Peculiar or unexpected behavior of Silt Density Index of pretreated seawater for RO desalination

Hiroshi IWAHORI, P.E.Jp

Co-Authors: Satoru ISHIHARA, Masaaki ANDO, Naoki TADA

Membrane Division
Nitto Denko Corporation

HYDRANAUTICS
A Nitto Denko Corporation
www.membranes.com

NITTO DENKO

Introduction:

No turbidity, but a high SDI-values in UF/MF membrane treated seawater:

This is an issue to be presented.
In a specific seawater condition, it is often observed to have a high SDI values unexpectedly in normal pretreatment conditions.

For example, UF/MF Pretreatment of seawater RO desalination:
We set up “Feed quality should be SDI < 4 , which is very easily achieved ”.
However, it is unexpectedly observed that UF or MF filtrate having no particulate indicates sometime SDI = 4 or more.

We set up a hypothesis that a key factor of increasing SDI-value should be micro-air bubbles in the seawater. Because, pretreatment of highly pressurizing and degassing SDI-test solution gives a lower SDI-value than non-treatment.

We surveyed SDI-value increasing factors by using various types of MF with the same 0.45μm pore size. Further investigation indicated the unexpected phenomena is caused by adsorption of dissolved organic compounds and other substance inside SDI-filter-pore structure due to hydrophobic nature of the membrane material.

SDI measurements ASTM: D4189-95

Seawater sample is passed through a 0.45micrometer membrane filter at a constant applied gage pressure of 207kPa(30psi), and the rate of plugging of the filter is measured.

The SDI is calculated from the rate of plugging;

$$SDI_T = \%P_{30} / T = [1 - t_i / t_f] \times 100 / T$$

where: $\%P_{30}$ = plugging rate percent at 207kPa feed pressure

T = total elapsed flow time, min(usually 15 min)

t_i = initial time required to collect 500ml of sample, second

t_f = time required to collect 500ml of sample after test time T (usually 15 min), second.

Therefore, normally the following **SDI_{15}** is used for RO feedwater evaluation.

$$\mathbf{SDI_{15}} = \%P_{30} / 15 = [1 - t_i / t_f] \times 100 / 15$$

SDI(5minutes) measurements

In case of raw seawater or $\%P30$ (plugging rate percent) exceeding 75%, 5-min measurement is applied. The smaller volume of sample size, 100ml is used.

$$SDI_5 = \%P_{30} / 5 = [1 - t_i / t_f] \times 100 / 5$$

Why not Measurement of Turbidity:

Drawback: SS analysis with optical-method used to be Poor Reliability in low concentration range in past days. Therefore, direct measurement of suspended matter by MF filtration was utilized.

First application: Quality control for Electronic Grade Water in 1969
Monitoring feed water QC for seawater RO in 1979
from DuPont technical operating manual.

The SDI measurement has become **a de facto standard** for RO feed water QC.

Have you had experienced of Peculiar phenomena with SDI ?

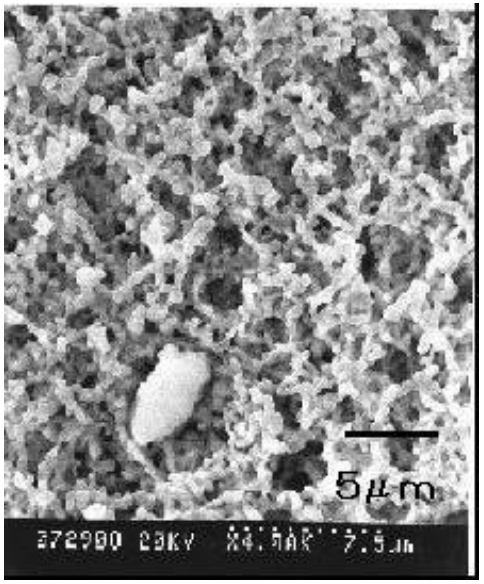
Unexpected high values of SDI:

In some SDI measurements with eutrophic seawater or sewerage water, even if UF or MF membrane pretreated it and no turbid matter existed, high levels of SDI-values which are not relating with particles in feed waters have been observed.

