Investigation of the newly developed filter media FILTRALITE on its general filtration performance in surface water treatment for drinking water and with special respect to removal of microbial contaminants

Final-Report

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Table of contents

1 Project goal

Project goal is the investigation of the filter material FILTRALITE MC in the treatment of surface water in pilot scale experiments. In particular, FILTRALITE MC is to be compared (in dual media filtration) with another filter material commonly applied in Germany. As agreed by email correspondence between Torgeir Saltnes from OPTIROC and the investigators, the material to which FILTRALITE is to be compared to is Hydrosanthrasit H (manufacturer Akdolit).

2 Filtration plant

2.1 Reconstruction of filtration plant

Since project start, a pilot plant already available at IWW was reconstructed to fit the needs for the filtration project. Old filter material in the filtration columns was removed and the filter columns were dismounted and cleaned thoroughly in order to make sure that the results obtained later during the project were no artifacts due to interference with dirt deposited in pipes and on surfaces from previous experiments.

New tanks, pumps and flow-meters were selected and mixing tanks scaled and selected for the coming filter runs. The flow-scheme of the new filtration plant after reconstruction is given in Fig. 2-1. In the plant that will be applied for the experiments, dechlorinated tap-water is fed to a mixing tank to which wastewater and a clay suspension are fed by peristaltic pumps to achieve desired turbidity and microbial contaminations. From the mixing tank the water is transferred by hydrostatic difference to three flocculation basins in series. Flocculant is dosed to the first chamber. The effluent of the last chamber is transferred to two parallel filtration columns.

Fig. 2-2 shows a photograph of the wastewater tank (the wastewater is pumped in circulation in order to prevent settling), clay suspension tank and mixing basin with pumps and stirrers. Fig. 2-3 shows the flocculant reservoir. Flocculant is mixed in the ochre coloured column and dosed into the flocculation basin by a membrane pump (not seen). Flocculation chambers are shown in Fig. 2-4 and the filtration columns in Fig. 2-5.

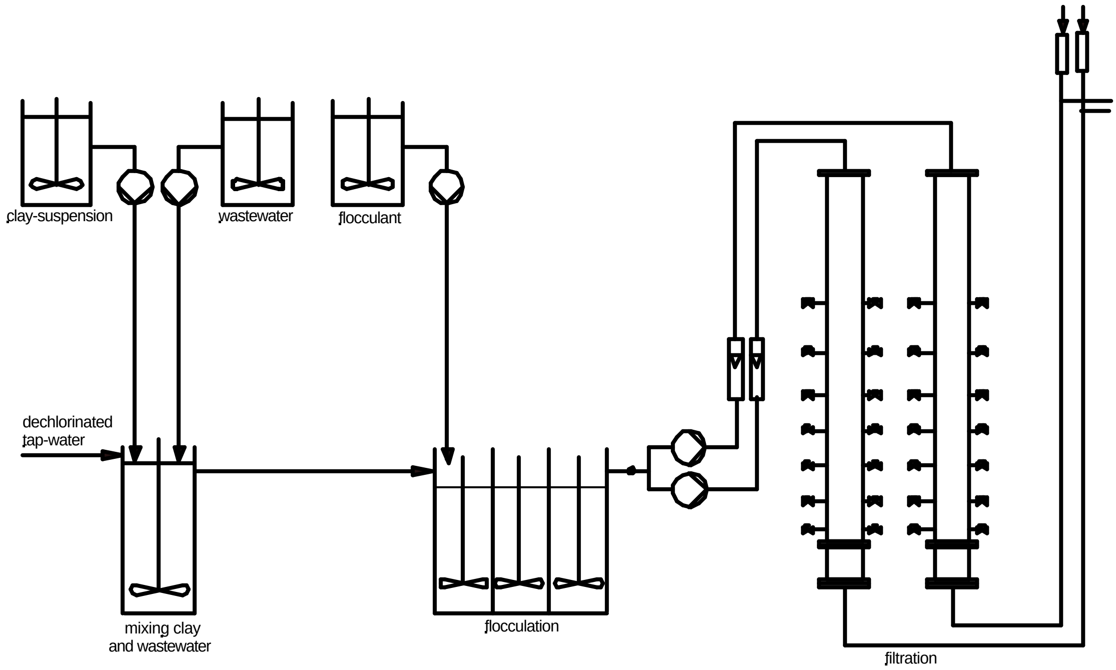

Fig. 2-1: Flow-scheme of filtration plant

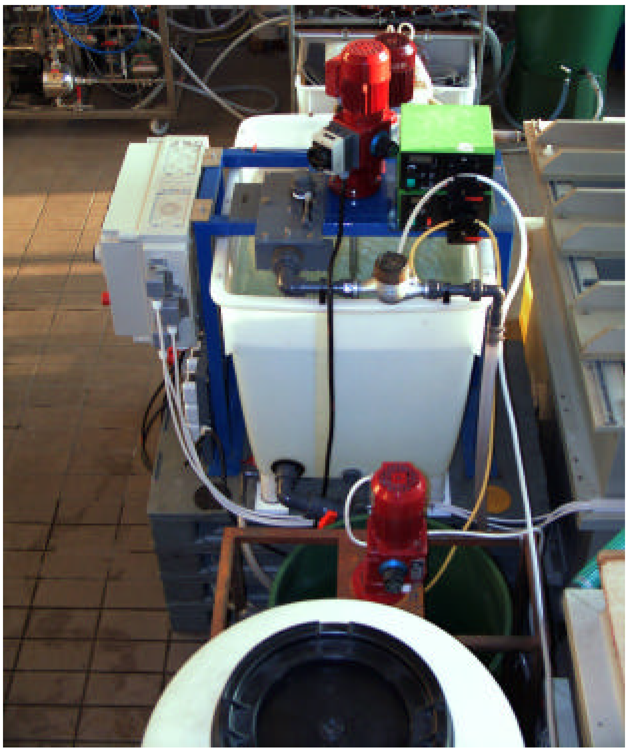

Fig. 2-2: Wastewater tank (in foreground, white with black cap), clay suspension (middle, dark green, with red stirrer) and mixing basin (white, with two peristaltic dosing pumps (green) on top and stirrer (red)

Fig. 2-3: Mixing tank (white, middle right), flocculant tank (ochre, middle left) and flocculation chambers (background left)

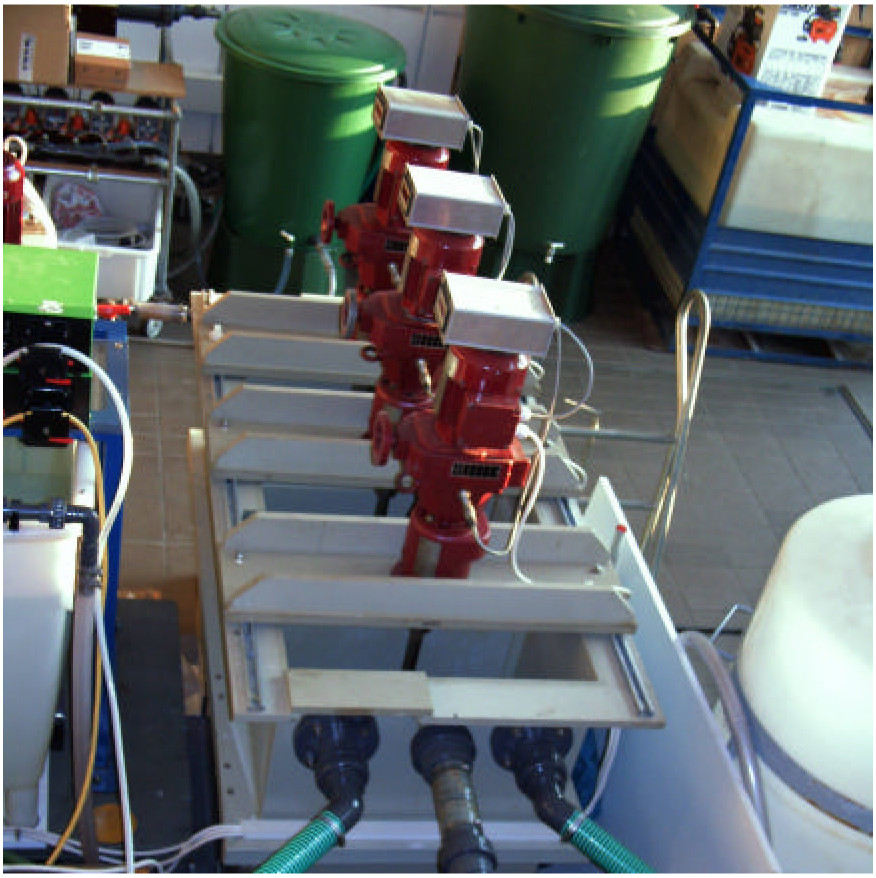

Fig. 2-4: Flocculation chambers with stirrers

Fig. 2-5: Filtration columns; the right column contains sand and OPTIROC FILTRALITE MC

2.2 Operation details

2.2.1 Clay suspension dosing

Clay was dosed to the feed water to a final turbidity of approximately 5 FTU. This is a turbidity comparable to the surface water of the river Ruhr, which is used as source water for drinking water treatment in Mülheim. During a two-year period (1995/1996) turbidity was measured in the river water 112 times. The 10 % highest turbidities were considered as outliers and discarded. No low-turbidity outliers could be identified. The average of the remaining 90 % was 5.0 FTU.

The clay T 4003, supplied by Kärlicher Ton und Schamottewerke, Mannheim, Germany was dosed. This clay was selected as it has a low content of iron oxides. Particle sizes (as supplied by manufaturer) are less than 6.3 µm (approx. 75 % of mass), only 3.4 % of mass are larger than 63 µm.

A linear turbidity versus concentration relationship was found for the clay in the concentration range between 0and 16 mg/l with a slope of 1.1 FTU/(mg/l). Thus, clay suspension will be dosed such that a final clay concentration of 4.5 mg/l will be achieved.

