FEEDBACKS ON PERFORMANCE TESTS WITH FILTRALITE MEDIA® COMPARED TO CONVENTIONAL MEDIA FILTERS AT PILOT SCALE

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ABSTRACT

More stringent standards for drinking water quality and a global trend towards resource degradation have driven research toward improving the performance of treatment plants. Filtration remains a key step for drinking water treatment, being effective for the elimination of turbidity, colour and microorganisms. SUEZ is focused on continuous optimization of filtration performances aimed at improving the filtered water quality and/ or reducing operating costs (energy, chemicals, water losses). For this purpose, the replacement of traditional granular media with new one such as Filtralite® products is considered. Filtralite® is composed of expanded clay aggregates whose particle size and particle density can be specifically selected depending on the quality of raw water and the treated water objectives. In this context, a study was carried out to answer the following questions: (1) What are the performances of Filtralite® media for particle retention in comparison with filter media commonly used? (2) What is the impact of raw water quality and filtration flow rate on the performances of Filtralite® in terms of filtered water quality and productivity of filters?

The different media was tested through a pilot made of 5 columns of filtration located at the CIRSEE in Le Pecq, near the Seine River. The pilot was fed successively with previously coagulated Seine river (turbidity < 20 NTU) then with settled water (turbidity 0.5 to 5 NTU). 2 filtration rates were tested (8 and 15 m/h). Both conventional filters (sand, sand/anthracite) and alternative filters with Filtralite® demonstrated very good performances in removing particles with a filtered water turbidity maintained at 0.2 ± 0.1 NTU. The lowest turbidities are obtained with Filtralite® media. The study of the filter productivity (UFRV) indicated a better efficiency of the Filtralite® media, especially the Mono-Multi, with a production 1.5 to 2 times higher than the best conventional media. Increasing the filtration rate does not seem to affect performance.

The deployment of these alternative media could be envisioned for both refurbishment purpose (subject to the adaptation of the backwash conditions), and new constructions.

KEY WORDS

Drinking water, rapid filtration, expanded clay, sand, turbidity, water productivity of filter

Background and objectives of the study

In a world where water resources tend to deteriorate and become scarce and where water quality standards become more stringent, it is necessary to implement efficient water treatment processes in terms of produced water quality and generated water losses. Filtration remains a key step for drinking water. More stringent standards for drinking water quality and a global trend towards resource degradation on parameters such as algae, organic matter and organic micropollutants have driven research towards improving the performance of treatment plants. Due to the increasing scarcity of freshwater in some parts of the world, treatment systems must be able to produce more drinking water. Finally, drinking water treatment plants must evolve to meet the objectives of the current ecological transition, by moving towards a reduction of chemicals and energy consumption.

Rapid filtration, used for the production of drinking water since the end of the 19th century, remains a key step in removing suspended solids, pathogenic bacteria and color. Quartz sand has historically been the most commonly used media, because of its low cost, its global availability and the vast experience of plant operators leading to reliable and predictable performance. In recent decades, the field of rapid gravity filtration has not experienced major innovations except for the implementation of bilayer or multilayer filters; for example, the implementation of sand / anthracite dual media filters since the 1960s has become usual, enabling to increase the duration of the filtration cycles.

In this context, SUEZ is focused on continuous optimization of filtration performances aimed at improving the filtered water quality and/or reducing operating costs. In this perspective, different approaches have been considered, such as the optimization of pretreatment (coagulation- flocculation and settling) and the replacement of traditional granular media with new ones such as Filtralite® products. Filtralite® is composed of expanded clay aggregates whose particle size (0.5 to 8 mm) and particle density (1,050-1,800 kg/m^3) can be specifically selected depending on the quality of raw water and the treated water objectives. It offers innovative solutions to water facilities both for drinking water and wastewater as a goal of physical filtration or biological treatment. This filter media can be applied for both greenfield and brownfield projects. Today, Filtralite® is implemented worldwide with references for biological treatment especially for ammonia removal. The performances of this media for particle retention has been less investigated. However, some references exist in Northern Europe indicating interesting returns on investment of the order of 2 to 3 years. For example, at the Bedrichov water treatment plant (600 l/s) in the Czech Republic, the replacement of the sand-filter media with Filtralite® media doubled production capacity and reduced energy costs by 75%. At the Fredrikstad water treatment plant (60,000 m^3/day) plant in Southern

Norway, the use of Filtralite® to replace the sand / anthracite dual media has reduced water losses by around 125,000 m^3/year. In 2007, Thames Water extensively tested 12 alternative filter media compared existing sand / anthracite dual media filters, which tended to become clogged quickly during episodes of raw algae-laden water [MIKOL et al., 2007]; the implementation of Filtralite® Mono-Multi (dual media) at several plants has resulted in filtration cycles 8 times longer with comparable filtered water quality. The productivity of the plants has thus been significantly increased without additional footprint.