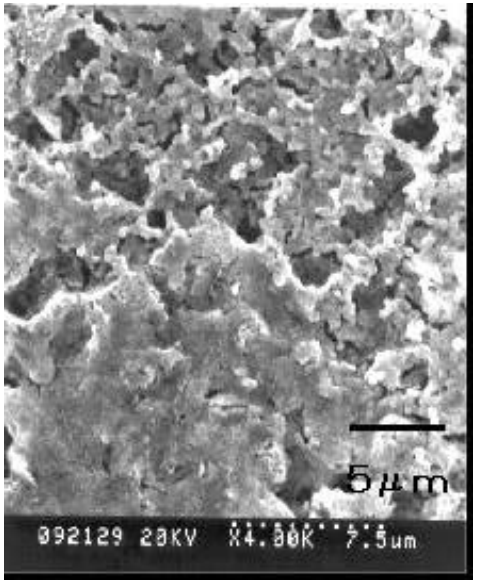
We found that pre-treatment of SDI test solution with high-pressurization at 6MPa decreased SDI-values and air bubbling increased SDI-values. Since degasification with membrane degasser results in reducing subsequent SDI values, we paid attention to micro-air-bubble.

In Actual Seawater RO pretreatment, comparison of turbidity levels between UF filtrate and DMF

SEM photo image of filter surface with tested SDI filter (0.45μm)