2.2.2 Wastewater dosage

Wastewater is dosed in order to achieve microbial contamination of the feed water. Wastewater from the effluent of a settling basin after activated sludge treatment of a municipal treatment plant is collected and transported to the lab.

Microbial contamination of the surface water of the river Ruhr is approximately $3 \cdot 10^3$ coliforms/(100 ml) and approximately 1000 E. coli/(100 ml). We expect an elimination of approximately 1 log-unit during filtration and have to consider elimination by flocculation. Thus, a target-concentration of approximately 3.000 coliforms/(100 ml) in our pilot feed water, achieved by dosing of wastewater, is adequate.

Preliminary investigation of the wastewater showed a microbial contamination of approximately $3 \cdot 10^6$ coliforms/(100 ml). Thus, at first, a wastewater was dosed to the tap water at a factor of 1:1.000 or 1 l/m^3. Viz. 1.5 l/h into the influent stream (total flow rate of influent 1.5 m^3/h).

During ongoing experiments, wastewater dosage was increased and set to factors of 1:500 with three microbiological sampling campaigns and 1:250 as well as 1:125 with one microbiological sampling campaign each.

2.2.3 Flocculant dosing, aggregation/flocculation

As flocculant Polyaluminiumchloride was chosen which usually proofs better for surface water treatment in the Ruhr-area. Dosage was set to 3mg/l, which is equivalent to 0.11 mmol Al/l.

The flocculant "Gilufloc 83" (Product-No. 23676) from BK Giulini Chemie, Ludwigshafen, Germany, was selected. Dosage details are given in Table 2–1.

Aggregation/flocculation was done in three chambers in series. Chamber sizes and stirrer design and stirrer speed are selected to ensure optimum flocculation conditions. Details are given in Table 2–2.

Table 2–1: Dosage of flocculant Gulifloc 83 (Giulini, prod. no. 23676)

Volumetric flow rate all filters		*no. of filters: 2*		
Q = 1,53 m³/h		total filter surface area	A_f =	0,102 m²
	⇨	superficial flow rate	v_f =	15,0 m/h
		basicicity of product:		83%
		density of product:	ρ =	1.340 kg/m³
		weight product Al-content	c_{Al} =	0,122 kg Al/kg product
		vol. product Al-content	c_{Al} =	163 g Al/l product
spec. dosage Al:				
c = 3,0 mg Al / l raw water	⇨	product dosage:	Q_{Prod} =	0,47 ml/min
c' = 0,11 mmol Al / l raw water		product dosage:	C_{Prod} =	18,39 ml/m³
		dayly dosage:	V_{Prod} =	0,7 l / day

Table 2–2: Dimensions and operation data of flocculation chambers

chamber no.	dimensions	volume	res.time	stirrer size	stirrer speed
unit	mm	m³	min	m	rpm
1	300*600*720	0,130	5,6	0,37	18
2	500*600*720	0,216	9,3	0,27	30
3	500*600*720	0,216	9,3	0,27	45

2.2.4 Filter columns

The pilot plant has two filter columns with an inner diameter of 255 mm each. Total hight of both columns is 2.50 m. Over length, both columns are equipped with several ports for sampling devices at different bed depths. For the experiments to be carried out during the course of the project it was decided that each column should be equipped with five ports. Position of the ports is described in in section 2.2.5.

2.2.5 Filter bed design

After agreement with OPTIROC the filter beds were designed as given in Table 2–3 and shown graphically in Fig. 2-6. In this figure, also the bed-expanding zone expected during backwashing was shown already.

The filter material Hydroanthrasit H is a coal based product which is thermally treated. This is <u>not</u> anthracite, although the brand name seams to suggest that. As a result of the thermal treatment it is somewhat porous, although not as porous as activated carbon. Furthermore, it performs some adsorption capacity. BET surface area is in the range of 160 to 260 m^2/g, which is very low when compared to activated carbon which has adsorption capacities in the range of 700 to 800 m^2/g.

In Germany, Hydroanthrasit H very often is the matter of choice for dual media filtration, in combination with quartz sand as lower layer. Therefore Hydroanthrasit H was suggested to OPTIROC by the investigators to compare FILTRALITE with this material.

Table 2–3: Characteristics of filter beds to be compared

	gravel (support layer, both columns)	quarz sand (lower layer, both columns)	Hydro-anthrasit H (upper layer, column 1)	Filtralite MC (upper layer, column 2)
bed density in kg/m^3	approx. 1450	approx. 1450	approx. 730	approx. 730
layer hight in cm	100	700	800	800
mass per filter in kg	7	52	46	46
grain size in mm	3,15 - 5,6	0,7 - 1,25	1,4 - 2,5	1,5 - 2,5
effective hydraulic grain size in mm		0,942	1,91	1,93
head loss expected in mbar		65,58	11,18	approx. 11

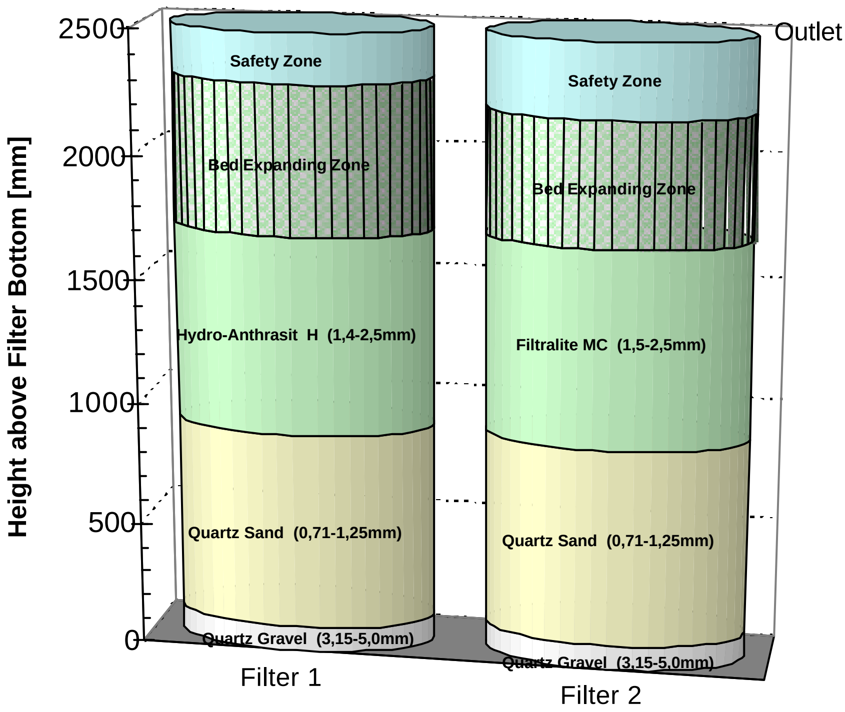

Fig. 2-6: Filter media composition

As mentioned in the previous chapter, the two columns were equipped with five sampling ports, at equal positions of the two filters. The first sampling port, during data evaluation termed "influent", is located in the bed expanding zone. The second port is located at approximately one third of the Hydro-Anthrasit H and Filtralite MC layer, to cover the filtration performance of the upmost layer. The third port in the transition between the Filtralite MC or Hydroanthrasit H, respectively, and the sand layer. The fourth port is after approximately two thirds of the sand layers. The fifth and last port is located at the end of the sand layers. Thus, the filter bed consisting of two layers can be devided into four segments. The segments are given in the following table

Table 2–4:

segment no.	from ... to	description	segment length
1	top of filter layer to port 2	after approximately one third of upper layer; covers behaviour of upmost filter material	26 cm
2	port 2 to port 3	in transition zone between upper layer and lower layer	53 cm
3	port 3 to port 4	after approx. two thirds of sand layer	50 cm
4	port 4 to port 5	end of sand layer	26 cm

2.2.6 Grain size distributions of filter media

Grain size distributions of Hydroanthrasit H and FILTRALITE MC were determined.

The results for Hydroanthrasit H (Filter 1) are displayed in Fig. 2-7 and further details are given in Table 2–5.

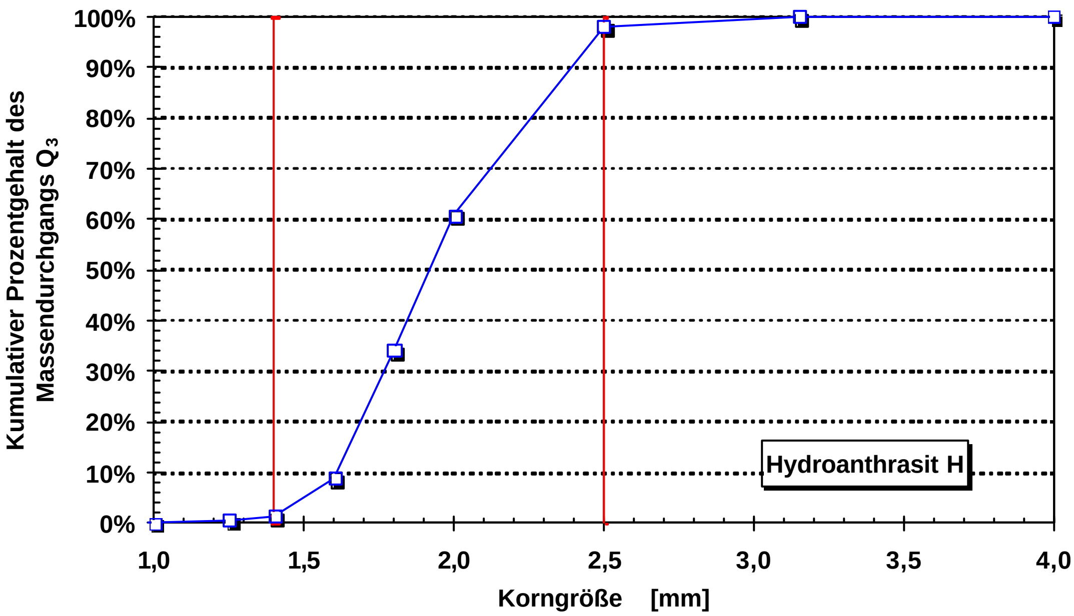

Fig. 2-7: Grain size distribution of Hydroanthrasit H (Filter 1)

Table 2–5: Results of sieve analysis for Hydroanthrasit H (Filter 1)

		requirement of DIN EN 12907:
undersize percentage (mass fraction < 1,4 mm [%]:	1,5%	**< 5 %**
overersize percentage (mass fraction < 2,5 mm [%]:	1,9%	**< 5 %**
minimum size d_1 [mm] :		
effective size d_{10} [mm] :	1,62	
size d_{60} [mm] :	1,99	
size d_{90} [mm] :	2,35	
uniformity coefficient U [-] :	1,23	**< 1,5**
hydraulic effective size d_h [mm] :	1,91	
mean size Q_3 [mm] :	1,96	

The results for FILTRALITE MC are displayed in Fig. 2-8 and further details are given in Table 2–6.

