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Characterization of filter materials in multimedia filtration for reverse osmosis desalination at the sorfert complex

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Abstract. The growing demand for high-quality freshwater makes seawater desalination essential. However, effective pretreatment is crucial to protect reverse osmosis membranes and ensure long-term efficiency. This study, conducted at the SORFERT complex, evaluates the performance of multimedia filtration by characterizing sand and Filtralite® Pure using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and UV spectroscopy. Results show that sand filtration led to increased turbidity (+3.1 NTU), suspended solids (+19 mg/L), and chemical oxygen demand (+12.28 mg/L). XRD analysis suggests structural modifications in the sand after filtration, while FTIR confirms Filtralite® Pure's superior adsorption capacity. The particle size distribution analysis reveals a shift in dominant particle sizes, highlighting the limitations of sand filtration. These findings demonstrate the importance of selecting optimal filter media to enhance seawater pretreatment for desalination.

Keywords: desalination; filtralite®; FTIR; multimedia filtration; pretreatment; pure; reverse osmosis; sand; seawater quality; XRD

1. Introduction

Water scarcity is a significant global problem that has been gaining attention for several decades (Abushawish *et al*. 2019). Factors such as population growth, changes in consumption patterns, climate change, uneven distribution of water resources and increasing individual water demands contribute to this problem (Kummu *et al*. 2016, Schewe *et al*. 2014, Almanassra *et al*. 2022, Aboelnga *et al*. 2020, Rana and Guleria 2018, Brown *et al*. 2019). The World Health Organization (WHO) predicts that half of the world's population will suffer from water scarcity by 2025 (WHO. 2021). Desalination of seawater and brackish water is considered a highly viable solution to meet global water needs, with seawater desalination being the dominant method accounting for approximately 60% of water desalination worldwide, followed by brackish water with approximately 20% Ziolkowska (2014). As the main approach is seawater desalination, feedwater pretreatment plays a vital role in increasing the efficiency and performance of reverse osmosis (RO) membranes (Abushaban *et al*. 2020). Proper pre-treatment ensures high-quality feed water with lower total dissolved solids (TDS) and organic and inorganic content, thereby extending membrane life (Hashlamon *et al*. 2015, Bick *et al*. 2011, Wang *et al*. 2021).

Traditional RO pretreatment technologies such as coagulation and granular media filtration are widely used in desalination processes. The key advantage of these conventional technologies is their long-term application, which has proven its effectiveness and established itself as a well-known option in the field (Lee *et al*. 2009). However, these processes have some limitations, including increased sensitivity to fluctuations in source water properties, which requires adjustments in chemical doses (Kavitha *et al*.2019). In recent years, advanced low-pressure membrane technologies such as microfiltration (MF) (Yu *et al*. 2021), ultrafiltration (UF) (Lu *et al*. 2021), nanofiltration (NF) (Baig *et al*. 2021) have been developed.

Microfiltration (MF) and ultrafiltration (UF) processes have recently been used as alternatives to conventional pretreatment, providing constant and high-quality feed for the sulfate removal process. Membrane filtration has already replaced conventional cartridge filters in some units, and its performance has been reported to improve significantly (Jezowska *et al*. 2009). However, MF and UF processes are generally insufficient for removing natural organic matter (NOM), because of the NOM molecule size (Monnot *et al*. 2016, Winter *et al*. 2016).

These technologies have also found applications in the chemical industry, food biochemistry, water treatment and other fields due to their high rejection rate, environmental benefit and ease of control (Jung *et al*. 2019, Abdel-Fatah *et al*. 2020, He *et al*. 2019, Moradi *et al*. 2018, Saleh *et al*. 2020). These studies highlight the importance of optimizing pre-treatment in reverse osmosis systems to ensure efficient and sustainable operation. As part of this study, the new reverse osmosis desalination unit at the SORFERT complex encountered problems with rapid fouling of the micro-filtration membranes located behind the multimedia sand filters. Analysis of particles in the water at the inlet and

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outlet of the multimedia filters revealed an anomaly in the pre-treatment phase, especially within the multimedia filters themselves. The primary objective of our work is to optimize the pretreatment in the SORFERT desalination plant by characterizing the filter materials used in multimedia filters, especially sand filters, using techniques such as X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and sieve granulometry. Furthermore, we will analyze the physico-chemical parameters of seawater before and after filtration through multimedia filters, including chemical oxygen demand (COD), suspended solids (SS) and turbidity. Our findings highlight the ineffectiveness of sand in retaining the unwanted materials responsible for clogging. However, we have found that by replacing the sand with alternative filter materials, such as pure Filtralite, it is possible to significantly improve the filtration process and remove the impurities responsible for clogging. This optimization of the pre-treatment process will preserve the integrity and lifetime of the microfiltration membranes while ensuring more efficient filtration and improved water quality.

Fig. 1 Geographical Situation of the SORFERT Complex

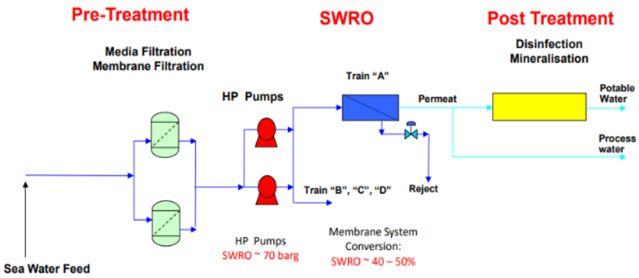


Fig. 2 Reverse osmosis desalination process

2. Materials and methods

2.1 Materials

2.1.1 Description of the study area

The SORFERT industrial ammonia complex is one of the most important industrial achievements in the hydrocarbon processing chain. The plant is part of a partnership between the Algerian company Sonatrach and the Egyptian company Orascom. It is designed to transport liquid ammonia and urea fertilizers.

The Sorfert complex is located in the Arzew industrial zone to the west of Béthioua, 6 km from the town of Arzew and 40 km east of Oran. It covers an area of 37 hectares and comprises several zones

2.1.2 Water treatment process at the Sorfert plant

The SORFERT complex is made up of three zones: Zone 1 (ammonia unit); Zone 2 (urea unit); Zone 3 (utilities zone), which represents the heart of the plant and includes several units:

- A seawater pump

A seawater intake located 550 m from the shore, with two filters and four 2700 m^3/h pumps.