(a) **UF filtrate**
(0.001NTU)
SDI_{15} = 4.0

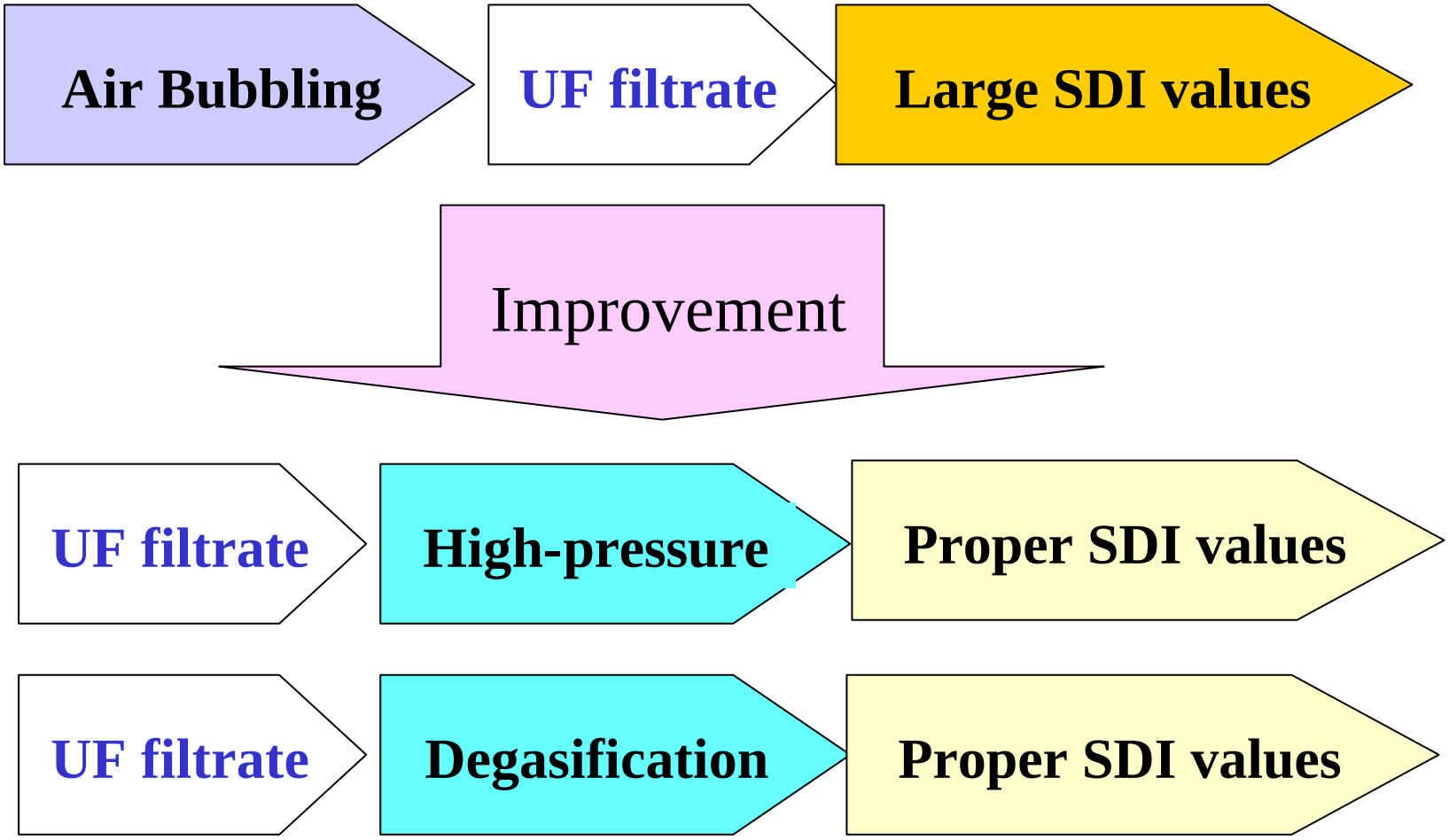


(b) DMF with coagulant
(0.01NTU)
SDI_{15}= 2.7

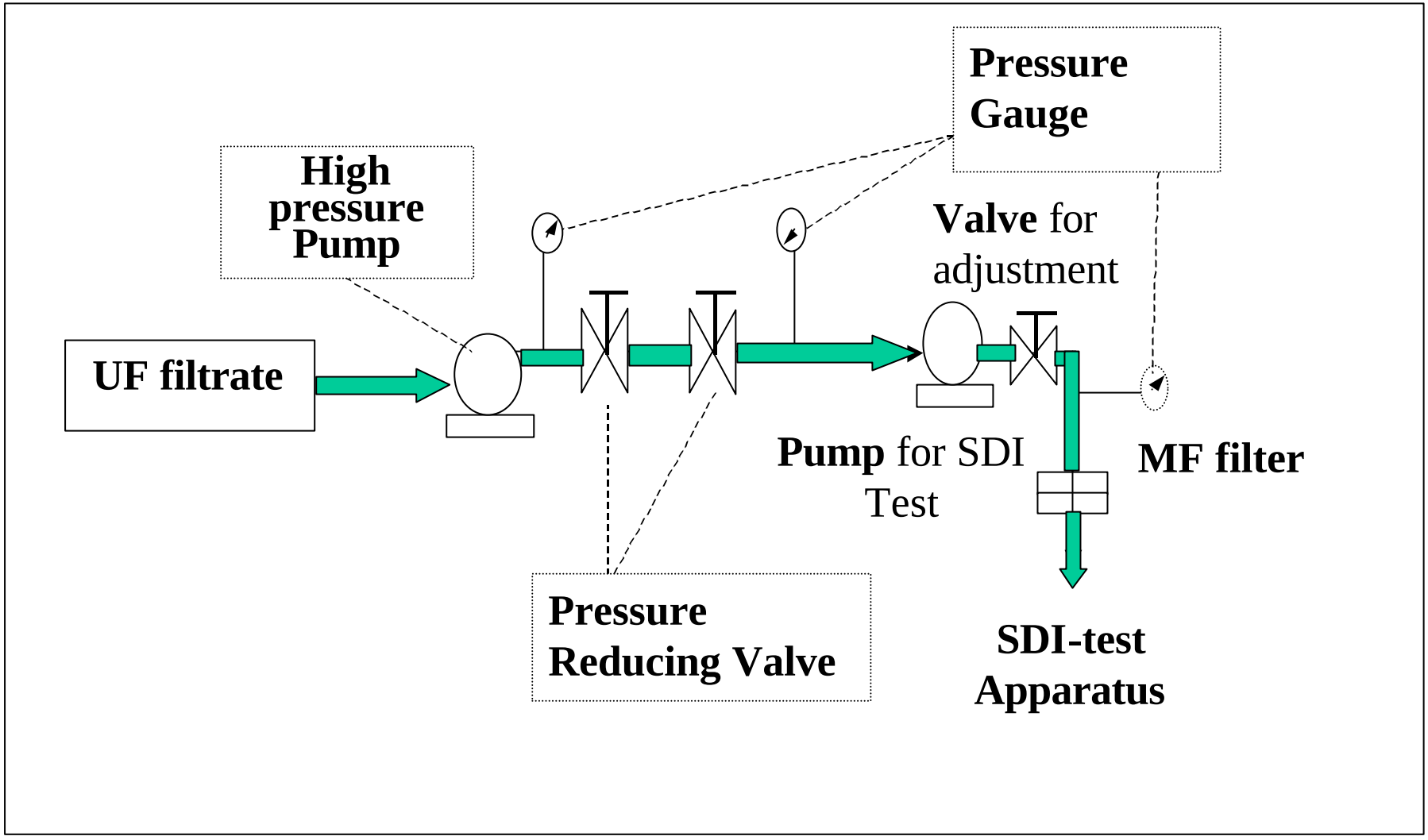
Unexpected behavior of SDI with pretreated seawater for RO desalination SDI tested filters is a high SDI-value without turbid substances in UF filtrate. However DMF filtrate with particulate substance has a good SDI-value.