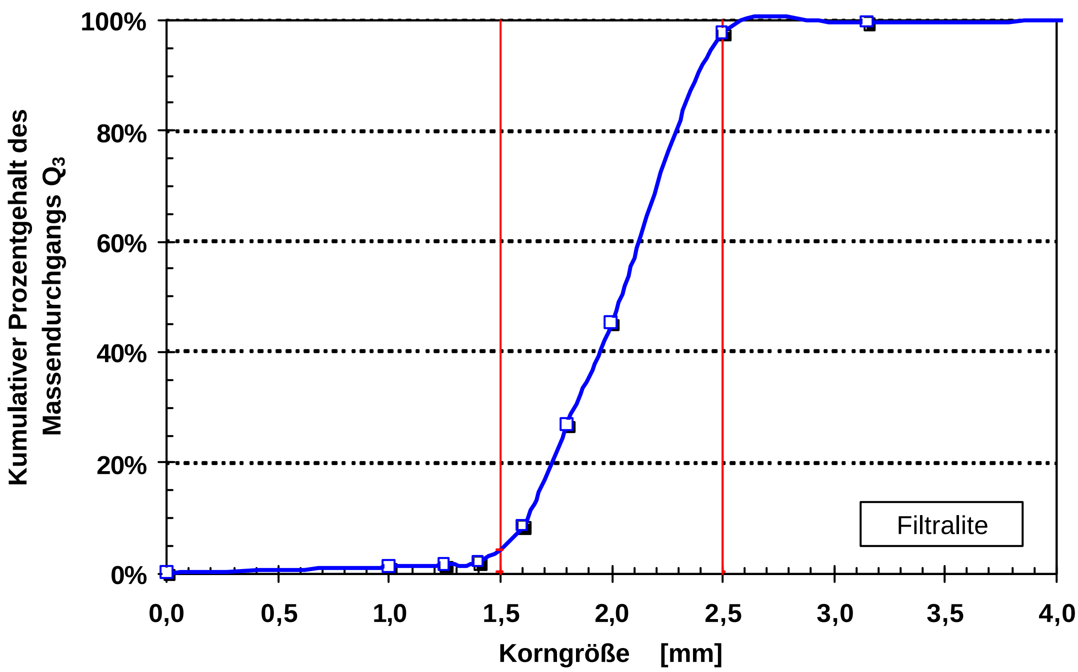

Fig. 2-8: Grain size distribution of FILTRALITE MC (Filter 2)

Table 2–6: Results of sieve analysis for FILTRALITE MC

		requirement of DIN EN 12905:
undersize percentage (mass fraction < 1,5 mm [%]:	4,1%	**< 5 %**
oversize percentage (mass fraction < 2,5 mm [%]:	2,4%	**< 5 %**
minimum size d_1 [mm] :		
effective size d_{10} [mm] :	1,61	
size d_{60} [mm] :	2,13	
size d_{90} [mm] :	2,39	
uniformity coefficient U [-] :	1,32	**< 1,5**
hydraulic effective size d_h [mm] :	1,93	
mean size Q_3 [mm] :	2,03	

Comparison of the sieve analysis of Hydroanthrasit H and FILTRALITE MC shows that the two materials to be compared with each other have (in limits of error) similar size ranges.

2.2.7 Filter filling and backwashing before operation

Before filling, filter materials (sand, Hydroanthrasit H and Filtralite MC) were soaked for one week and pre-washed manually. Fine abrasives were directly washed away as far as possible. Floating grains were skimmed off.

At first, sand was filled sedimenting into the columns which were filled with water before. After filling the sand layer, the columns were closed again and the sand layer was backwashed until the water above the expanded bed appeared clear. This happened to be after 45 min backwashing with 2 m^3/h, corresponding to approximately 45 m/h. After sedimenting, the columns were opened again and a few centimeters of sand were scraped off. Sand layers in both columns were scraped to exactly the same bed height.

After that, the columns were filled with water again and FILTRALITE MC and Hydroanthrasit H, respectively, were sedimenting filled into the columns to equal bed depth. Then the filters were backwashed for 30 min with water at a flow rate of 60 m/h for Hydroanthrasit H and 70 m/h for Filtralite, which guarenteed comparable bed expansion. After 30 min. of backwashing all abrasives had been washed out and the effluent was clear.

No scraping of the upper layer was done for Hydroanthrasit H and FILTRALITE MC. The reason was that OPTIROC had not supplied reserve filter material which would have allowed a somewhat higher bed than desired and scraping.

2.2.8 Backwashing regime between filter runs

2.2.8.1 Water backwash only

Backwashing experiments were performed in order to determine ideal backwashing flow rates and to avoid mixing of sand and Hydroanthrasit or FILTRALITE, respectively. It was decided to omit backwashing with air, as this - in the pilot columns - can cause mixing of different filter materials. However, in full scale filters backwashing with air is expected to be applicable without problems.

Backwashing after a filter run is carried out with tap water at flow rates of 65 m/h and for 30 min. Approximate expansion of the filter bed under backwashing is shown in Fig. 2-9

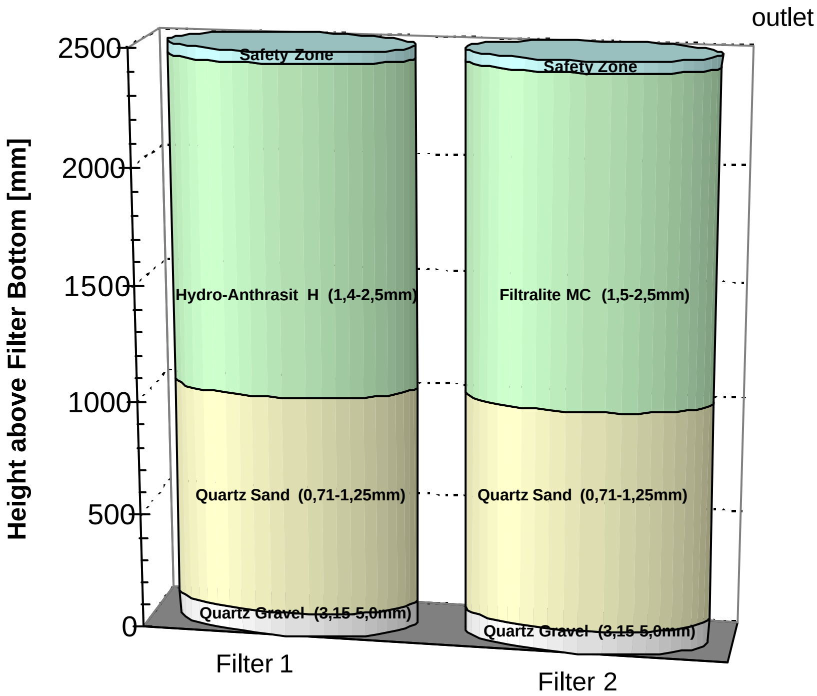

Fig. 2-9: Bed expansion during backwashing with 60 to 65 m/h

In pilot columns during backwashing with air, there always is a risk, that eddies, due to the low diameter/bed length ratio, result in an intermixing of the two layers which can hardly be returned. Therefore, it was decided that the two columns should be backwashed with water only for most of the filter runs. As this can result in incomplete removal of deposits from the filter grains, later filter runs were performed air and water backwashing.

2.2.8.2 Water/air backwash

After the major part of the filter runs had been carried out, three additional filter runs were done, before which the filters were backwashed with air scour and with water. These backwashes were carried out as follows.

At first, water was drained off to the level of the bed. Then air flow was opened for 10 min at a flow rate of 3 Nm^3/h, corresponding to 60 m/h. Bed expansion was approximately 32 cm. After 2 min. rest water backwash was started as described in section 2.2.8.1.

2.2.9 Filtration and termination of filter runs

Filtration was done at superficial flow rates of 15 m/h (760 l/h per filter column). Filter runs had to be finished when head loss of 120 mbar was exceeded.

3 Results of filtration experiments with water backwash only

3.1 Turbidity of influent to filters

As mentioned in chapter 2.2.2, wastewater dosage was altered in between filter runs in order to adapt different microbial contamination of the filter influents. As a consequence, this affected influent turbidities. Furthermore, influent turbidities were of course subject to some variation, which also reflects typical scatter of analysis. Influent turbidity was always measured in the influent of both filters, i. e. with Hydroanthrasit H and FILTRALITE MC. Fig. 3-1 and Fig. 3-2 show turbidities of the two filters, measured during the two filter runs. Comparing the influents to both filters for each run shows, that the influent turbidities were comparable. Also, it can be seen that the turbidities were in the order of magnitude intended, i. e. comparable to typical turbidities of surface water of the river Ruhr.

