microbiological and chemical contamination:

Stress on the filter membranes by rinsing the filter membranes with 100L of a suspension containing the following parameter:

Legionella pneumophila	10 ⁵ CFU/mL	10 ¹⁰ CFU total
Copper	25 mg/L	2500 mg total
Manganese	25 mg/L	2500 mg total
Iron	25 mg/L	2500 mg total
Chrome	25 mg/L	2500 mg total
Mercury	25 mg/L	2500 mg total
Cadmium	25 mg/L	2500 mg total
Nickel	25 mg/L	2500 mg total
Lead	25 mg/L	2500 mg total
Arsenic	25 mg/L	2500 mg total
Zinc	25 mg/L	2500 mg total

The bacterial count in relation to Legionella pneumophila and the concentration of heavy metal ions in the filtrate is determined following flushing with flush volumes of 50L and 100L respectively. At the same time the differential pressure is determined across the filter membranes following flush volumes of 50L and 100L respectively.

In relation to Legionella pneumophila the logarithmic reduction factor is calculated. In relation to the heavy metals the reduction of the concentration in percentage terms is determined by using the filter matrix.

1.2 Practical application test:

The ceramic filter membrane is flushed with a suspension with the following microbiological and chemical parameters:

1.2.1 Chemical parameters, inorganic compounds

Chlorine	4.1 mg/L
Chlorine dioxide	1.5 mg/L
Aluminium	2.0 mg/L
Lead	0.5 mg/L
Iron	1.0 mg/L
Nitrite	1.0 mg/L
Nitrate	8.0 mg/L
Bromate	0.5 mg/L
Calcium	98.0 mg/L
Magnesium	72.0 mg/L
Fluoride	0.5 mg/L

1.2.2 Chemical parameters, organic compounds

MCPA	0.6 µg/L
Mecoprop	0.5 µg/L
Benzene	3.0 µg/L
1,2-Dichloroethane	15.0 µg/L
Trichloroethylene	25.0 µg/L
Bisphenol A	50.0 ng/L
Estradiol	1.0 ng/L

1.2.3 Microbiological parameters:

Cryptosporidium spp., Oocysts	18 Oocysts / L (=200 Oocysts / 11L)
Giardia lamblia	18 Oocysts / L (=200 Oocysts / 11L)
Legionella pneumophila	810 CFU/100mL
Escherichia coli	50000 CFU/100mL

100L, 1000L and 1500L of this suspension are flushed through the ceramic filter membrane. The aforementioned parameters are determined in the filtrate following flushing with the three volumes.

Thus the reduction power of the filter membranes in concentration ranges of untreated water and contaminated potable water can be determined, while testing at the same time whether a rupture of the filter occurs under real application conditions.

2. Methodology:

2.1 Preparation of the standard solutions, microbiological parameters:

Starting from pure cultures, microbiological suspensions of *Legionella pneumophila* and *E.coli* are obtained by surface runoff and further enrichment in tryptic soya broth. Starting point for the pure culture concerned is a freeze-dried reference culture from the Deutsche Sammlung für Mikroorganismen und Zellkulturen (DSMZ) in Braunschweig (German Collection of Microorganisms and Cell Cultures). Yeast extract, activated charcoal, and a GVPCH inhibitor cocktail are added to the aforementioned enrichment broth in order to cultivate *Legionella pneumophila*.

The *E.coli* suspension can be used as is. For *Legionella pneumophila* the activated charcoal is separated by decanting prior to use.

Cryptosporidium and *Giardia lamblia* (eukaryotic micro-organisms) are obtained from the Veterinary Medical Institute in cell culture suspension.

The culture broths are cultivated to the point when the final application suspension, having been appropriately diluted (to 100L, or for use over 15m³), approximately reaches the counts set out in Item 1.

2.2 Preparation of the standard solutions, chemical parameters:

The inorganic-chemical parameters specified under Item 1 are obtained, by stoichiometric calculation, from the respective salts which are dissolved in a