SDI-filter Membrane Fouling as to physical phenomenon

Category	Substance	Fouling Mode	Permeability for SDI filter
Particle	Colloids	Plugging pore	Blocking occurs at surface or inside pore, largely
	Bacteria	Plugging pore	
Solute	Organics, Protein,	Humic acids adhesion inside pore	Maintaining permeability, but slightly declining
Gas	Micro-air bubbles	Micro-air bubbles adhere inside pore	Maintaining permeability with a very slight decline



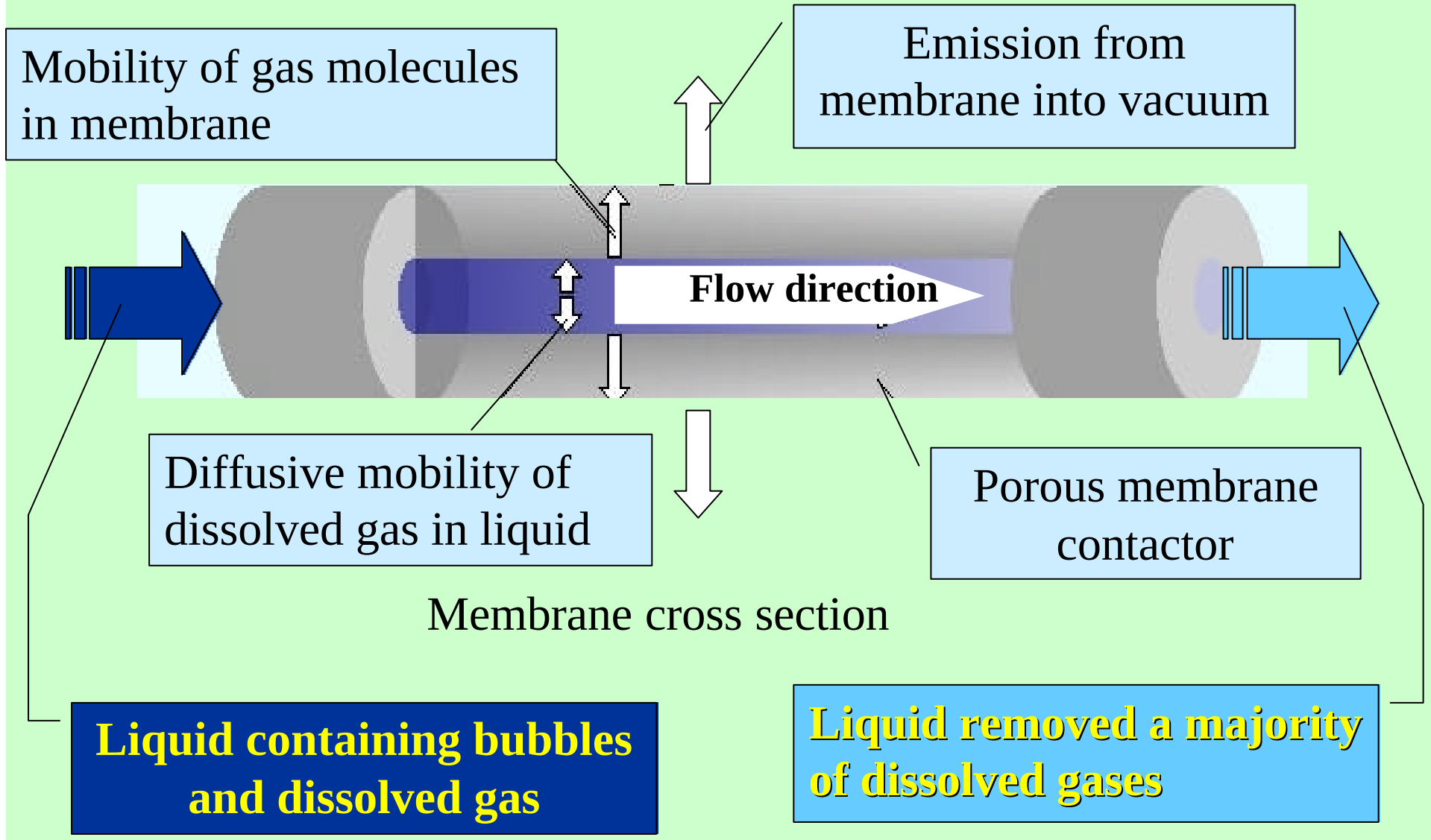
SDI-measurements will be improved by a High-pressure pre-treatment or degasification to reduce micro-bubbles in SDI-test solution