- Desalinated water production section

Desalinated water is produced using ejector-compressor desalination processes. This Air plant comprises three parallel desalination units U510/U520/ U530 and a reverse osmosis membrane process U600, comprising three identical trains.

- A treated water production section

Treated water production (demineralized water, polished water) has a capacity of 1,200 m^3/h.

The demineralized water unit has to treat process condensate containing ammonia and desalinated water containing mainly sodium chloride, which have passed through the membranes of the reverse osmosis unit. The demineralized water is stored in demineralized water tank 090T001. Treatment by the mixed-bed filter of unit 090 U200 provides fully demineralized water, known as polished water, used for HP steam generation in stand-alone boilers 083 U100/ U200/ U300, the polished water is collected in polished water tank 090T002.

- Two seawater cooling towers

The seawater cooling towers are semi-open towers with a total capacity of 53,000 m^3 / h.

- Two closed polished-water cooling loops

The closed cooling loops are designed as plate heat exchangers cooled by seawater, with polished water filling the two closed circuits, which have an overall capacity of 45,000 m^3/h.

2.1.3 Physico-chemical characteristics of the raw seawater from the desalination plant of SORFERT

Table 1 shows the physico-chemical characteristics of the seawater to be treated. This water is characterised by high hardness and conductivity, high sulphate and bicarbonate contents and is very rich in chloride and sodium ions.

2.1.4 The physicochemical properties of membrane

Typical features:

Model: FLT HF 405, HF CART, PP, 40", 5

Table 1 The specific growth rate and maximum growth rate of *Anabaena* cultured at four different nitrate N concentrations (N1~N4)

Parameters	Value	Chemical parameters	Value
pH at 18.8 °C	8.10	Calcium (Ca^{2+}) (mg/L)	449
Conductivity at 18.8°C(mS/cm)	60.764	Magnesium (Mg^{2+}) (mg/L)	1387
TDS (mg/L)	39385	Bicarbonate (HCO_3^-) (mg/L)	158
Total hardness (TH) (°f)	200	Chloride (Cl^-) (mg/L)	2155 5
Calcium hardness (°f)	112.25	Barium (Ba) (mg/L)	1.1
Magnesium hardness (°f)	577.92	(SiO_2) (mg/L)	8
Taste and flvour	Bland	Sulphates (SO_4^{2-}) (mg/L)	3200
Odour	Odourless	Sodium (Na^+) (mg/L)	12182
Appearance	Murky	Potassium(K^+) (mg/L)	418
	-	Strontium (Sr) (mg/L)	13
	-	Fluorine (F) (mg/L)	2

Table 2 Characteristics of the membrane used (data from Nitto hydranautics)

Membrane	Maximum temperature	Maximum pressure (MPa)	Matériau
FLT HF 405 (MF)	60-80°C	2-5bar	Polypropylène (PP)

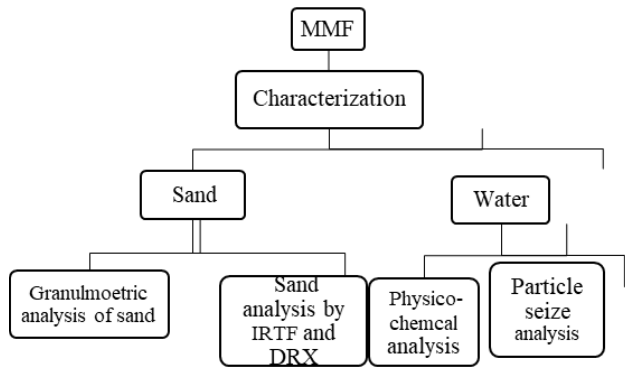


Fig. 3 MMF MultiMedia filter characterization flow chart for SORFERT's new desalination plant

Membrane type: Microfiltration (MF)
Material: Polypropylene (PP)
Length: 40 inches (1016 mm)
Diameter: 5 inches (127 mm)
Configuration: Cartridge (HF CART)

Flow rate: Depends on manufacturer, but generally, microfiltration membranes have high flow rates due to their large pores (0.1 to 10 micrometers,).

Pore size: The pore size of the microfiltration membrane used in this study is 5 micrometers..

Maximum operating temperature : Varies according to manufacturer, but generally around 60-80°C for PP membranes.

Maximum operating pressure: Approximately 2 to 5 bar, depending on manufacturer's specifications.

Table 3 Dual-layer multimedia filter configuration

	Gravel	Sand	Anthracite
Particle size of the Multimedia Filter of the new RO unit [mm]	[3-5 mm]	[0.4-0.8 mm]	[0.6-0.8 mm]
Particle size of Multimedia Filter from old RO unit [mm]	[2-3mm]	[0.7-1.2mm]	[1.4-2.5 mm]

Table 4 Configuration using a new "Filtralite® pure HC

	Gravel	Filtralite
Granulometry [mm]	[3-5 mm]	[0.8-1.6mm]

Table 5 Configuration using a new "activated carbon" material

	Gravel	Activated Carbon
Granulometry [mm]	[3-5 mm]	[1-1.5mm]

Chemical compatibility: Good resistance to acids, alkalis and common organic solutions.

Typical applications: Pre-treatment for reverse osmosis, particle filtration, liquid clarification, wastewater treatment. (Acme Filtration Technologies. (2024)).

Fig. 3 below shows the characterization flow chart for the multimedia filter (MMF) of the new reverse osmosis desalination unit, commissioned in January 2022 to meet the desalinated water needs of the SORFERT complex, following the shutdown of the first unit. However, during the start-up period of this new unit, rapid clogging of the 5 µm micro-filters (placed downstream of the multimedia filters (MMF)) was observed.

In order to identify the factors responsible for the rapid clogging of 5 µm micro-filter membranes, as well as to test the reliability of the sand filter bed for seawater pre-treatment, we analyzed the quality of the filter material used (sand) using techniques such as FTIR (Fourier Transform Infrared Spectroscopy) and XRD (X-ray Diffraction) analysis before and after filtration. We then configured other filtration systems using different filter materials, while maintaining the same filtration principle. The aim was to compare the performance of different filter materials in the laboratory to determine the best material for filtering seawater in the filter bed.