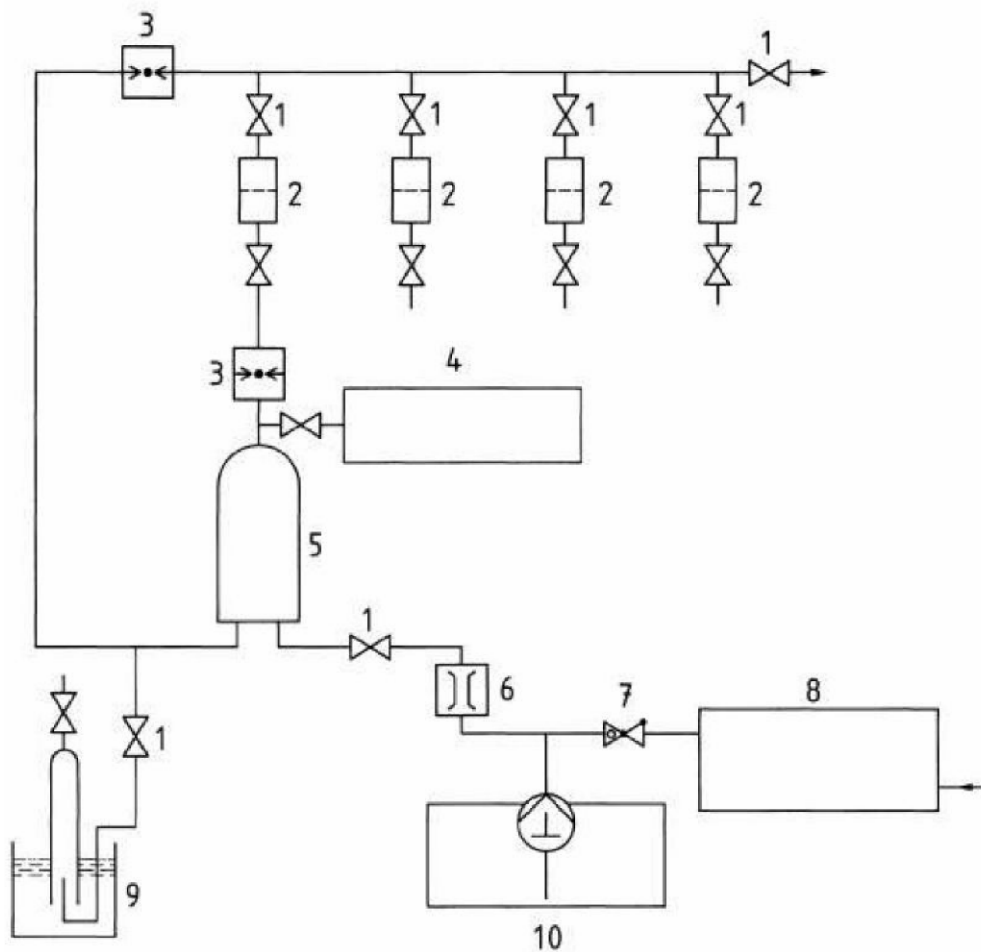
defined water volume, and dilution of the application solutions to the desired concentration.

Organic parameter are procured as ready-made standard solutions with 1000 mg/L for each substance. From this, the dilution to the final mass concentration of the respective tests (1.1 and 1.2) is generated.

2.3 Performance of the adsorption test:

The testing of the adsorption performance is carried out in accordance with DIN 58356.

The following test apparatus (test assembly) is used:



Source: DIN 58356, Fig. 1 - Test assembly

Legend:

- 1 Shut-off valve (3/4")
- 2 Control filter
- 3 Pressure gauge
- 4 Integrity measurement device
- 5 Cartridge filter housings with filter test specimen
- 6 Flow meter
- 7 Control valve
- 8 Sterile filter unit
- 9 Diffusion measurement
- 10 Test suspension

Note: The control filter is omitted from the test. The filtrate of the filter to be tested (5) is collected at the start of the test, during the test, and at the end of the test, and analysed in relation to each of the specified parameters. Thus it can be determined whether the retention performance is identical at the start and at the end of the test. Any rupture of the filter under test conditions will also be indicated under these conditions.

The percentage reduction of the chemical parameters and the logarithmic reduction of the microbiological parameter are determined by a comparison between the initial concentration and the concentration of the respective parameter in the filtrate after it has reached the specified target value.

3. Results:

Filter: Ceramic Membrane Art. Code: WS10042CH

3.1 Results of the stress test with a high microbiological and chemical load:

Parameters:	Concentration initial	Concentration after 50L	% Red.100	Concentration after 100L	% Red.100L
Legionella	$3.2 \cdot 10^5$ /mL	$<1.0 \cdot 10^0$ /mL	100%	$<1.0 \cdot 10^0$ /mL	100%
Cu	25 mg/L	0.012 mg/L	99.95 %	0.010 mg/L	99.96 %
Mn	25 mg/L	0.083 mg/L	99.67 %	0.079 mg/L	99.68 %
Fe	25 mg/L	0.108 mg/L	99.57 %	0.104 mg/L	99.58 %
Cr	25 mg/L	0.054 mg/L	99.78 %	0.053 mg/L	99.79 %
Hg	25 mg/L	0.183 mg/L	99.27 %	0.172 mg/L	99.31 %
Cd	25 mg/L	0.098 mg/L	99.61 %	0.090 mg/L	99.64 %
Ni	25 mg/L	0.072 mg/L	99.71 %	0.064 mg/L	99.74 %
Pb	25 mg/L	0.109 mg/L	99.56 %	0.110 mg/L	99.56 %
As	25 mg/L	0.051 mg/L	99.80 %	0.040 mg/L	99.84 %
Zn	25 mg/L	0.118 mg/L	99.53 %	0.095 mg/L	99.62 %