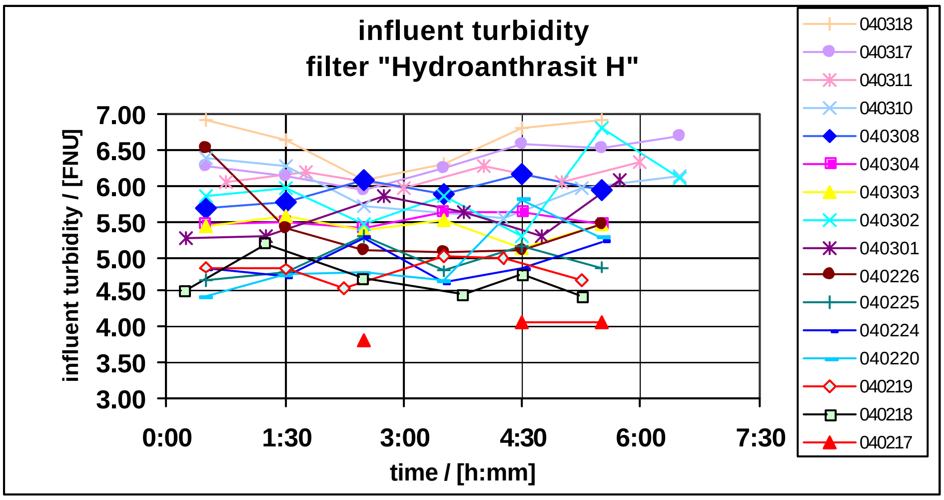

Fig. 3-1: Influent turbidity to Filter Hydroanthrasit H during filter runs

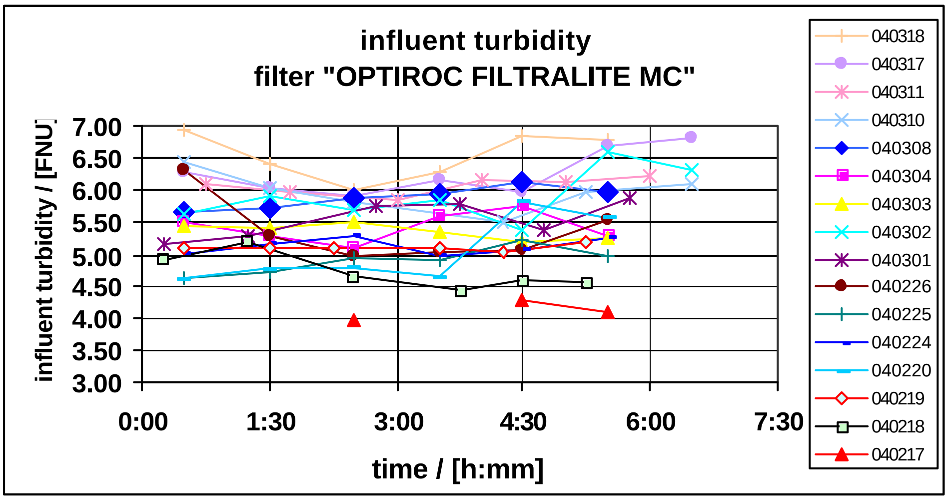

Fig. 3-2: Influent turbidity to Filter FILTRALITE MC during filter runs

3.2 Turbidity removal

Total turbidity removal (i. e. from the lower sand layer and the upper layer of Hydroanthrasit H and FILTRALITE MC, respectively) is plotted in Fig. 3-3 and Fig. 3-4, respectively, in the form of integrated turbidity removal. The integrated, or cumulative, removal of a quantity ΔX at time t_N is calculated according to

$$\Delta x_{int,t_N} = \sum_{i=1}^{N} \left(Q_i \cdot (t_i - t_{i-1}) \cdot \Delta x_i \right)$$

with

$$\Delta X_i = (X_{eff'} - X_{inf})$$

The advantage of this method of data evaluation is that with increasing time, the result is obtained from several measurements. Thus, the precision increases with increasing time and differences between (here) two filter materials can be shown which could not be shown by comparing single measurements at discrete times.

Furthermore, the integrated amount of a quantitiy X removed can be directly expressed as a load of quantity X in the filter segments.

As for turbidity, the unit of integrated turbidity removal is FNU · m^3.

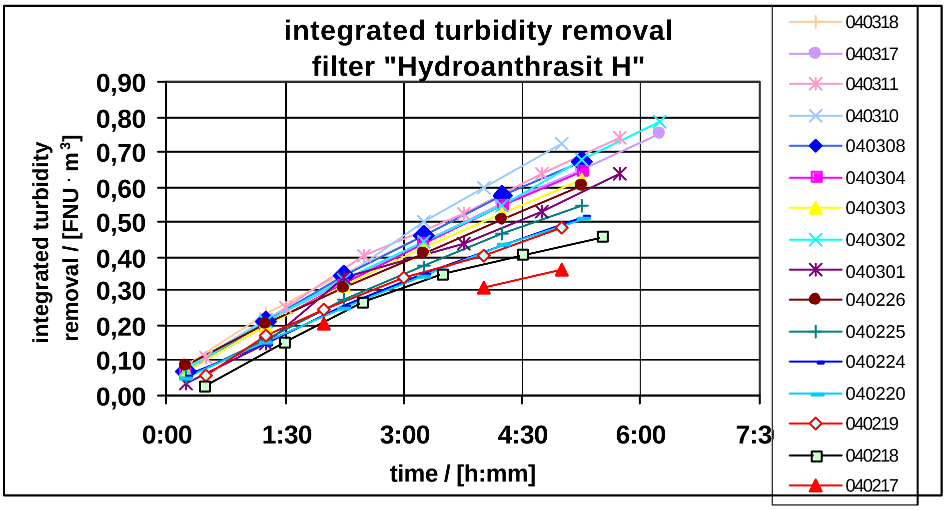

Fig. 3-3: Total integrated turbidity removal for filter "Hydroanthrasit H"

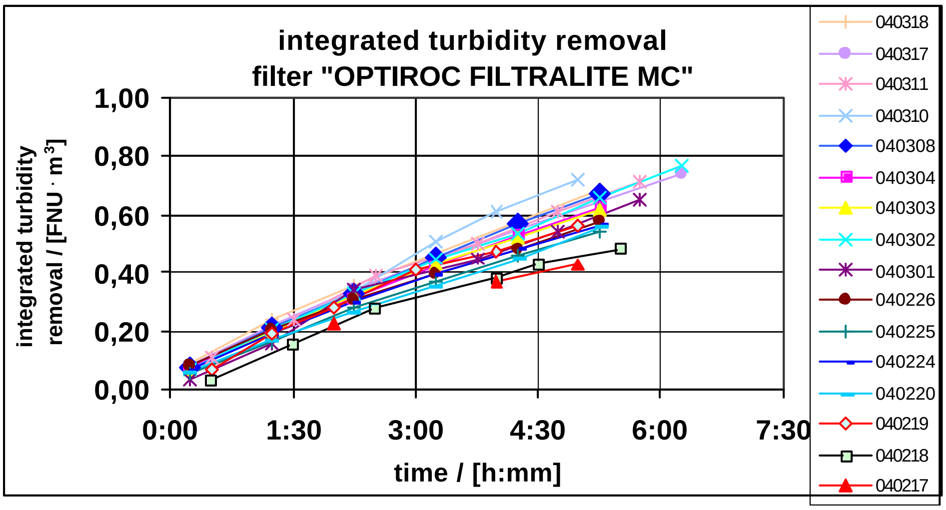

Fig. 3-4: Total integrated turbidity removal for filter " FILTRALITE MC"

In general, there is no significant difference in total integrated turbidity removal for the two filters with Hydroanthrasit H and FILTRALITE MC. By directly comparing the two filter's performance for each filter run it can be seen, that the filter with FILTRALITE performed better than Hydroanthrasit H with respect to turbidity removal during the first four filter runs. However, after the fourth run, the performances of the materials had aligned to each other. Although, in general, performance of both materials improved from run to run.

Most likely reasons for that are the coagulation and deposition of aluminum hydroxide layers in grain pores and on the filter grains. These layers block the pores of porous filter materials like FILTRALITE and thus result in the bringing together of performance of FILTRALITE and Hydroanthrasit H. On the other hand, these coatings result in a surface of similar chemistry like the flocs. As a consequence, they are better surfaces to induce coagulation and deposition of flocs from the bulk phace and keep them catched. Therefore, an improved removal of trubidity from run to run can be observed. This improvement will, however, not continue for an unlimited time.

A reservation in the interpretation of improving filtration performance from run to run has to be made. The dosage of wastewater was increased, as already explained in section 2.2.2. This resulted in increasing turbidity in the influent. For example, average turbidity during fourth run was 4.81 FNU, while 6.61 FNU during run 17. As in filtration particle (or turbidity) removal is dependent on particle concentration, higher removal efficiencies for later filter runs may also have been due to higher influent concentrations.

In order to illustrate the alignment of the filtration performence of Hydroanthrasit H and Filtralite MC more clearly, as an example integrated turbidity removal during the fourth run (19.02.2004) and the twelth run (04.03.2004) as well as 17th run (18.03.04) are shown in the following figures.

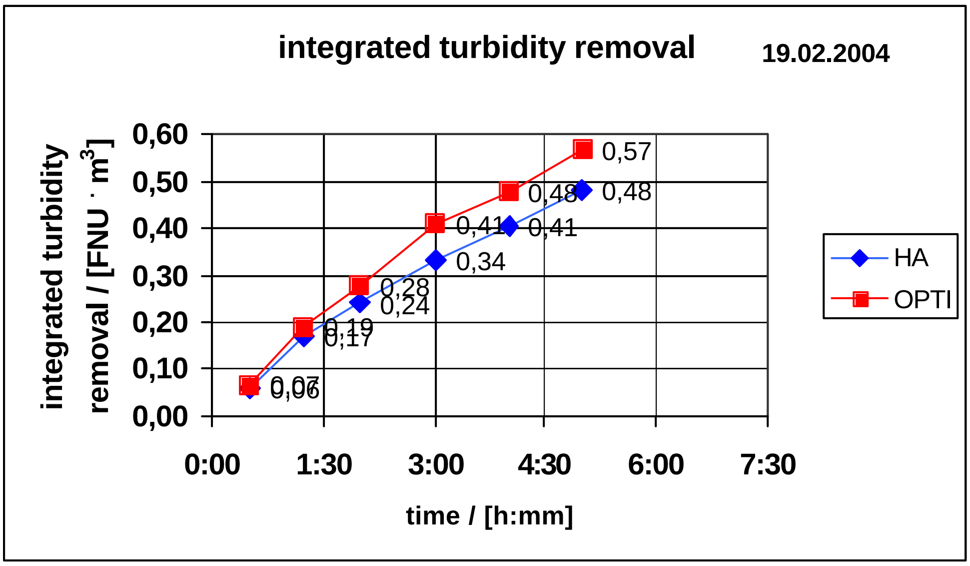

Fig. 3-5: Integrated turbidity removal of filters with Hydroanthrasit H and FILTRALITE MC during fourth filter run.
(average influent turbidity: 4,81 FNU, ± 4.1 %, n = 18)