2.2 Methods

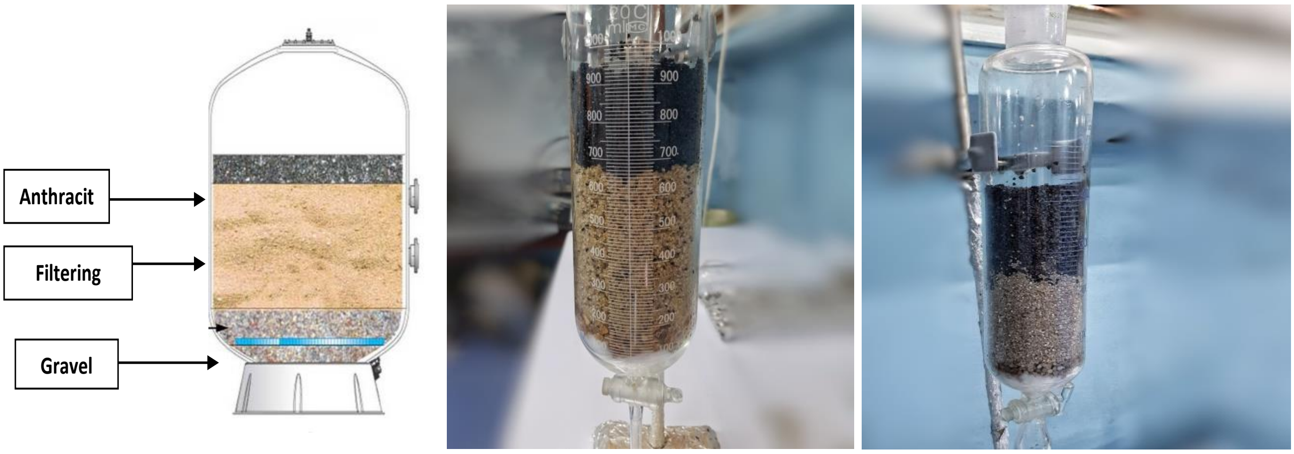
2.2.1 Configurations carried out:

- Configuration 1: Bilayer configuration (sand and anthracite);

In this configuration, we kept the same configuration of the complex, respecting the volumes of the filter bed and the thickness of each material, but on a laboratory scale. We used a graduated ampoule to reproduce filtration conditions. This approach enabled us to test and evaluate the efficiency of the filtering materials under controlled conditions and on a small scale.

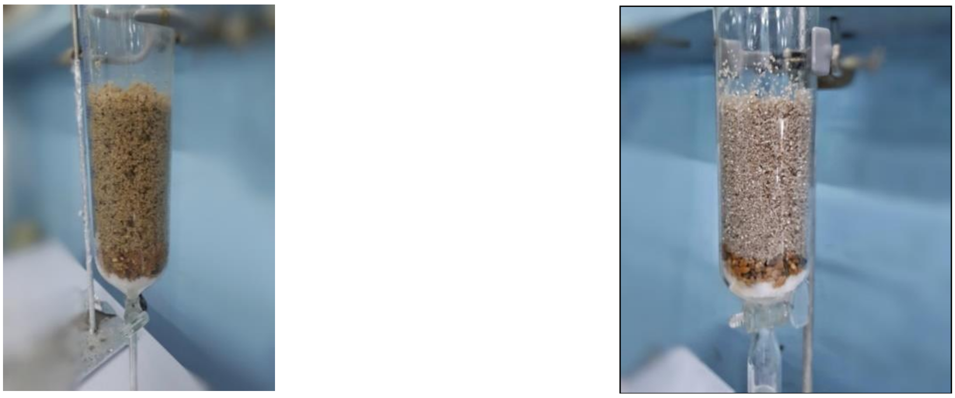
- Configuration 2: Single-layer configuration

In this configuration, we retained the same filter layer



(a) SORFERT sand filter configuration (b) Configuration of new RO unit (c) Configuration of old RO unit

Fig. 4 Two-layer configuration of SORFERT RO multimedia filter



(a) Sand 1 (b) Sand 2

Fig. 5 Monolayer configuration

Fig. 6 Filtralite® pure HC single-layer configuration

thickness but changed the filter material. The materials used are as follows:

- Sand 1: sand used in the multimedia filter of the new reverse osmosis desalination unit.
- Sand 2: sand used in the multimedia filter of the old reverse osmosis desalination unit.
- Filtralite® HC pure: [0.8-1.6mm]; is an innovative filter media made from natural materials such as diatomaceous earth and silica. It is designed for use in filtration systems for drinking water purification and turbidity reduction.
- Activated carbon: is a porous material obtained from carbonaceous materials such as wood, coconut or charcoal. It is treated with oxidizing agents to create a porous surface that absorbs impurities and contaminants from water or air. We used activated carbon from the Beni Saf Water Campany plant.

These materials were selected on the basis of their specific filtration properties to meet the quality requirements of the treated water.

1. Dual-layer multimedia filter configuration

2. Single-layer configuration:

Table 6 Comparison of analytical results for water control parameters between two configurations: site and laboratory

Configuration's Parameters	Conductivity (mS/cm)	Turbidity (NTU)	TDS (mg/L)	T (°C)	pH	TSS (mg/L)	DCO (mg/L)
Complex Configuration							
Water before MMF	47.2	0.78	33040	25	7.8	17.7	163.3
Water after MMF	47.7	3.97	33390	25	8	19.6	175.58
Laboratory Configuration							
Configuration 1 Bilayers: Sand1+anthracite	47.6	3.87	33 320	25	7.96	18.2	174.86
Difference	0 .1	0 .1	70	0	0.04	14	0.72

Table 7 Analysis results of water control parameters for different configurations

Configuration's Parameters	Conductivity (mS/cm)	Turbidity (NTU)	TDS (mg/L)	T (°C)	pH	TSS (mg/L)	DCO (mg/L)
Configuration 2 Bilayers: Sand 2+anthracite	42.2	2.80	29540	25	8	-	-
Configuration 3 Mono layer: sand1 (new unit)	47.9	5.91	33530	25	7.97	-	-
Configuration 4 Mono layer: sand2 (old unité)	43.2	3.63	30240	25	8	-	-
Filtralite® (pure)	29.6	0.45	20720	25	7.96	14.3	152.72
Activated Carbon	39	2.41	27300	25	8	-	-

In this configuration, we tested the filtration quality of two types of sand: that used in the multimedia filter of the new reverse osmosis (RO) unit and that used in the multimedia filter of the old RO unit.