In this context, a study was conducted to answer the following Key Questions:

KQ1-What are the performances of Filtralite® for particle retention in comparison with filter media commonly used on drinking water treatment plants in terms of filtered water quality and productivity?

KQ2-What is the impact of raw water quality on the performance of Filtralite® media?

KQ3-What is the impact of filtration flow rate on the performance of Filtralite® media?

Material and methods

Quality of raw water tested. In order to qualify filtration performance on various media, a pilot was implemented for 3 months at the CIRSEE, located at Le Pecq (78), near the Seine and the Croissy ground water recharge plant (production capacity of 136,800 m^3/day) which includes a complete clarification step. The pilot was fed successively with Seine water previously coagulated and then with settled water. This allowed to successively simulate the processes " coagulation on filter" and "complete clarification". The coagulant used is, in both cases, ferric chloride 41% (at a dosing rate around 15 ppm as commercial solution). The coagulant injection points are displayed in Figure 1.

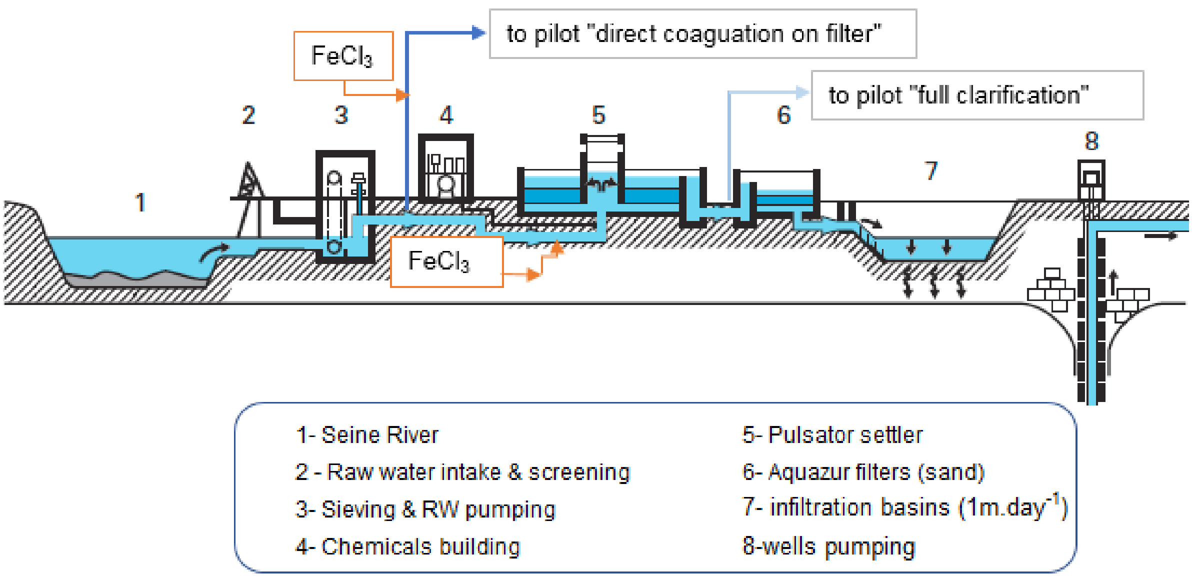

Figure 1: flow diagram of Croissy recharge plant

Pilot unit description. The different media was tested through a pilot made up of 5 columns of filtration (internal diameter of 192 mm) over a period of 3 months. The filter media depth was between 1.2 and 1.4 m to be similar to the plant's filters and allow a comparison with the full-scale results. Two Filtralite® media were tested comparatively with three reference media used for conventional treatment. The global configuration of the pilot unit is presented in Figure 2.