Note: Legionella was not detected in the filtrate after 50L and 100L. The total microbiological load after 100L is $3.2 \cdot 10^{10}$ /mL. No rupture was observed under these conditions, and the tested filter type therefore achieved a total reducing power of $>3,2 \cdot 10^{10}$ CFU, equivalent to >10 log levels.

At the same time, an investigation was carried out in the run up to the test as to whether a heavy metal concentration of 25 mg/L for each heavy metal with 10 different metal salts would have an adverse effect on Legionella. The test confirmed that the existing heavy metal concentration does not have an adverse effect on Legionella pneumophila over a period of 10 days. Therefore it was possible to carry out a test with parallel doping of the suspension with Legionella pneumophila and 10 heavy metal salts of 25mg/L each.

3.2 Results of the practical application test:

3.2.1 Results for chemical parameters, inorganic compounds:

Parameter	Concentration initial	Concentration 100L	%	Concentration 10000L	%	Concentration 15000L	%
Cl ₂	4.1 mg/L	0.230 mg/L	94.39 %	0.024 mg/L	99.41 %	0.020 mg/L	99.51 %
ClO ₂	1.5 mg/L	0.040 mg/L	97.33 %	0.034 mg/L	97.73 %	0.038 mg/L	97.47 %
Al	2.0 mg/L	0.010 mg/L	99.50 %	0.013 mg/L	99.35 %	0.010 mg/L	99.50 %
Pb	0.5 mg/L	0.006 mg/L	98.80 %	0.008 mg/L	98.40 %	0.009 mg/L	98.20 %
Fe	1.0 mg/L	0.008 mg/L	99.20 %	0.006 mg/L	99.40 %	0.006 mg/L	99.40 %
NO ₂ -	1.0 mg/L	0.014 mg/L	98.60 %	0.010 mg/L	99.00 %	0.015 mg/L	98.50 %
NO ₃ -	8.0 mg/L	0.021 mg/L	99.74 %	0.019 mg/L	99.76 %	0.018 mg/L	99.78 %
BrO ₃ -	0.5 mg/L	0.008 mg/L	98.40 %	0.011 mg/L	97.80 %	0.013 mg/L	97.40 %
Ca	98.0 mg/L	52.400 mg/L	46.53 %	54.600 mg/L	44.29 %	55.100 mg/L	43.78 %
Mg	72.0 mg/L	44.900 mg/L	37.64 %	46.300 mg/L	35.69 %	46.900 mg/L	34.86 %
F-	0.5 mg/L	0.010 mg/L	98.00 %	0.011 mg/L	97.80 %	0.015 mg/L	97.00 %

3.2.2 Results for chemical parameters, organic compounds:

Parameters:	Concentration initial	Concentration 100L	%	Concentration 10000L	%	Concentration 15000L	%
MCPA	0.6 µg/L	0.100 µg/L	83.33 %	0.024 µg/L	96.00 %	0.020 µg/L	96.67 %
Mecoprop	0.5 µg/L	0.012 µg/L	97.60 %	0.034 µg/L	93.20 %	0.038 µg/L	92.40 %
Benzene	3.0 µg/L	0.190 µg/L	93.67 %	0.013 µg/L	99.57 %	0.010 µg/L	99.67 %
Dichlorethyl	15.0 µg/L	0.098 µg/L	99.35 %	0.008 µg/L	99.95 %	0.009 µg/L	99.94 %
Trichlorethyl	25.0 µg/L	0.130 µg/L	99.48 %	0.006 µg/L	99.98 %	0.006 µg/L	99.98 %
Bisphen.A	50.0 ng/L	1.300 ng/L	97.40 %	0.010 ng/L	99.98 %	0.015 ng/L	99.97 %
Estradiol	1.0 ng/L	0.230 ng/L	77.00 %	0.019 ng/L	98.10 %	0.018 ng/L	98.20 %

3.2.3 Results for the microbiological parameters:

	Initial:	After 15000L
Cryptosporidium spp.,	22 Oocysts / L	0 (< 3.3*10 ⁵ CFU)
Giardia lamblia	25 Oocysts / L	0 (< 3.8*10 ⁵ CFU)
Legionella pneumophila	890 CFU/100mL	0 (< 1.3*10 ⁹ CFU)
Escherichia coli	60000 CFU/100mL	0 (< 9.0*10 ⁹ CFU)

Analogous with the result of the direct load test no rupture of the tested filter was observed during the practical application test.