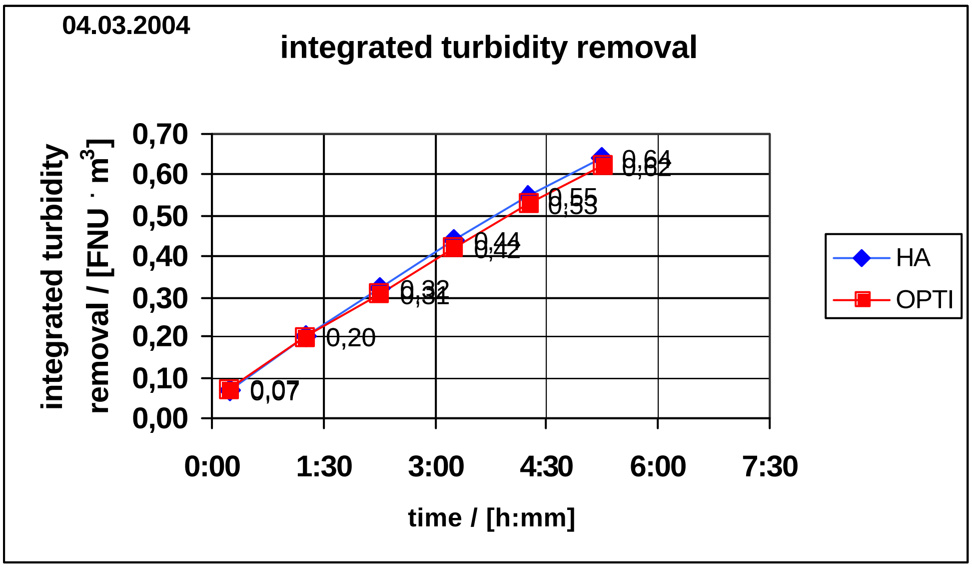

Fig. 3-6: Integrated turbidity removal of filters with Hydroanthrasit H and FILTRALITE MC during 12th filter run.
(average influent turbidity: 4.43 FNU, ± 15.7 %, n = 18)

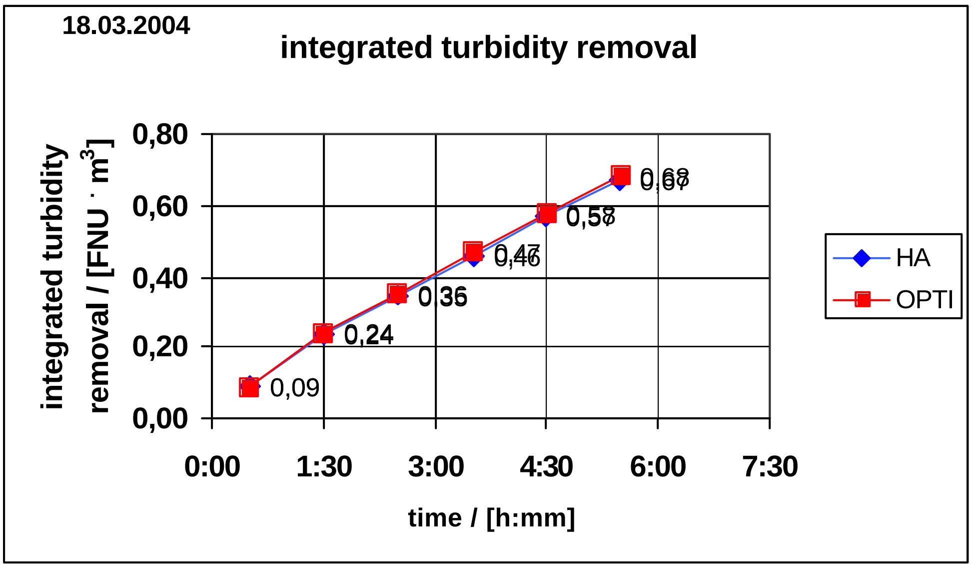

Fig. 3-7: Integrated turbidity removal of filters with Hydroanthrasit H and FILTRALITE MC during 17th filter run.
(average influent turbidity: 6.61 FNU, ± 5.0 %, n = 18)

As integrated (or accumulated) turbidity removal may be somewhat abstract, influent and effluent turbidities of the filters and for the same runs as in Fig. 3-5 and Fig. 3-6 are shown in Fig. 3-8 and Fig. 3-9.

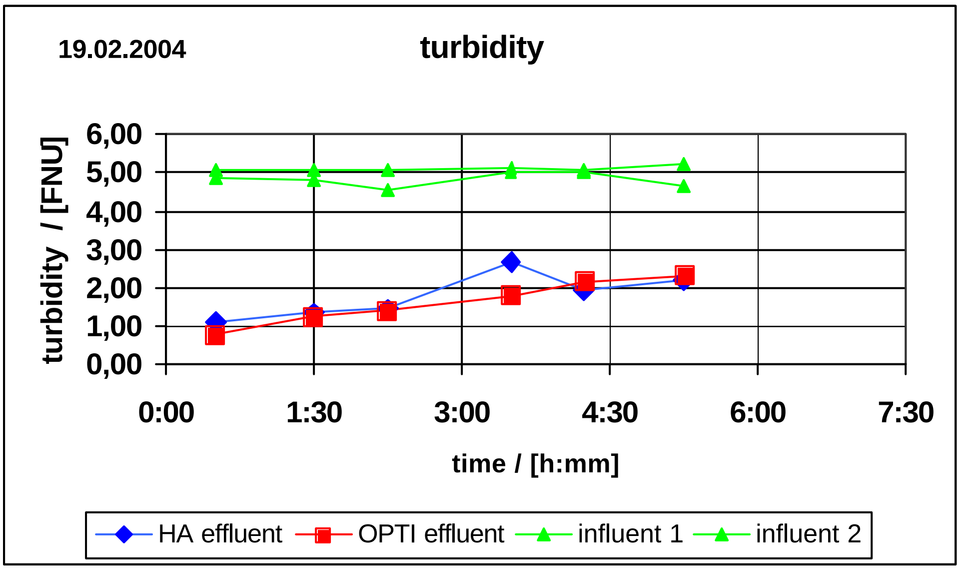

Fig. 3-8: Influent and effluent turbidities during filter run analysed in Fig. 3-5.

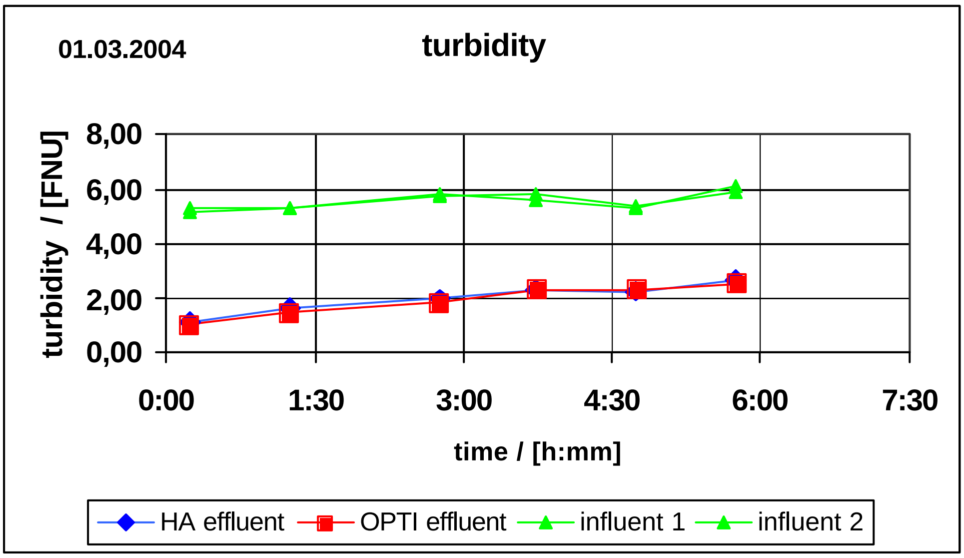

Fig. 3-9: Influent and effluent turbidities during filter run analysed in Fig. 3-6.

3.3 Total head loss

Total head loss (i. e. between influent and effluent of filter) as function of filtration time for all filtration runs is shown in Fig. 3-10 (Hydroanthrasit H) and Fig. 3-11 (FITRALITE MC). Comparing the initial head loss for the beginning of the runs with those estimated for the filter beds and given in Table 2–3 shows, that the filter with FILTRALITE performs as expected. However, the filter with Hydroanthrasit H shows a somewhat minor performance than expected, in that the head loss is somewhat higher.