3. Configuration using a new "Filtralite® pure HC" material:

In this configuration, to evaluate the efficiency of the filter materials, we proposed replacing the sand with Filtralite pure.

4. Configuration using a new "activated carbon" material:

In this configuration, to evaluate the efficiency of filtering materials, we proposed replacing sand with activated carbon. Activated carbon is a material widely used for water filtration due to its excellent contaminant adsorption properties. This substitution was considered in order to improve filtration capacity and reduce the presence of undesirable compounds in the treated water.

2.2.2 Analysis of filtrate material

1. Particle size analysis by Mastersizer laser diffraction:

Particle size analysis was carried out in Turkey by Mastersizer 2000 laser diffraction, The analysis process with the Mastersizer begins with sample preparation. The powder or suspension sample is dispersed in a suitable dispersion medium, such as water or a transparent liquid. Once the sample has been prepared, it is introduced into the Mastersizer measuring cell.

The Mastersizer 2000 laser diffraction particle size range sets the standard for particle size measurement in liquid dispersions. It enables the volume percentage of the liquid to be expressed as a function of particle size over a particle size range from 0.1 µm to 3000 µm.

2. Particle size analysis of sand by sieving: (Analysis carried out at the ADWAN laboratory)

Equipment used and basic principle:

A sieve column consists of a series of sieves stacked one on top of the other, in ascending order of mesh size (from bottom to top).

A representative sample of the sand to be analyzed is deposited on the sieve, and all the sieves are shaken together to distribute the particles along the sieve column. This shaking is performed by an electric sieve shaker. Each sieve divides the particles applied to it into two fractions:

- Reject: corresponding to the particles retained on the sieve;
- A sieve cake: corresponding to the particles applied to the lower sieve.

After agitation, the rejects from each sieve are collected and carefully weighed.

In this work, two different sand granulometries are used.

3. X-ray diffraction (XRD):

Principle of X-ray diffraction (XRD):

X-ray diffraction analysis of sand can be used to determine the mineralogical composition of the material. In fact, X-ray diffraction is a technique that can be used to determine the crystalline structure of a material, as well as the size and shape of crystalline grains.

To carry out a diffraction analysis on a sand sample, the following is required:

- Sample preparation: the sample must be prepared as a fine, homogeneous powder to enable accurate analysis.
- Mounting the sample on a support: the sample is placed on a flat, rigid support that can be rotated around an axis.
- Sample irradiation: an X-ray beam is directed onto the

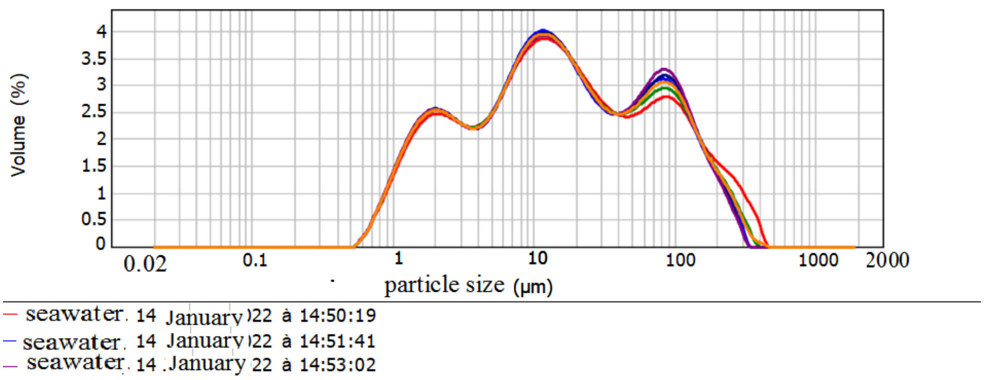


Fig. 7 Particle size distribution of seawater at the inlet of the multimedia filter