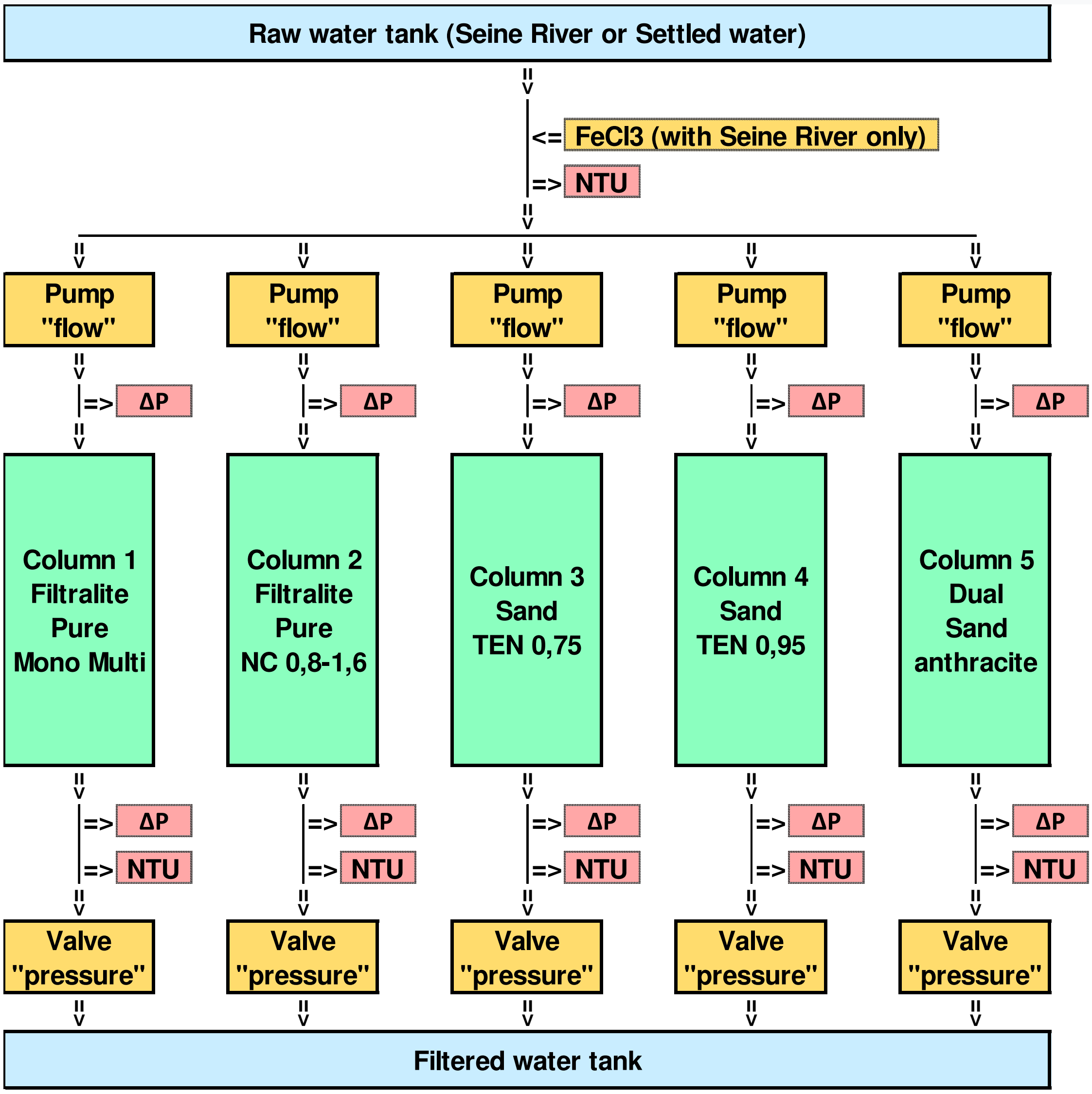

Figure 2: Pilot plant configuration

Filtralite® media are prepared by crushing them in angular grains and targeting a porosity greater than that of sand. Filtralite® Pure NC grains (normal density, crushed) are lightweight and highly porous, while Filtralite® Pure HC grains (high-density, crushed) have a higher density than Filtralite® NC.