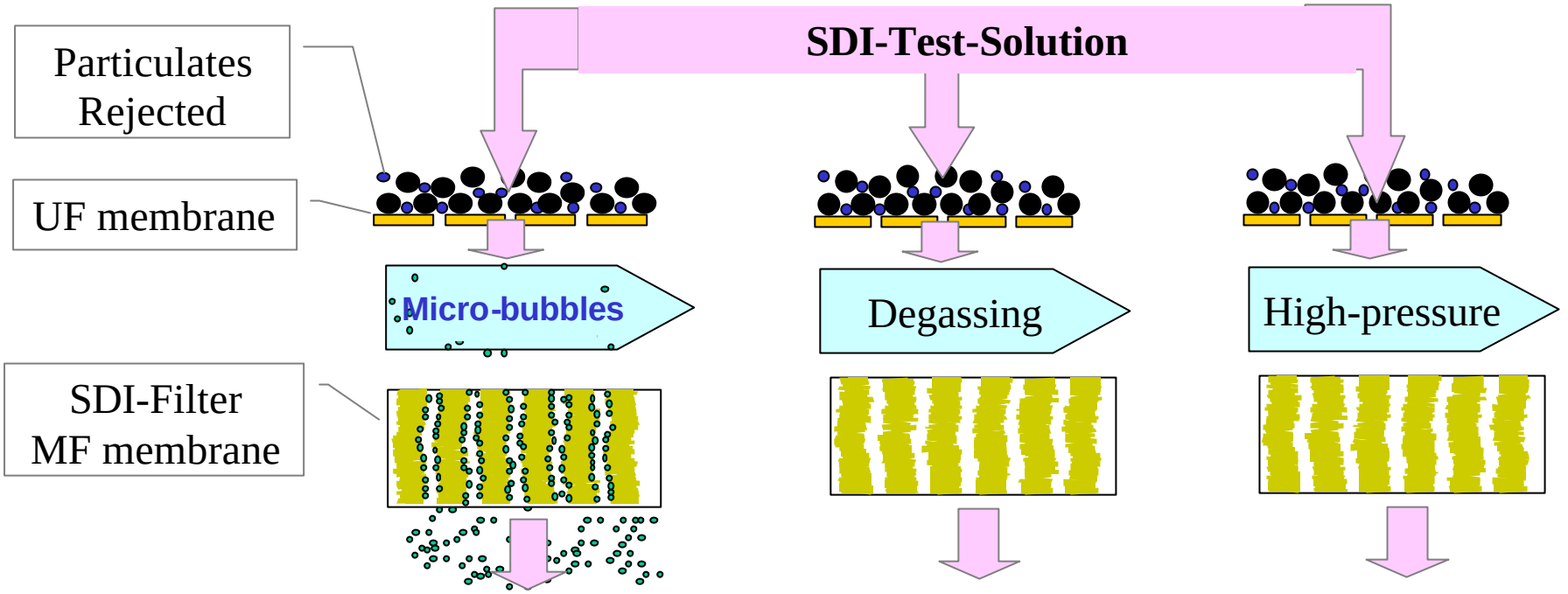


Flow Diagram of SDI-measurements with /without High-pressure Treatment in Advance