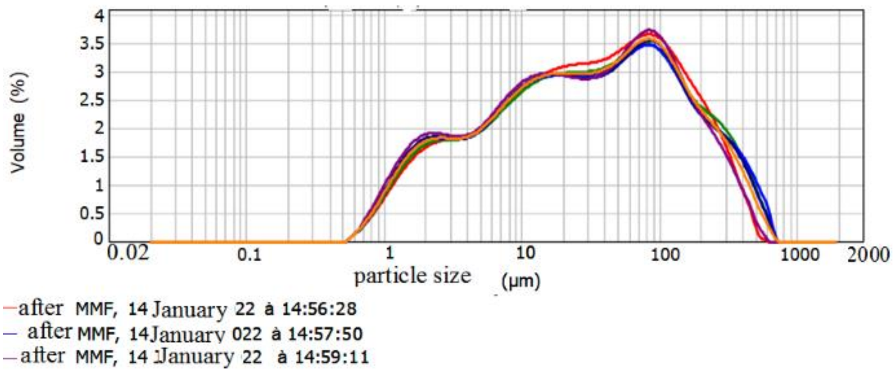


Fig. 8 Seawater particle size distribution at the multimedia filter outlet

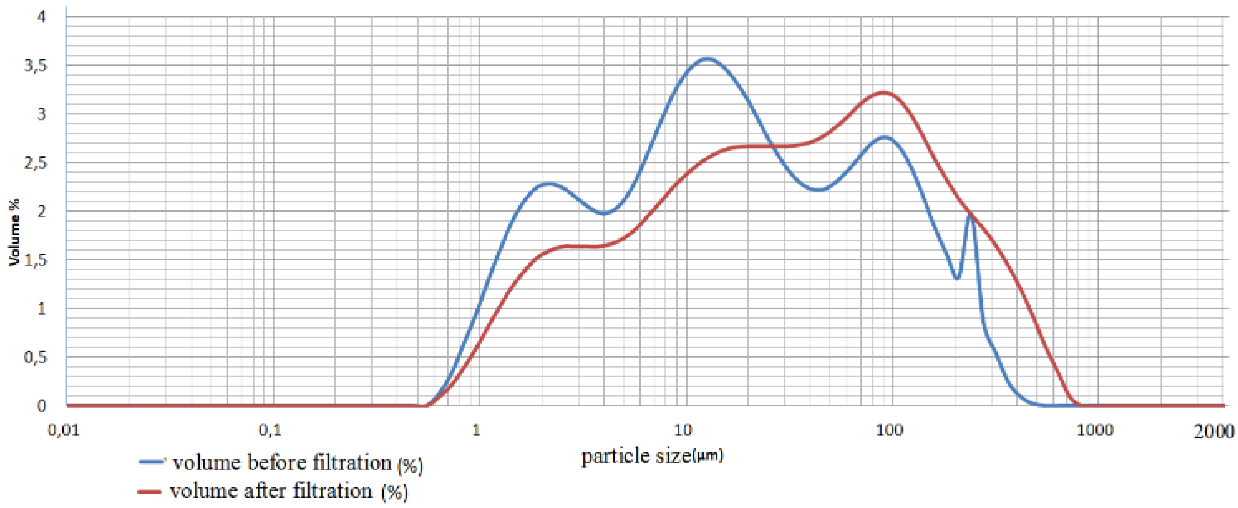


Fig. 9 Seawater particle size distribution before and after filtration by the multimedia filter

sample, and the rays are diffracted by the sample atoms.

- Data collection: the diffracted X-ray beam is detected and data are collected for each diffraction angle.

- Data processing: the data are analyzed to determine the crystal structure of the sample.

Interpretation of results: results are interpreted to identify the components present in the sand sample and their crystalline arrangement.

4. Fourier transform infrared spectroscopy (FTIR):

Fourier transform infrared spectroscopy (FTIR) is an analytical technique commonly used to characterize solid materials, including before and after seawater filtration. It provides information on the chemical bonds and functional groups present in the material.

Before seawater filtration, FTIR spectroscopy can be used to obtain the reference infrared spectrum of the solid material. This spectrum represents the material's specific molecular vibrations, such as C-H, O-H, N-H, C=O etc. bonds. It provides information on the chemical composition, structure and purity of the material.

FTIR spectroscopy complements other analysis techniques, such as the X-ray diffraction (XRD) technique mentioned

Table 8 Particle size analysis of the sand used in the MMF filters of the complex (filter layer mixed with anthracite)

Sieve Opening (mm)	Reject Mass mr (g)	Cumulated Reject Mass Mc (g)	Percentage of reject (%)
2.00	10	10	0.00
1.00	18	28	33.42
0.85	20	48	28.92
0.60	30	78	35.77
0.50	40	118	1.49
0.30	50	168	0.37
0.212	70	238	0.02
0.125	140	378	0.01
0.090	200	398	0.00
0.040	230	628	0.00

Table 9 Physical characteristics of filter beds

Effective Diameter d10 (mm)	0.55
d60 (mm)	0.60 /1
Uniformity Coefficient CU	1.09
Fineness Modulus (%)	1

Table 10 Grain size analysis of sand used in complex filters (White sand)

Sieve Opening (mm)	Reject Mass mr (g)	Cumulated Reject Mass Mc (g)	Percentage of reject (%)
2.5	8	8	0.00
2	10	18	0.00
1.4	15	33	1.65
1	18	51	29.88
0.6	30	81	64.42
0.5	35	116	3.49
0.4	40	156	0.24
0.3	45	201	0.08
0.25	60	261	0.12
0.20	70	331	0.12

above. The combined use of these techniques can provide a more complete characterization of the chemical and structural modifications undergone by the material after seawater filtration.

3. Results and discussion

Interpretation of the results presented in the table below (6) of the water analyses between the site and the laboratory configuration shows similarities, with a possible slight discrepancy. This could be due to differences in analytical methods, equipment used, environmental conditions and processing time.

The results of the water analysis above Table 6 before and after passing through the multimedia filter (MMF) indicate a significant increase in post-treatment loads. The turbidity value increased by 3.1 NTU suggesting an increase in the concentration of suspended particles in the water. In addition, the total suspended solids (TSS) concentration increased by 19 mg/L, indicating an increase in the amount of solid particles present in the water. In addition, the concentration of chemical oxygen demand (COD) increased by 12.28 mg/L, suggesting an increase in the load of organic matter present in the water. These results highlight the ineffectiveness of the multimedia filter in reducing turbidity, TSS and COD in treated water. It may be necessary to consider alternative water treatment methods to improve filtration efficiency and achieve desired water quality objectives.

In the bilayer configuration, using sand from the old unit, we observed a decrease in turbidity and TDS compared with sand from the new unit. This difference can be interpreted as an indication of the better quality of the sand from the old unit. Similarly, in the single-layer configuration, we found that the sand from the old unit was more effective than the sand used in the new configuration, as it reduced turbidity.

In the last two configurations, we replaced the sand with two other filter materials: pure filtralite and activated carbon. We found that these two materials were notably effective in reducing TSS, TDS and organic matter.

Mastersizer laser diffraction particle size analysis results at the multimedia filter inlet

The results of the particle size distribution of the seawater at the inlet to the multimedia filter Fig. 7 reveal the presence of particles dispersed over a size range from 1 µm to 700 µm. Interestingly, particles as small as 13 µm represent a maximum volume of 3.56%, exceeding the pore size of the microfiltration membrane by 5 µm. It is worth noting that the particle size detection range of the Mastersizer 2000 extends from 0.02 µm to 2000 µm, ensuring precise measurement of the distribution.

This observation explains the rapid clogging of microfiltration membranes. Indeed, 13 µm particles, being larger than the membrane pores, tend to accumulate and rapidly clog the pores, reducing the membrane's filtration efficiency.