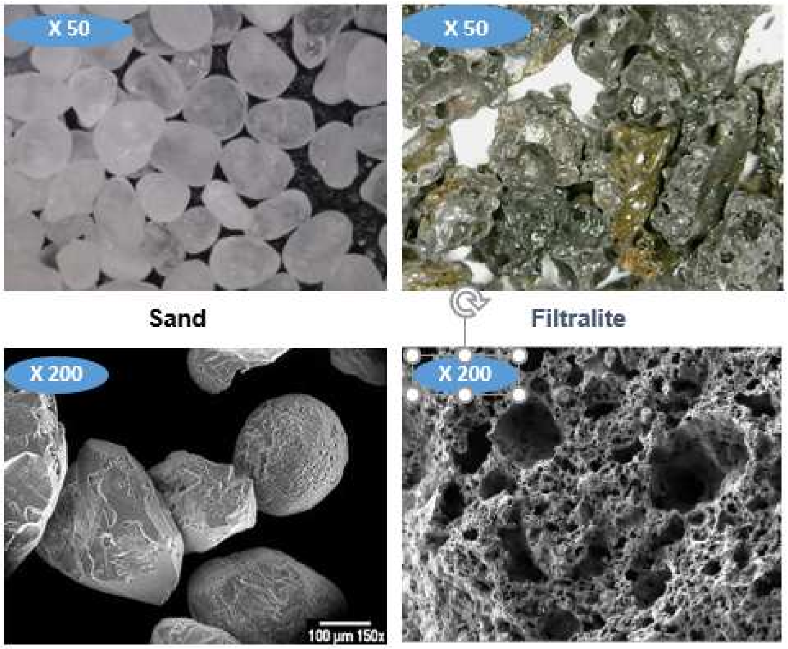

Figure 3: microscope views (X 50, X 200) Filtralite® versus sand

Both materials can be combined in a single media or dual media filtration solution. Table 1 provides the different filtration configurations studied during the pilot tests.

Table 1: Configurations of filter media studied

Column n°	Filter media	Particle size range (mm)	Height (m)	Bulk density (kg/m^3)	Porosity (%)
C1	**Filtralite® Mono-Multi**	Pure HC 0.8-1.6 Pure NC 1.5-2.5	0.7 0.5	850 500	55 60
C2	**Filtralite®**	Pure NC 0.8-1.6	1.2	530	61
C3	**Sand**	0.6-1	1.2	1,450	43
C4	**Sand**	0.8-1.2	1.2	1,550	43
C5	**Sand + Anthracite**	sand 0.6-1 anthracite 1.5-2.5	0.8 0.6	1,450 730	43 48

Pilot tests - operating conditions and data monitoring. Four test configurations were implemented involving 2 qualities of raw water (Seine water previously settled and coagulated raw water) and 2 filtration rates (8 m/h and 15 m/h). Each test was conducted 3 times to check the repeatability of the results obtained.

The end of filtration cycle was defined either by a turbidity breakthrough (> 0.5 NTU) or when an excessive pressure drop was exceeded (> 200 mbar). Filter media backwash was carried out following the instructions given in the Filtralite® media data sheets and following SUEZ recommended practices for conventional media.

In addition to the on-line monitoring (turbidity of raw water and filtered water, head loss), analyses were carried daily for raw water and at the outlet of each column (turbidity, color, bacteriological counts, metal residual).
For each configuration tested (2 water qualities and 2 filtration rates), the following performance indicators were calculated as follows: filtration cycle in m^3 (volume of filtered water during a filtration cycle), filtered water turbidity in NTU (average online turbidity obtained during a filtration cycle), Unit Filter Run Volume or UFRV in m^3/m^2 (volume of filtered water during a filtration cycle per filtration area), ripening period after backwash in minutes (time required to achieve a turbidity <0.5 NTU after backwash).

Results and discussions

Quality of raw water tested. The on-line monitoring on the raw water indicated that the average turbidity of the raw water is 7.6 NTU with variations between 5 and 20 NTU, while the average turbidity of the settled water is 1.5 NTU with variations between 0.5 and 5 NTU. Additional analyses indicated very low concentration for both iron (< 0.05 mg/L) and natural organic matter (UV absorbance @254 nm for raw water and settled water respectively of 2.6 m^{-1} and 0.6 m^{-1}.

Filtered water quality. Both conventional filters and alternative filters with Filtralite® demonstrated very good performances in removing particulates: the turbidity was maintained at 0.2 ± 0.1 NTU, for an inlet turbidity ranging from 0.5 to 20 NTU. The lowest residual turbidities are obtained with Filtralite® media as shown in figure 4. The values obtained comply with both the French regulations and the SUEZ internal objectives (filtered water turbidity <0.5 NTU 100% of the time and <0.2 NTU 95% of the time).