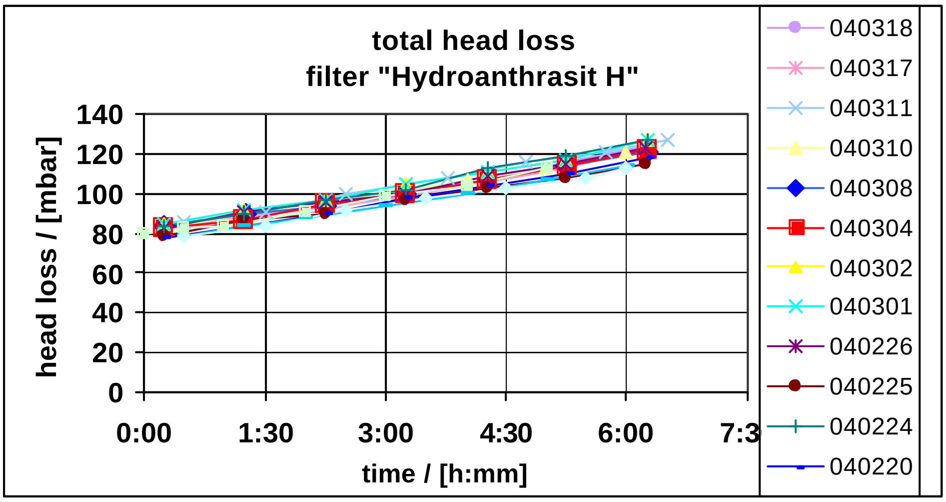

Fig. 3-10: Total head loss as function of run time for all filtration runs and filter with Hydroanthrasit H

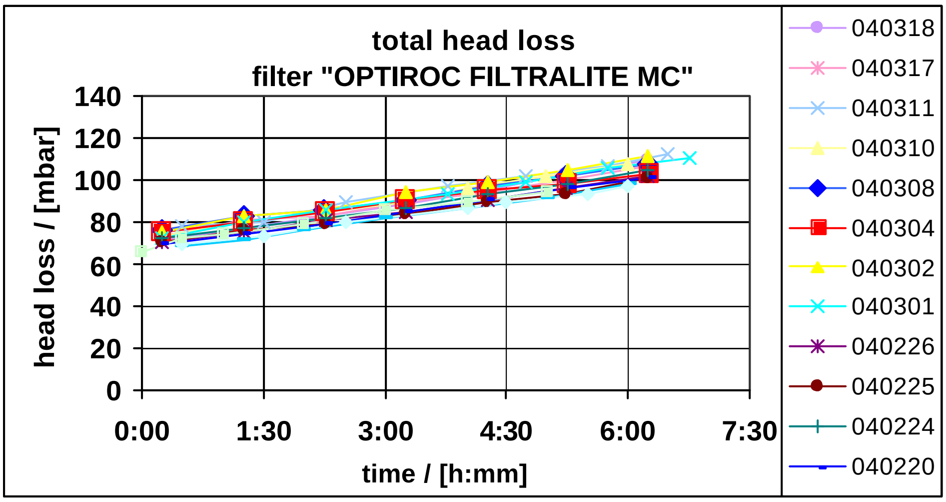

Fig. 3-11: Total head loss as function of run time for all filtration runs and filter with FILTRALITE MC

Also, it can be seen that the difference between Hydroanthrasit H and Filtralite even increases. At the end of a run head loss for the filter with Hydroanthrasit H is about 15 % higher compared to FILTRALITE. A reason may be that Hydroanthrasit H is more sensitive to abrasion during filtration and backwashing and that smaller grains are accumulated at the filter top.

3.4 Comparison of filter run times

In the pilot experiments, filter runs had to be finished when a total head loss of 120 mbar was exceeded in one of the two columns. As can be depicted from Fig. 3-10 and Fig. 3-11 always the filter with Hydroanthrasit H was the first to reach this point. Projecting the run time of the FILTRALITE MC filter to a total head loss of 120 mbar, this filter could have been run for 1.5 hours longer which corresponds to an increase in run time of approximately 25 % between two backwashes.

3.5 Incremental head loss in filter sections

In order to follow the reason for higher head loss in filter 1 with Hydroanthrasit H compared to FILTRALITE, incremental head loss (i. e. head loss per unit length filter depth) as function of turbidity removed was analysed closely. The results are plotted in Fig. 3-12 for Hydroanthrasit H and Fig. 3-13 for FILTRALITE.

For that purpose the turbidity removed in a segment (i. e. integrated or accumulated turbidity removal) is normalized to filter volume of that segment. This is termed averaged turbidity load. Consequently, the units of averaged turbidity load are [FNU · m^3/m^3].

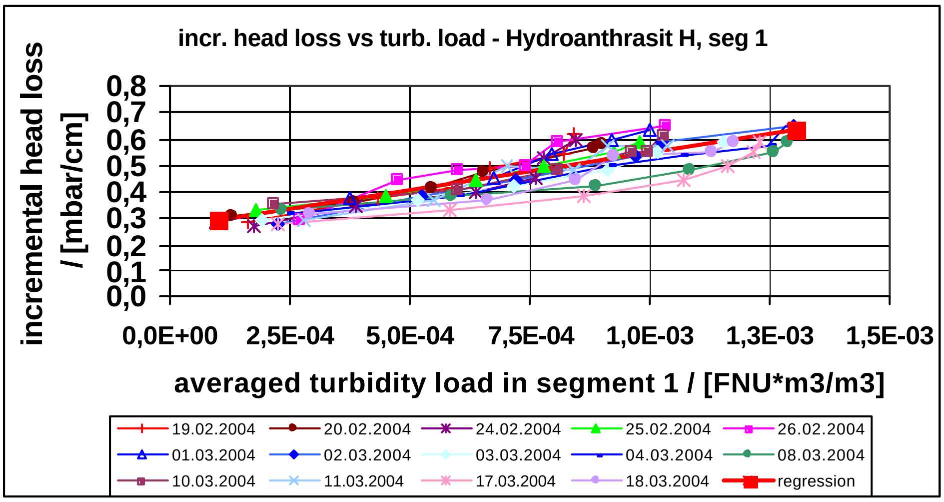

Fig. 3-12: Incremental head loss as function of averaged turbidity load for filter 1 with Hydroanthrasit H

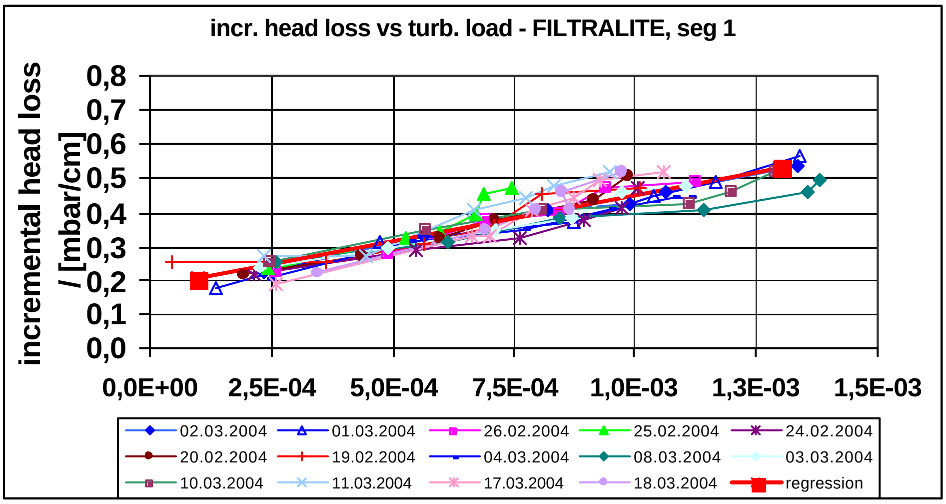

Fig. 3-13: Incremental head loss as function of averaged turbidity load for filter 2 with FILTRALITE MC

Especially when comparing the regression lines, it can clearly be seen, that in the upper segment of the filter with Hydroanthrasit incremental head loss is higher than in the segment of the filter with FILTRALITE. This is not only due to turbidity removed, as the differences already exist at turbidity loads near zero.

This result is more clearly shown in Fig. 3-14, where only the two regression lines are plotted. As can be seen from the graph, the two lines are almost parallel. This means, that for both filters the deposition of turbidity results in the same increase of head loss. The difference in head loss of the two filters is only a result of head loss in the beginning of the filtration run. Thus, probably due to finer grains on top of the filter with Hydroanthrasit H.

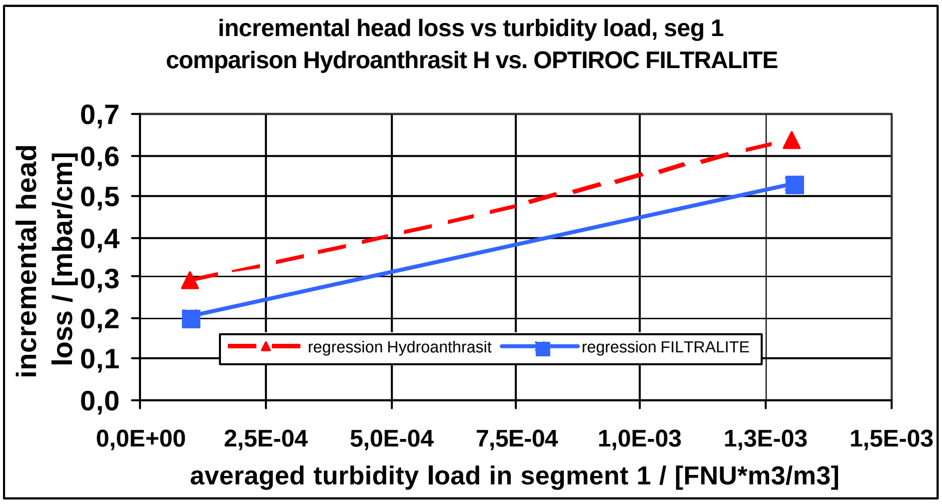

Fig. 3-14: Regression of incremental head loss vs averaged turbidity load in upper segments of filters with Hydroanthrasit H and FILTRALITE MC.

This finding is further supported by the fact that in the second filter segment incremental head loss in the two filters with Hydroanthrasit H and FILTRALITE MC, as function of turbidity deposited, is almost equal. This is shown in Fig. 3-15. The difference at high turbidity loads is not significant.