Pressure levels:	Admission pressure	p = 4.0 bar
	Filtrate after 100L	p = 3.8 bar
	Filtrate after 10000L	p = 3.2 bar
	Filtrate after 15000L	p = 2.6 bar

4. Evaluation and Summary:

Overall, with regard to the *load test with a high microbiological and chemical load* (see Item 2.1) no rupture in relation to *Legionella pneumophila*, and a reducing power of > 99% vis-à-vis 10 heavy metals, were observed (see Item 3.1). The load was represented by $3.2 \cdot 10^{10}$ CFU *Legionella pneumophila* and 2500mg for each tested heavy metal. Overall, the metals Cu, Mn, Fe, Cr, Hg, Cd, Ni, Pb, As and Zn were tested in the form of their ions in an aqueous solution.

In this test constellation the filter indicates a sterile filtration. The heavy metals are reduced by > 2 powers of 10 (> 99%). The results of the tests confirm the filter to be adequate and safe under massive microbiological and chemical stress.

The investigations in the *practical application test following flushing with 15000 litres of moderately contaminated water* (see Item 2.2) produced comparable findings.

- In regard to the tested micro-organisms, *Cryptosporidium* spp., *Giardia lamblia*, *Legionella pneumophila* and *Escherichia coli*, no rupture was detected following flushing with 15000L (see Item 3.2).
- Following flushing with a volume of 15000L of moderately contaminated water the adsorption performance in relation to heavy metals was determined to be > 98%.
- Chlorine was eliminated by ca. 94%, / chlorine dioxide by ca. 97% and bromate by ca. 98% after a flushing volume of 15000L.
- Following the same flushing volume, other inorganic salts (nitrate, nitrite) were adsorbed through (by) the filter by > 98%.
- Fluoride, too, is eliminated by ca. 98%.
- The reduction of the hardness ions in the filtrate in comparison with the flushing liquid was determined to be ca. 50% in regard to calcium and ca. 30% in regard to magnesium.
- Furthermore, plant protection products and biocidal products are adsorbed through (by) the filter by > 83%. Organic halogen substances are eliminated by > 99%
- Endocrine disruptors, using Estradiol as an example, are eliminated by > 77%.

The test constellation under practical application conditions presents a complete elimination of the tested micro organisms, as well as the elimination of plant protection products, biocidal products, oxidative disinfectants, Fluoride and Estradiol, to a level appropriate for an adequate risk reduction. Under this test constellation, too, the adsorption behaviour of the filters is safe.

Overall, the tested filter modules present a safe adsorption behaviour with regard to bacterial and eukaryotic micro-organisms. Under the tested conditions, the filters achieve sterile filtration and show adequate adsorption behaviour vis-à-vis inorganic and organic chemical parameters.

The filters are adequate to ensure a risk reduction vis-à-vis infections and intoxications transmitted through potable water over a flow-through volume of 15000L.

The life of the filters following their installation can therefore not be specified as a time interval, but rather depends on the circulated volume. The analysis of the microbiological testing of the filter membranes did not indicate a traversal or intermingling of the filter matrix.

Therefore the useful life span of the tested filter membranes must be seen as a function of the circulated volume.

The microbiological and chemical analysis also provided no indication of an adverse influence on the filtered potable water by components of the filter or the filter matrix.

Taking all the test results into consideration we provide a positive vote for the tested filter membrane in respect of potable water and medical devices applications.

The results of our investigations prove that the tested product does not pose any risks. The statements in relation to an infectiological and toxicological risk reduction in filtered potable water are confirmed for an operating volume of 15000L. We provide a positive vote for a CE mark pursuant to EEC 93/42 (Medical Devices Directive). The CE conformity declaration must be processed through an Authorised Body.

Note:

The tested filter was installed in product WS1 0042CH. Identical hollow capillary filters are installed in the WS10031WH, WS10032WH, WS10033WH, WS10034WH, WS10041CH, WS10042CH, WS10043CH and WS10044CH products of the Water Shield Company. Therefore this test report applies correspondingly to the aforementioned filter applications.

In case of queries you can reach the performer of these tests by telephone under 0049-175-9150334.

Yours faithfully



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