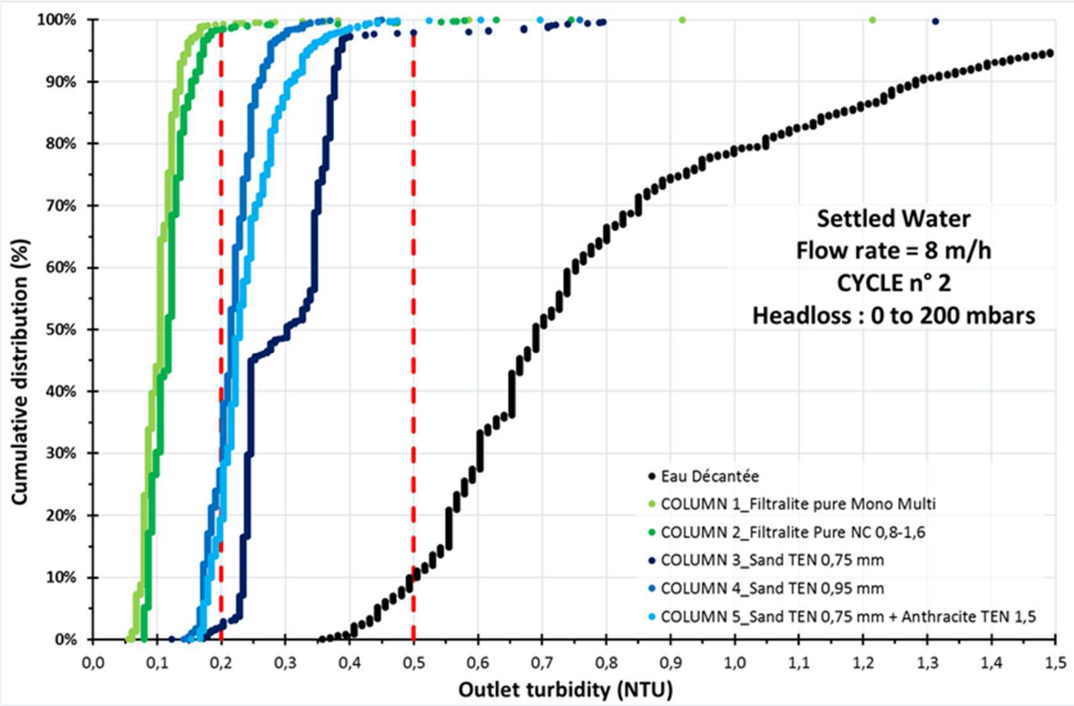

Figure 4: example of results obtained for turbidity of filtered water

The increase of flow rate to 15 m/h had little impact on the performance of the different filtration media in terms of filtered water quality; the turbidities measured were almost equivalent regardless the configuration tested.

Whatever the configuration is, there is also a good retention of iron flocs with dissolved iron values lower than 0.02 mg/L on filtered water. Regarding the microbiological parameters, a reduction of 1 log of germs was measured between the inlet and the outlet whatever the filter media was.

Length of filtration cycles. The study of the filter productivity (UFRV) indicated a better efficiency of Filtralite® media, especially the Mono-Multi. The Mono-Multi configuration resulted in a water production 1.5 times higher than the conventional dual media (sand/anthracite), and 2 times higher than the conventional media mostly used on sites (sand 0.8-1.2 mm).