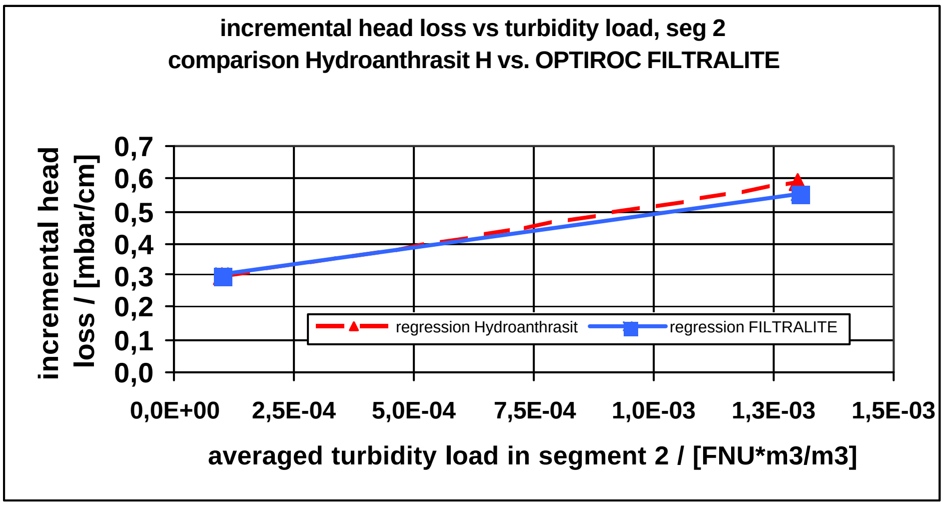

Fig. 3-15: Regression of incremental head loss vs averaged turbidity load in second segments of filters with Hydroanthrasit H and FILTRALITE MC.

When incremental head loss in segment 2 is extrapolated to 0 averaged turbidity load (interception on ordinate), an incremental head loss of approximately 0.28 mbar/cm is obtained for both granular media. However, for FILTRALITE, this value is higher than 0.18 mbar/cm for the first segment. At first glance, this seems to be contradictory, as higher values for the first segment would be expected, as with Hydroanthrasit H. But is has to be taken into account, that segment 2 is already influenced by the sand layer, as after backwashing the filters a transition zone was formed where sand and FITRALITE or Hydroanthrasit H are mixed. Thus, the higher incremental head loss than expected in FILTRALITE segment 2 also is determined by the smaller sand grains.

3.6 Michau-diagrams for head loss

In Michau-diagrams, pressure as a function of bed depth is compared to hydrostatic pressure. Thus, they are an excellent means to analyze and interpret the development of head loss during filter operation.

Michaud-Diagrams In Fig. 3-16 and Fig. 3-17 show pressure at the beginning of a filter run and at the end of the filter run, i. e. after about 6 h filter operation. For the clean beds it can be seen, however not as clearly as in the diagrams with incremental head loss versus turbidity load, that head loss in the combined segments 1 and 2 (= layer 1) is somewhat lower for FILTRALITE compared to Hydroanthrasit H.

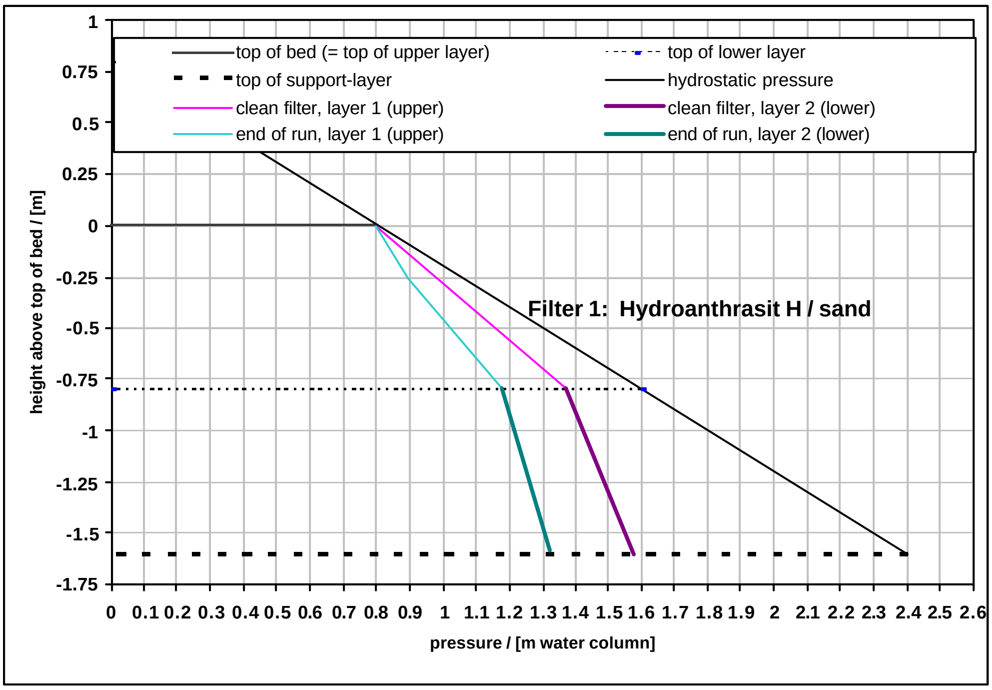

Fig. 3-16: Michaud-Diagram for one filter run, filter 1: Hydroanthrasit H/sand

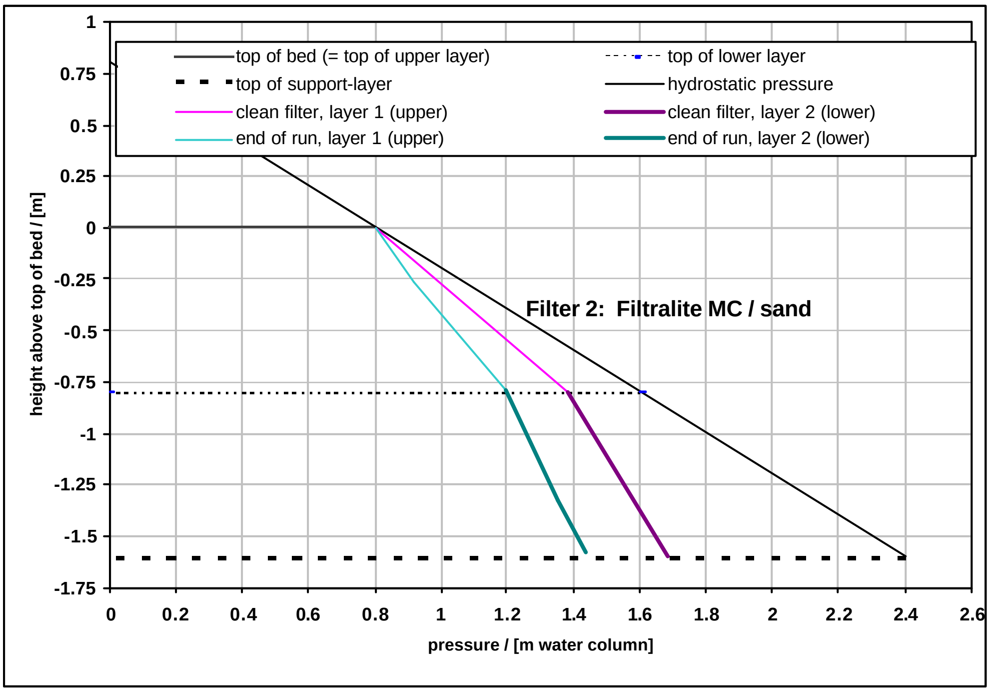

Fig. 3-17: Michaud-Diagram for one filter run, filter 2: FILTRALITE MC/sand

It is interesting to note that, in combined segments 3 and 4 (=layer 2) , head loss is higher for the Hydroanthrasit H/sand filter. At first, this is unexpected, as in both filters segments 3 and 4 are filled with the same sand. Therefore, a closer investigation of head loss in clean segments 3 and 4 of the two filters was made. We found, that in segments 4, i. e. the lowest ones, head loss was the same for both filters, as expected. The difference between the Hydroanthrasit H and FILTRALITE filters resulted completely from segments 3. Closer visual analysis of the two filters showed that there was a more pronounced mixing zone between FILTRALITE and sand than between Hydroanthrasit H and sand, respectively. So, as more sand was found in segment 2 and increased headloss (see section above), also FILTRALITE was mixed into segment 3 and decreased headloss in this segment, due to an increase in porosity.

At the ends of the filter runs, as already discussed in section 3.3, total headloss is somewhat higher for the Hydroanthrasit H/sand-filter when compared to the FILTRALITE/sand-filter. In the Michau-Diagrams, pressure for the run shown is about 1.32 m wc for filter 1 and 1.45 m wc for filter 2.

3.7 Microbial contamination

In total, six sampling campaigns for microbial contamination of the water at different bed depths were carried out.

During the first campaign, wastewater was dosed at a relation of 1:1000. Results are given in Table 3–1. Influent to the two columns was sampled twice, i. e. once from both columns. Comparing the influent values (A and B) shows the variation of the microbiological analysis. Each filter column was then sampled at two bed depths: in the middle and at the end of the Hydroanthrasit H and FILTRALITE MC layers, respectively. From these results, no differences in the removal efficiencies of Hydroanthrasit H and FILTRALITE can be derived.

Table 3–1: Results of the first microbiological sampling campaign (wastewater dosage at 1:1000).

sampling point	colony count (20°C) [cfu/ml]	coliforms [MPN/ 100 ml]	E. coli [MPN/ 100 ml]	Enterococci [cfu/100 ml]
influent A	182	74	11	2
influent B	158	31	2	3
HA-middle	199	89	11	2
HA-end	184	53	9	2
OPTI-middle	140	66	12	3
OPTI-end	510	201	24	1

As it was hoped that higher wastewater dosage should yield higher bacterial contamination and thus hopefully differences between the two filter materials should be detectable, the afterfollowing filtration runs were done at doubled wastewater dosage.

However, as can be depicted from Table 3–2, microbial contamination was even less than during the first run, which is due to variations in wastewater composition from the wastewater treatment plant. Furthermore, as also this table shows, variation of microbiological analysis is so pronounced, that no differences can be seen between the filter materials of Hydroanthrasit H and OPTIROC FILTRALITE MC.