The results of the particle size distribution of the seawater at the multimedia filter outlet Fig. 8 show a variation in the percentage of volume as a function of particle size. The maximum volume decreases from 3.56% to 3.22%. However, there is a significant increase in the presence of 91 µm particles.

This observation indicates that despite the overall decrease in particle volume, there is an increased concentration of 91 µm particles in the seawater sample after passage through the multimedia filter. It is important to analyze in detail the cause of this increase and assess whether it corresponds to the quality and efficiency objectives of the filtration system.

A comparison between Figs 7 and 8 seems to indicate that a fraction of small particles (<10 µm) was removed by the filter. This could explain the reduction in membrane fouling. However, it allows a significant volume of 91 µm particles to pass through, which could clog the pores of the microfiltration membrane.

This inefficiency can cause damage to the micro-filtration membranes that represent the next stage of treatment.

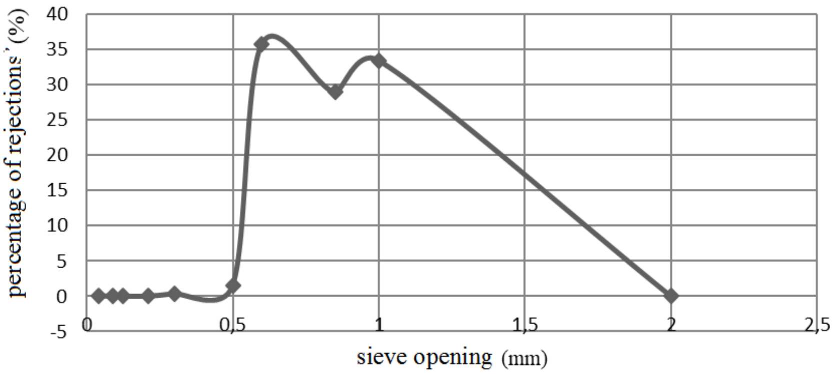


Fig. 10 Particle size analysis of the sand used in the complex's filters (filter layer of sand mixed with anthracite)

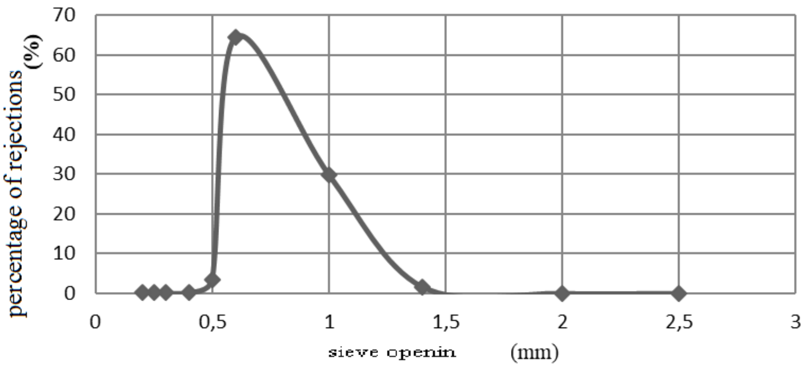


Fig. 11 Particle size analysis of sand used in complex filters (White sand)

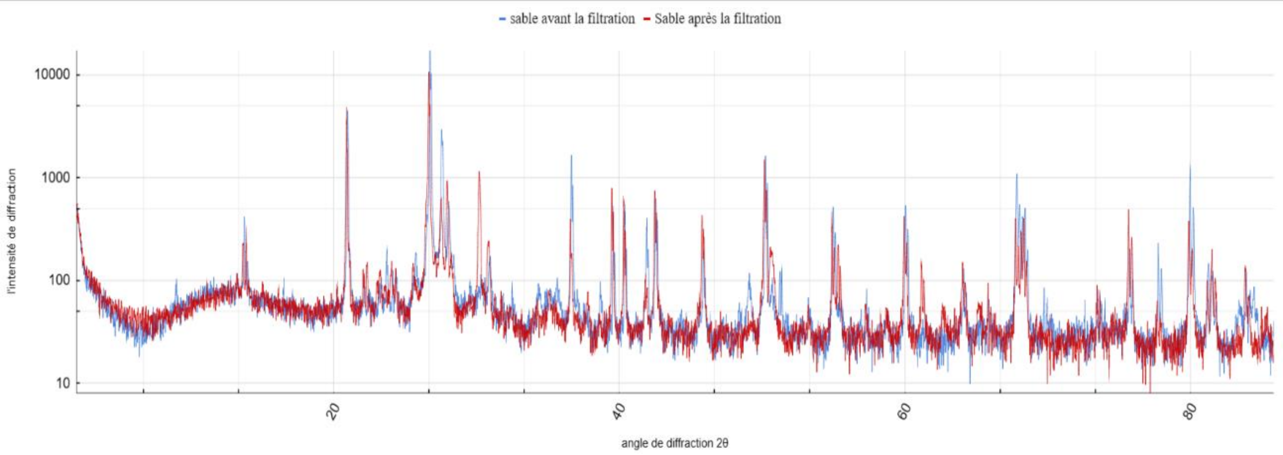


Fig. 12 X-ray diffraction analysis of sand before and after filtration

The inability of multimedia filters to retain fine particles can be due to a number of factors, such as the size of the sand grains used in the filter, excessive clogging of the filter media or incompatibility between the pore size of the microfiltration membrane and the target particles. Results of sand particle size analysis by sieving.

According to the results obtained, the effective diameter of the sand is 0.55 mm, indicating the presence of fine grains. This type of sand is generally used in water treatment plants.

Fig. 10 shows a bimodal curve with two distinct peaks, indicating the presence of two categories of grain with the highest values. This suggests a bimodal distribution, meaning that the sand is heterogeneous.

Mesh diversity, measured at 35.77% and 33.42% respectively, indicates the percentage of the analyzed sample mass that passes through 0.60 mm and 1 mm apertures. This means that there are two distinct ranges of particles in the sample, which may differ in size and shape. These differences can affect water filtration efficiency.

The calculated uniformity coefficient is 1.09, with a ratio S=1.04. This value indicates that the sand is well graded, meaning that there is a relatively uniform distribution of grain sizes in the sample.