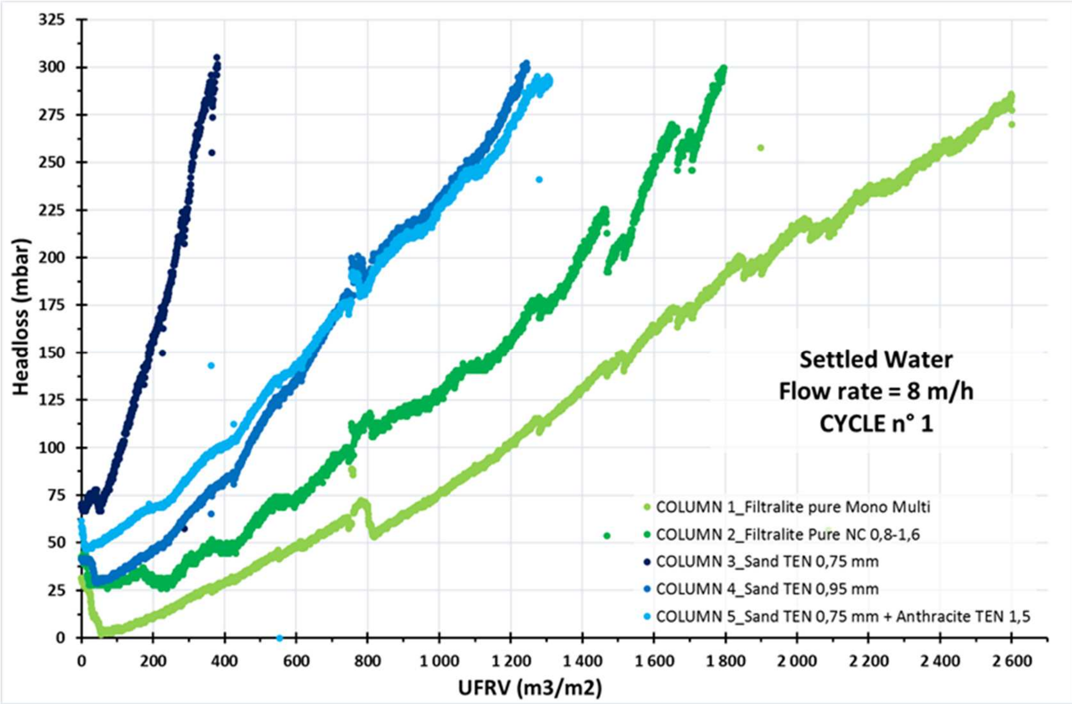

Figure 5: example of results obtained for the on-line monitoring of headloss

The inlet water quality had a significant impact on water production, with a factor on UFRV ranging from 1 to 10. However, whatever the raw water quality was, Filtralite® media always performed better in terms of UFRV compared to sand and sand-anthracite solutions.

The flow rate did not affect the performance of the filtration media (UFRV and residual turbidity) for the water qualities studied. With a flow rate of 8 and 15 m/h, the UFRV was quite similar for the filtration of settled water. However, the UFRV was higher at 8 m/h than at 15 m/h with direct coagulation of Seine River. Some differences could be attributed to the suspended solids load varying between tests, and to the use of the filter over its height (surface clogging and / or depth filtration). It is also interesting to mention that UFRV values obtained at pilot scale on settled water are close to those obtained at industrial scale on the Croissy recharge plant with same filtration media.

The performances obtained on Filtralite® media confirm the conclusions of previous studies [SALTNES, 2002; ALBUQUERQUE, 2008; MITROULI et al., 2009] indicating both a significant increase in the duration of filtration cycles and the production of a stable filtered water quality.

Ripening period. After running a backwash, the ripening period was between 3 and 5 minutes whatever the configuration tested. The turbidities measured just after the filters restart are higher when the filters are fed with coagulated raw water.

Summary of results. The main UFRV results obtained for both coagulated Seine water and settled water are illustrated in figures 6 and 7 respectively. The turbidity value given in grey for each media tested is the average value obtained during all the combined filtration cycles.