Table 3–2: Results of microbiological analysis from filtration runs at wastewater dosage of 1:500.

sampling point	colony count (20°C) [cfu/ml]	coliforms [MPN/ 100 ml]	E. coli [MPN/ 100 ml]	Enterococci [cfu/100 ml]	Clostridium perfiringens [cfu/100 ml]
influent A	39	4	0	0	0
influent B	63	2	0	0	0
HA-middle	51	1	0	0	1
HA-end	44	0	0	0	0
OPTI-middle	69	3	0	0	1
OPTI-end	23	0	0	0	0
influent A	410	4	1	0	1
influent B	205	4	0	0	1
HA-middle	78	4	1	0	1
HA-end	26	1	0	0	2
OPTI-middle	53	2	0	0	0
OPTI-end	41	1	0	0	2
influent A	84	12	1	1	1
influent B	73	14	3	2	1
HA-middle	74	14	1	6	0
HA-end	21	14	3	1	0
OPTI-middle	40	15	2	1	0
OPTI-end	57	8	2	3	0

In afterfollowing filter runs, wastewater dosage was further increased to factors of 1:250 and 1:125 (2 runs each; one each sampled for microbial contamination). These results are tabulated in Table 3–3 and Table 3–4. Also for these high dosages, which were the absolutely highest dosages that can be run at the pilot plant, scatter of microbiological contamination data is still too high in order to be able to show differences between two filter materials.

Table 3–3: Results of microbiological analysis from filtration runs at wastewater dosage of 1:250.

sampling point	colony count (20°C) [cfu/ml]	coliforms [MPN/ 100 ml]	E. coli [MPN/ 100 ml]	Enterococci [cfu/100 ml]	Clostridium perfiringens [cfu/100 ml]
influent A	79	22	4	3	3
influent B	74	24	11	1	2
HA-middle	77	25	6	3	2
HA-end	59	19	3	2	3
OPTI-middle	43	16	8	2	2
OPTI-end	37	27	12	2	8

Table 3–4: Results of microbiological analysis from filtration runs at wastewater dosage of 1:125.

sampling point	colony count (20°C) [cfu/ml]	coliforms [MPN/ 100 ml]	E. coli [MPN/ 100 ml]	Enterococci [cfu/100 ml]	Clostridium perfiringens [cfu/100 ml]
influent A	184	2	0	0	3
influent B	74	12	0	0	0
HA-middle	48	10	2	0	0
HA-end	53	14	1	0	3
OPTI-middle	41	11	2	0	3
OPTI-end	38	4	2	0	2

4 Results of filter runs with air scour and water backwash

4.1 Background

During the first filter runs differences between FILTRALITE MC and Hydroanthrasit H were obvious which disappeared after already four runs. This may be due to the effect that pores of filtralite are blocked by aluminium hydroxide precipitates which were not removed by backwashing. Thus we decided to carry out three further filter runs with air scour backwash.

4.2 Results

As for the filter runs with water backwash only, integrated (or cumulative) turbidity removal for the filters with FILTRALITE MC and Hydroanthrasit H was similar between the two materials for all three filter runs. Fig. 4-1 shows that exemplarily for one of the three filer runs.

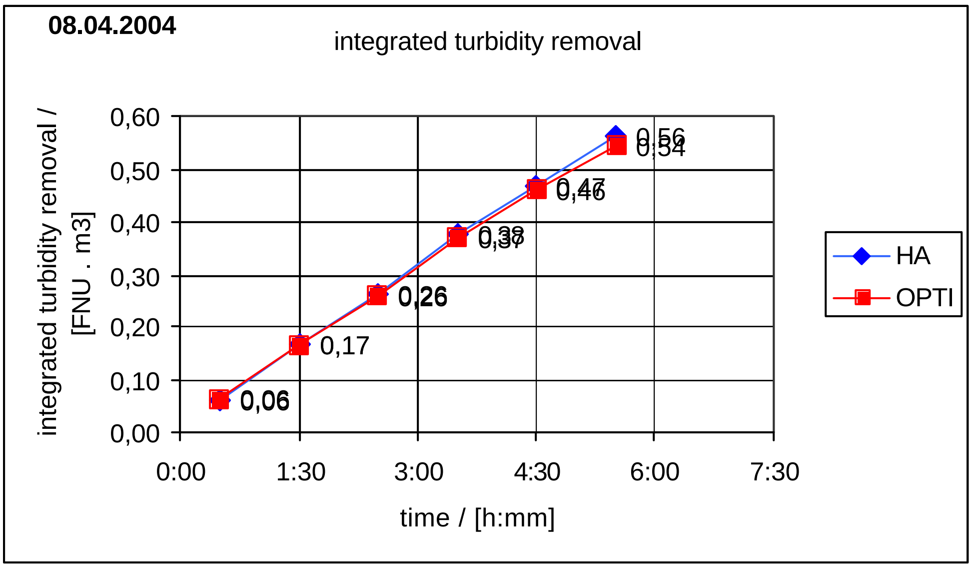

Fig. 4-1: Intgegrated turbidity removal during one of the filter runs with water and air scour backwash before filtration

For the same filter run, total head loss is shown as a function of filtration time in Fig. 4-2. Also here, head loss was higher, already initially, for Hydroanthrasit H than for FILTRALITE MC. For both filters, initial head loss is about 5 mbar lower than for the filter runs with water backwash only (compare with Fig. 3-10 and Fig. 3-11). This may be due to a better removal of deposited material and/or removal of filter media abrasives as a consequence of backwashing with air scour. However, the absolute differences between Hydroanthrasit H and FILTRALITE MC remain mostly the same in that Hydroanthrasit H causes a higher head loss. Extrapolated to backwash criterium of 120 mbar, a filter with FILTRALITE can be operated longer than a filter with Hydroanthrasit H. The increase in operation time is also about 25 %.

The reason for better performance of FILTRALITE may be abrasion of small particles from the activated carbon like Hydroanthrasit H. However, it has to be taken into account, that the upmost filter layer was not scraped before the filters were taken into operation. Yet, from the investigations carried out, the long-time performance of FILTRALITE when compared with Hydroanthrasit H, is not clear. It is expected that FILTRALITE will stand longer as a result of better resistance to abrasion. However, this cannot be proven by the investigations carried out yet.

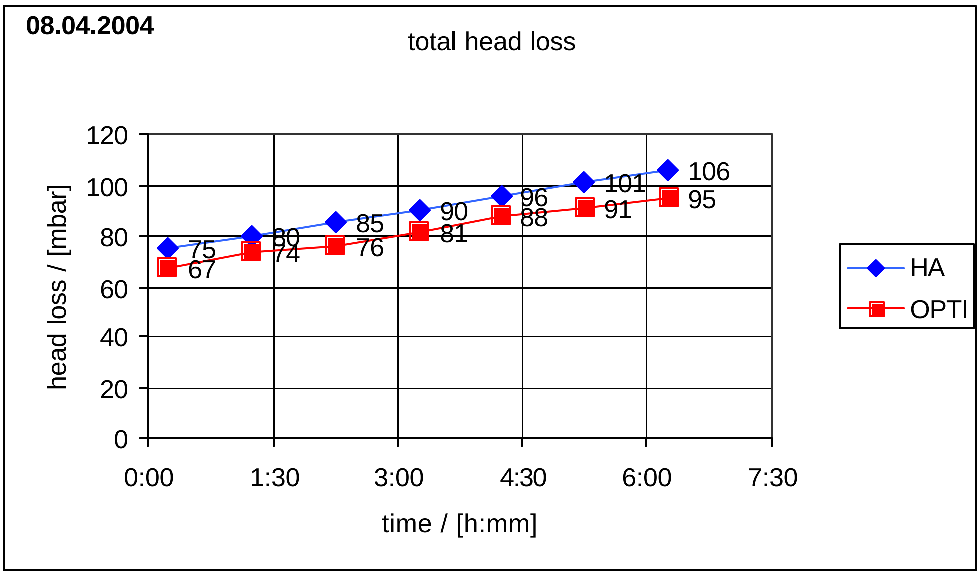

Fig. 4-2: Total head loss as function of filtration time during one of the filter runs with water and air scour backwash before filtration.

5 Summary and conclusions

Under controlled conditions, the two filter materials FILTRALITE MC (supplied by OPTIROC) and Hydroanthrasit H (supplied by Akdolit) were compared in the filtration of a synthetic surface water. The surface water was prepared from dechlorinated drinking water to which clay particles and activated sludge treatment plant effluent were dosed such that turbidity and microbial contamination were comparable to those found in the river Ruhr, Germany, on average.

Before filtration, the water was treated by flocculation with polyaluminiumchloride in three flocculation chambers in series.

Both materials to be compared with each other were applied in filter columns of 2.5 m height and 255 mm inner diameter. Filters were dual media filters, total bed height was 150 cm with 70 cm sand and 80 cm Hydroanthrasit H or FILTRALITE MC. Effective hydraulic grain size of both media were approximately 1.9 mm and approximately 0.9 mm for sand. Between filter runs, the filters were cleaned by backwashing. During the major part of the experiments, the filters were backwashed with water only at 65 m/h for 30 min. During some of the experiments, the filters were first backwashed with air sour at 60 m/h and then with water.

Concerning turbidity removal, FILTRALITE and Hydroanthrasit H performed equal. A somewhat better performance of FILTRALITE in the first three runs ceased, probably due to the blockage of pores providing additional storage volume for particles in the beginning.

Regarding head loss, the FILTRALITE filter performed better than Hydroanthrasit H. Closer analysis of incremental head loss in four segments of the filter beds showed that the main difference resulted from the first few centimeters on top of the bed. This finding even did not change when the filters were backwashed with air scour and water instead of water only. The reason seems to be a more pronounced classification of Hydroanthrasit. Furthermore, Hydroanthrasit H is eventually abrased by backwashing to a higher extent than FILTRALITE. However, it has to be noted that the Hydroanthrasit H and FILTRALITE layers were not scraped before taken into operation as OPTIROC had not supplied surplus filter media.

For filters as set up and operated in our investigations, for backwash criterium 120 mbar total head loss, with FILTRALITE 25 % longer filter cycles compared to Hydroanthrasit H are possible.

Probably, main advantages of FILTRALITE are it‘s higher resistance to abrasion, which might enable higher application times in full scale filters. However, abrasion needs to be compared in separate experiments. Also, scientifically guided full scale investigations are absolutely necessary to really proof the superiority of FILTRALITE under conditions relevant for practice.

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