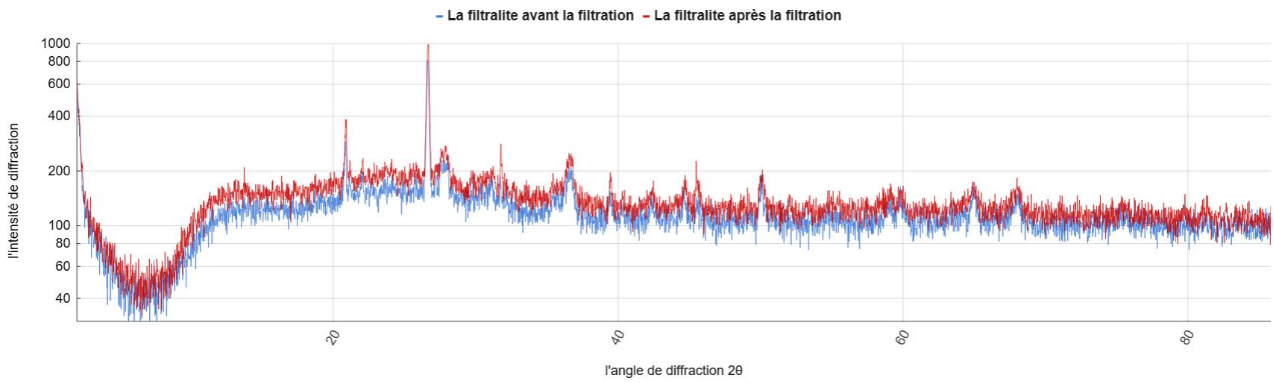


Fig. 13 X-ray diffraction analysis of pure filtralite® before and after filtration

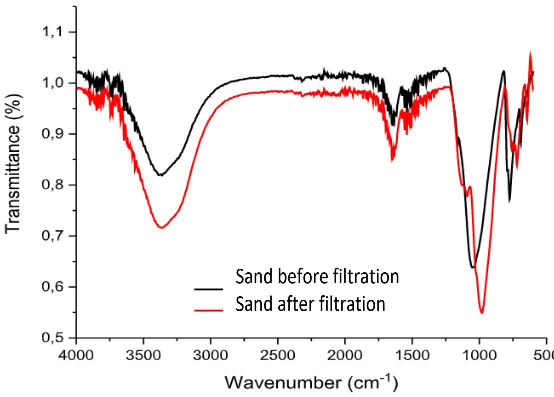


Fig. 14 MMF sand analysis (IRTF) before and after filtration

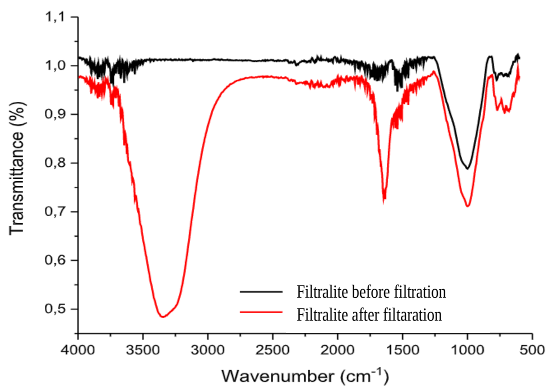


Fig. 15 Pure filtralite ®HC (IRTF) analysis before and after filtration

Fig. 11 shows a particle size analysis curve for white sand (old unit), which shows a dominance of grains with a diameter of 0.6 mm with a fraction of 64.42%, the effective diameter is 0. 5 mm, so the 60% diversity expressed in millimeters is given by the mesh opening allowing 60% by weight of the sample mass to pass through, which is 0.6 mm, these results indicate that the sand has fine grains. The uniformity coefficient calculated is 1.2 mm, which is less than 1.6 mm, indicating that the sand is well classified.

Results X-ray diffraction (XRD):

Fig. 12 shows the X-ray diffraction analysis of the sand. We observe a change in the intensity of the diffraction peaks and in their positions before and after filtration. These changes suggest that the material has undergone crystalline modifications following seawater filtration, which may be due to a chemical reaction between certain components of the water and the filter material. It is also possible that crystals of salts dissolved in seawater have grown on the surface of the material.

It is important to note the instability of the diffraction intensity in the sand sample after filtration. The diffraction intensity decreases for certain diffraction angles, ranging from 20 to 50. This decrease may indicate that some of the sand crystals have been dissolved or altered by seawater, which would explain the increase in particle size found in the water after filtration through this sand.

On the other hand, the increase in diffraction intensity at certain angles after filtration suggests that certain salts present in the seawater may react with the sand, depositing and crystallizing on the sand particles.

The X-ray diffraction analysis Fig. 13 shows a uniform increase in the intensity of the Filtralite® Pure sample after filtration. This uniform increase in intensity may indicate adsorption of contaminants.

This suggests that the filter material, in this case Filtralite® Pure, was effective in adsorbing contaminants present in the water. Adsorption is a process by which undesirable substances are captured and retained on the surface of the filter material.

Results of Fourier Transformed Infrared Spectroscopy (IRTF):

The infrared spectrum Fig. 14 represents the absorption or transmission of infrared energy by the material at different wavelengths (wave number). The x axis is generally the number of waves, expressed in cm^{-1}, and the y axis represents the percentage of transmittance, which is a measure of the amount of energy transmitted through the material.

Variations in the transmittance percentage can provide indications of the amount of energy absorbed by the material at different wavelengths. Significant variations may indicate electronic transitions, molecular interactions or other physical and chemical phenomena.

This analysis technique Commonly used to identify and characterize functional groups in organic and inorganic molecules.

Table 11 Comparison with the Work of Other Researchers

Authors	Parameters Studied
Teli *et al*. 2018	Membrane
García-Ávila *et al*. 2020	The following were evaluated: filtration velocity, initial filtration quality, filtration runs duration, filter bed expansion, duration of the washing process, washing velocity, granulometry, and mud balls
Barloková *et al*. 2024	Monitored wereas the pH, turbidity, color, alkalinity, CODMn, TOC, aluminum, number and size of particles, and hydrobiology in the samples of raw and treated

The presence of an absorption band centered at 750 cm^{-1} is noted; This band can correspond to bonding vibrations of different molecules and can therefore not be directly associated with a particular functional group.