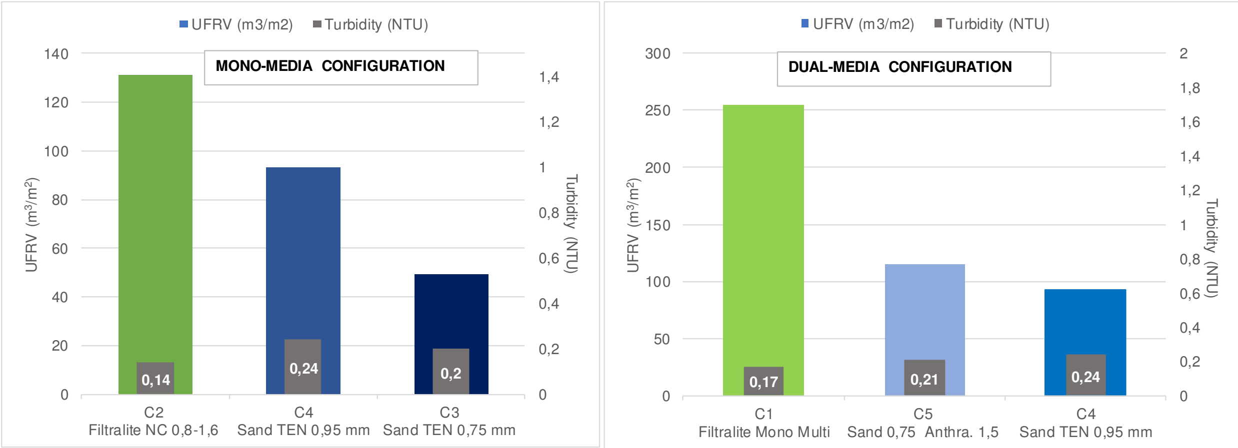

Figure 6: Synthesis of the results obtained (previously coagulated Seine water- 8 m/h)

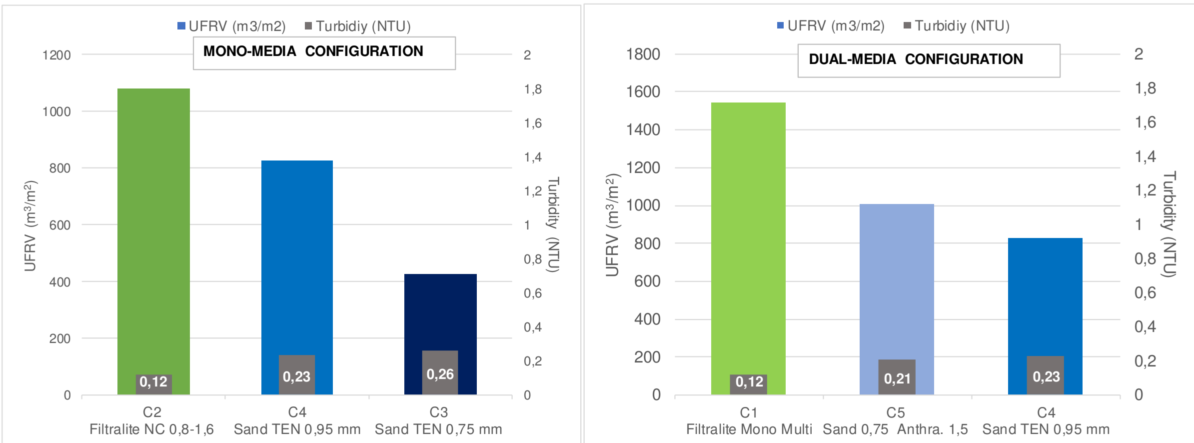

Figure 7: Synthesis of the results obtained (settled water - 8 m/h)

Conclusions and perspectives

The qualification tests conducted at the CIRSEE on Filtralite® media in comparison with conventional media led to the following outcomes:

- The filtered water quality is very satisfactory regardless of the filter media studied: the turbidity is maintained at 0.2 ± 0.1 NTU, for a raw water turbidity between 5 and 20 NTU. The lowest residual turbidities are obtained with Filtralite® media.
- Increasing the filtration rate does not affect the performance of the different filter media tested, whether in terms of filtered water quality or UFRV.
- Among all the media tested, the combination of Filtralite® Pure NC 1.5-2.5 mm and Filtralite® Pure HC 0.8-1.6 mm ("Filtralite "mono-multi") provided the best performance, both in terms of filtered water quality and UFRV. The reduction of backwash frequency with this configuration may have a significant impact on operating costs reduction (lower air and water consumption for filter backwash, lower water losses).
- Filtralite mono-multi is clearly more efficient than conventional media (increase of UFRV by a factor of 1.5 to 2). Its use offers more flexibility, allowing to accept a degradation of water quality at filter inlet and a higher filtration rate.

Filtralite® can be recommended for new Drinking Water Treatment Plants allowing a footprint reduction estimated up to 50%. Filtralite® may also be recommended for existing installations where the water production capacity must be increased with existing filtration infrastructures while reducing energy costs. With a lower density than other conventional media, Filtralite® allows to maintain existing treatment and pumping facilities.

There are also interesting perspectives of applying these media as pre-treatment of membrane installations (desalination plants or low pressure reverse osmosis / nanofiltration plants treating soft waters) to improve the quality of the water entering the membranes and reduce its fouling propensity.