Principle of Membrane

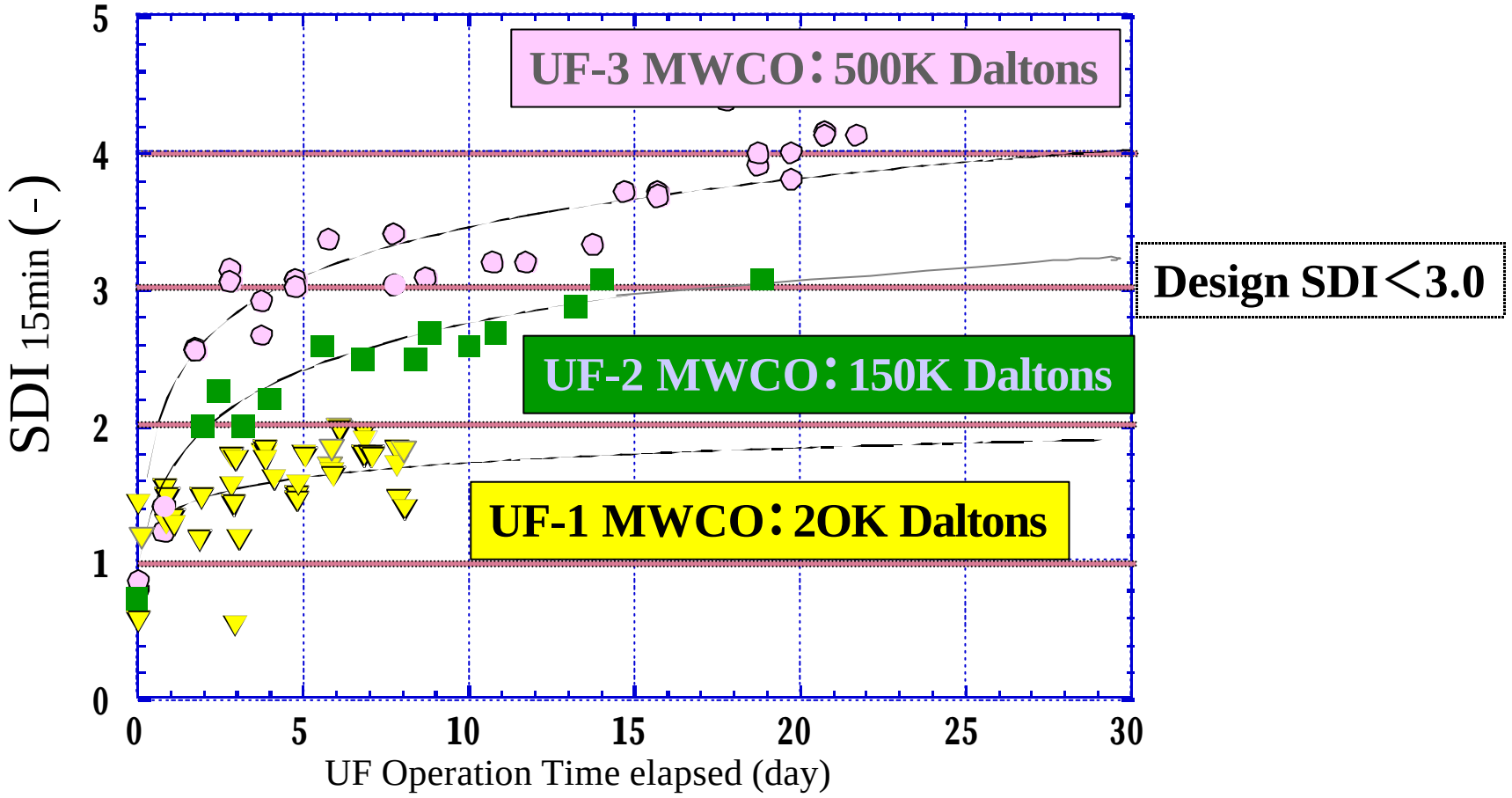
Contactor Degasification, “Degasser”





SDI-Test Solution	Micro-air-bubbles exist	Degasified No micro-air-bubble exists	High-pressurized at 6MPa No micro-air-bubble exists
SDI_{15}	2.77	1.81	1.74
DO	8.30	7.42	7.46

SDI readings of three types of UF filtrate



UF filtrate with 20K Daltons achieved SDI ＜2 , because UF-1 can remove the lower molecular weight organic compounds than UF-2,3.