The presence of an absorption band between 760 and 1250 cm^{-1} is noted, centered at 1000 cm^{-1} characteristic of Si-O links.

The presence of an absorption band between 1540 and 1750 cm^{-1}, centered at 1640 cm^{-1} is noted, characteristic of carbonylated bonds carbon and oxygen bound by a double bond, which can be present in functional groups such as ketones, aldehydes or carboxylic acids.

The presence of an absorption band between 3000 and 3625 cm^{-1} is noted, centered at 3375 cm^{-1} characteristic of OH bonds (hydroxyles). These OH bonds may be present in different forms of silicates (minerals containing silicon and oxygen) present in the sand; it is also important to note that the absorption band centered at 3375 cm^{-1} may also be found in the infrared spectrums of other organic compounds containing OH links, such as alcohols, carboxylic acids, phenols, etc.

The presence of this absorption band at 3375 cm^{-1}, with the presence to 1640 cm^{-1} centred carbonylated bond absorption band, can give important information on the chemical composition of the material, which can indicate to confirm the presences of organic compounds such as carboxylic acids. The emergence of new spectra, such as those observed with the Filtralite® Pure material Fig. 15, suggests that this material has the ability to adsorb specific components present in seawater. This adsorption ability enables the material to successfully eliminate undesirable contaminants, such as particles, sediments, organic matter or metal ions, which may be found in water.

The elimination of these undesirable contaminants leads to a significant improvement in the quality of treated water. This is reflected in the emergence of new spectrum characteristic of cleaner and purified water. In other words, spectral analysis of treated water reveals changes that indicate that pollutants have been successfully reduced or eliminated.

Thus, the interpretation of the appearance of these new spectra suggests that the Filtralite® Pure material is capable of adsorbing undesirable contaminants effectively.

These results demonstrate the benefits of using this material in water treatment, as it produces cleaner, purified and better quality water. The presence of an absorption band between 760 and 1250 cm^{-1} is noted, centered at 1000 cm^{-1} characteristic of Si-O links.

However, due to the presence of various mineral impurities, additional absorption bands can also be observed in the infrared spectrum of the sand.

The appearance of a new absorption band between 1540 and 1750 cm^{-1} cent to 1625 cm^{-1} is noted, characteristic of activated charcoal bonds (-COOH). The presence of this absorption band in the infrared spectrum of activated charcoal is an indicator of carboxyl groups on the surface of the material,

The appearance of a new absorption band between 3000 and 3750 cm^{-1} cent to 3400 cm^{-1} is noted characteristic of O-H bonds (hydrogen-oxygen bonds) The organic material in the sample may include humic and fulvic acids, proteins, polysaccharides and lipids, all of which contain functional O-H groups. The intensity of the absorption band at 3400 cm^{-1} is directly proportional to the amount of organic matter present in the sample, which makes it possible to estimate the total organic material content.

Based on this analysis, we find that the seawater particle size distribution at the inlet and outlet of the multimedia filter ranges from 1 µm to 700 µm. A comparison of the data reveals that a significant fraction of smaller particles (<10 µm) was effectively removed by the filter, which could explain the observed reduction in fouling on downstream membranes. However, the presence of a substantial volume of 91 µm particles after filtration highlights a key limitation of the sand-anthracite filters. Despite these particles being much larger than the 5 µm pore size of the microfiltration membranes, their passage through the filter suggests inefficiencies in retaining particles of intermediate size. This, in turn, increases the risk of clogging and operational issues in the microfiltration stage.

The physical characterization of the filter bed, composed of sand mixed with anthracite, reveals the presence of fine grains commonly used in water treatment facilities. Granulometric analysis indicates that 35.77% and 33.42% of the sample mass pass through sieves with 0.60 mm and 1 mm openings, respectively, pointing to a dual size range within the material. The calculated uniformity coefficient of 1.09 and the classification ratio of S = 1.04 confirm that the sand is well-sorted. However, this granulometric distribution appears inadequate for efficiently retaining particles smaller than 91 µm, resulting in their passage through the filter and subsequent interaction with downstream membranes.

X-ray diffraction (XRD) analysis of the sand before and after filtration reveals changes in the intensity and positions of diffraction peaks. These shifts suggest that the material undergoes crystalline modifications due to chemical interactions with seawater components. Such changes may contribute to the long-term degradation of the sand's filtration efficiency, further underscoring its limitations as a filtration medium in marine environments.

In contrast, XRD analysis of Filtralite® Pure demonstrates a uniform increase in diffraction intensity after filtration. This observation indicates effective adsorption of contaminants by the Filtralite® material, highlighting its superior performance compared to traditional sand. Filtralite® Pure also showed an improved ability to retain fine particles, as evidenced by the reduction in fouling on downstream membranes and the enhanced quality of the filtered water.

These findings emphasize the limitations of sand-anthracite filters, particularly their inability to retain particles in the intermediate size range between 5 µm and 91 µm, which are primarily responsible for microfiltration membrane clogging. On the other hand, the use of alternative filter materials such as Filtralite® Pure offers significant advantages, including better particle retention and structural stability. This study supports the integration of Filtralite® into pretreatment systems as a sustainable solution to optimize water quality, reduce operational costs, and extend the lifespan of reverse osmosis membranes.

4. Conclusions

In conclusion, this study underscores the limitations of sand-based multimedia filters in effectively retaining fine particles smaller than 5 µm, which leads to rapid fouling and increased turbidity, suspended solids, and chemical oxygen demand (COD). The particle size analysis revealed the heterogeneous nature of the sand, while X-ray diffraction indicated chemical changes in the material after filtration, highlighting the need for alternative filter materials. The use of Filtralite® Pure and activated carbon improved filtration efficiency, reducing turbidity and organic contaminants. These findings emphasize the importance of selecting appropriate filter materials, considering particle size characteristics, and optimizing filter design to enhance seawater pretreatment for desalination processes. Future research should focus on refining filtration systems and exploring advanced materials to achieve higher water quality standards.

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