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Annex 1: main results of pilot tests

Table A: Main results: Settled Water & flow rate 8 m/h

Production Time (hour)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	243	180	34	105	108
Cycle n°2	189	106	76	128	154
Cycle n°3	155	127	52	82	121

Online Residual Turbidity (NTU)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	0,15	0,16	0,36	0,31	0,25
Cycle n°2	0,11	0,12	0,33	0,22	0,24
Cycle n°3	0,09	0,09	0,11	0,16	0,15

KPIs	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Production Time Average (hour)	196	137	54	105	128
Filtration Cycle (m^3)	44,7	31,2	12,3	23,9	29,2
UFRV (m^3/m^2)	**1 543**	**1 079**	**425**	**827**	**1 008**
Water for BW (liters)	151	151	93	93	131
Water Losses (%)	0,34%	0,48%	0,75 %	0,39%	0,45%
Online measurement Average (NTU)	**0,12**	**0,12**	**0,26**	**0,23**	**0,21**
Laboratory measurement Average (NTU)	0,32	0,35	0,33	0,31	0,30

Table B: Main results_Settled Water & flow rate 15 m/h

Production Time (hour)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	123	105	54	88	124
Cycle n°2	84	61	39	53	67
Cycle n°3	95	71	39	63	90

Online Residual Turbidity (NTU)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	0,33	0,26	0,21	0,29	0,22
Cycle n°2	0,22	0,18	0,20	0,23	0,20
Cycle n°3	0,27	0,16	0,18	0,28	0,24

KPIs	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Production Time Average (hour)	100	79	44	68	94
Filtration Cycle (m^3)	43,4	34,1	18,9	29,2	40,4
UFRV (m^3/m^2)	**1 499**	**1 178**	**652**	**1 009**	**1 395**
Water for BW (liters)	151	151	93	93	131
Water Losses (%)	0,35%	0,44%	0,49 %	0,31%	0,32%
Online measurement Average (NTU)	**0,27**	**0,20**	**0,20**	**0,27**	**0,22**
Laboratory measurement Average (NTU)	0,33	0,33	0,34	0,32	0,30

Table C: Main results_Seine River Water & flow rate 8 m/h

Production Time (hour)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	23	17	2	6	11
Cycle n°2	38	15	10	16	18
Cycle n°3	36	18	7	14	15

Online Residual Turbidity (NTU)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	0,26	0,15	0,37	0,29	0,25
Cycle n°2	0,13	0,14	0,12	0,23	0,20
Cycle n°3	0,12	0,12	0,12	0,22	0,19

KPIs	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Production Time Average (hour)	32	17	6	12	15
Filtration Cycle (m^3)	7,4	3,8	1,4	2,7	3,3
UFRV (m^3/m^2)	**255**	**131**	**49**	**93**	**115**
Water for BW (liters)	151	151	93	93	131
Water Losses (%)	2,04%	3,97%	6,50%	3,45%	3,94%
Online measurement Average (NTU)	**0,17**	**0,14**	**0,20**	**0,24**	**0,21**
Laboratory measurement Average (NTU)	0,39	0,40	0,41	0,41	0,39

Table D: Main results: Seine River Water & flow rate 15 m/h

Production Time (hour)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	13	7	3	5	7
Cycle n°2	1	8	4	6	7
Cycle n°3	14	8	4	5	10

Online Residual Turbidity (NTU)	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Cycle n°1	0,16	0,14	0,12	0,22	0,20
Cycle n°2	0,16	0,14	0,12	0,21	0,20
Cycle n°3	0,14	0,13	0,12	0,21	0,21

KPIs	C1 Filtralite® Mono Multi	C2 Filtralite® NC 0,8-1,6	C3 Sand TEN 0,75 mm	C4 Sand TEN 0,95 mm	C5 Sand 0,75 Anthra, 1,5
Production Time Average (hour)	13	8	4	5	8
Filtration Cycle (m^3)	5,5	3,3	1,7	2,3	3,4
UFRV (m^3/m^2)	**189**	**114**	**59**	**79**	**116**
Water for BW (liters)	151	151	93	93	131
Water Losses (%)	2,77%	4,58%	5,42%	4,06%	3,90%
Online measurement Average (NTU)	**0,15**	**0,13**	**0,12**	**0,21**	**0,20**
Laboratory measurement Average (NTU)	0,39	0,41	0,42	0,39	0,37