Table 4 Increasing factors of SDI values in Lab-test with UF pretreated seawater

	Impact for SDI values with UF pretreated seawater	**Substance of increasing SDI values**	**Remarks**
Temperatures	The higher temperatures, the larger SDI values were shown.	Secondary contaminants, or another factors	It is prone to increase SDI over 30C with Japan seawater.
Adjusting pH of UF filtrate with H_2SO_4 or NaOH	The higher pH of UF filtrate, the larger SDI values were shown.	In alkaline side, $CaCO_3$ precipitation	In alkaline condition, Calcium carbonate is prone to precipitate.
Dosing Cl_2 Concentration in Pretreatment	The higher Cl_2 concentrations, the larger SDI values were shown.	Fe and Ca compounds, and others	SBS dosing decreases SDI, due to resolving plugging solid (colloidal substance).

During 15 minutes filtration, at the higher temperature, the more permeate will plug the SDI filter membrane to reduce the flux at 15 minute that gives larger SDI value.

In seawater condition, increasing the pH at 8 or more gives the more scaling potential of CaCO3. So more colloidal risk will come appear in high alkaline side.

Since we use NaOCl solution for chlorine adjustment, some nuclei of salt particle may be generated. Since some colloid concentration will increase, more plugging occurs.

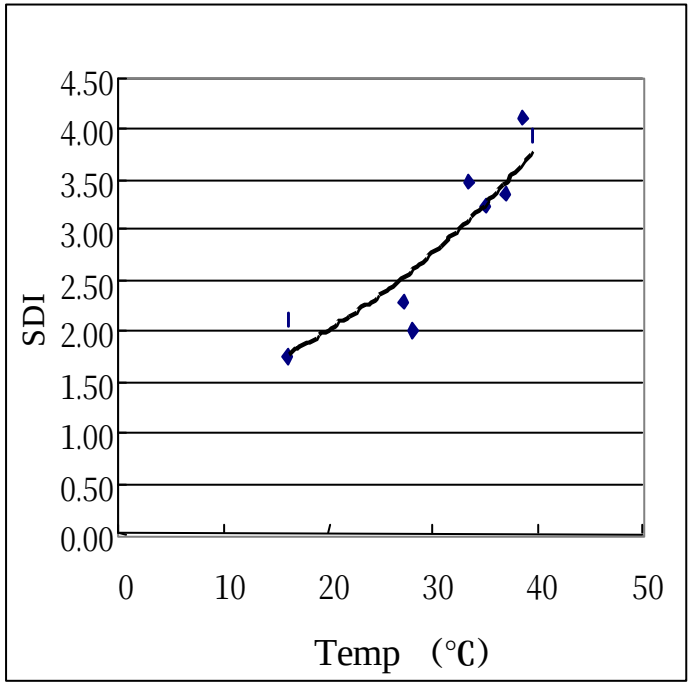


Figure 2 SDI values vs Temperature

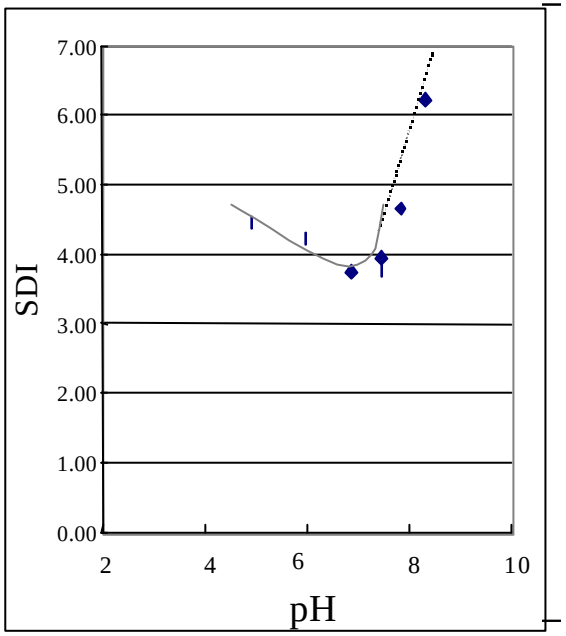


Figure 3 SDI values vs pH

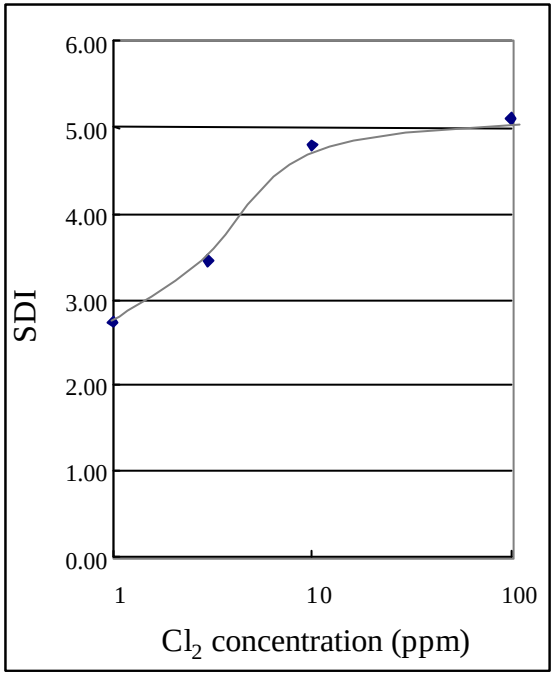


Figure 4 SDI values vs Cl_2 concentration

SDI-value Changing Parameters with UF filtrate of Standard Seawater

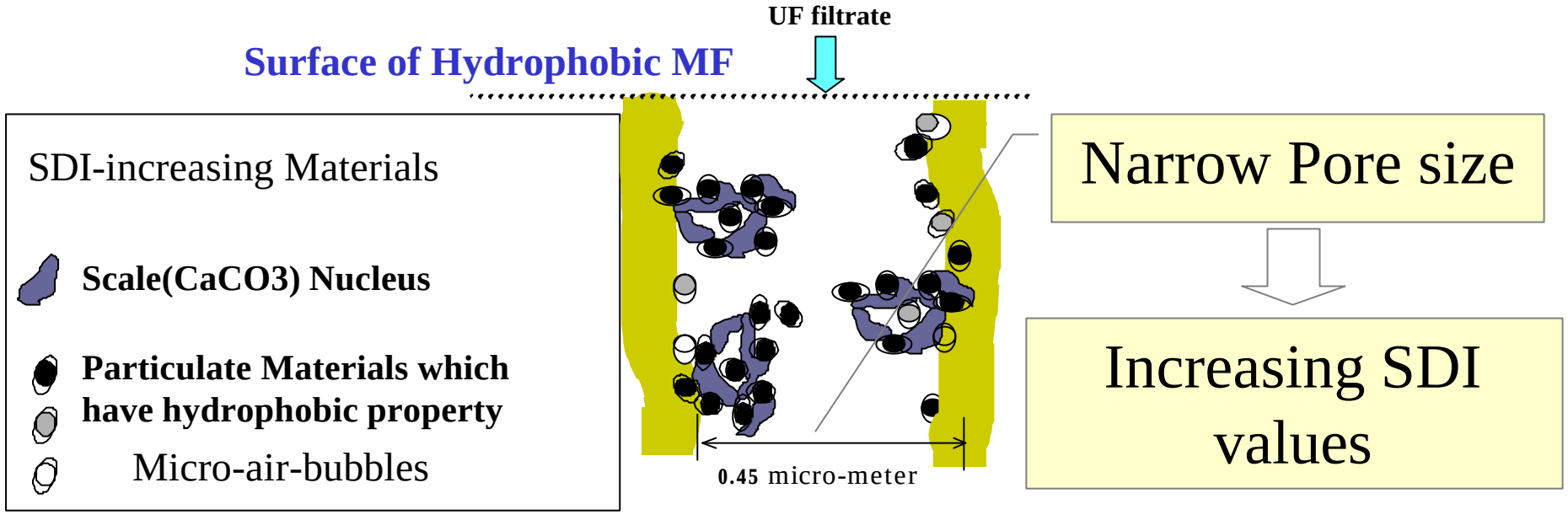
Table 5 Comparison of SDI data of 0.45 µm pore size, using different hydrophilic and hydrophobic MF filters with typical UF filtrate

Filter code	Material	Wettability	SDI values with different filter		Standard SDI values with HAWP filter, as control	
			SDI_{15min}-value	T_0 / T_{15} (S)	SDI_{15min}-value	T_0 / T_{15} (S)
HAWP	**MCE**	hydrophilic	**3.22**	20.30 / 39.32	**3.08**	19.30 / 35.90
HVLP	**PVDF**	hydrophilic	**1.23**	22.33 / 27.37	**3.27**	17.95 / 35.28
HVHP		hydrophobic	**3.38**	31.65 / 64.15	**3.28**	18.45 / 36.28
JHWP	**PTFE**	hydrophobic	**4.38**	30.69 / 89.36	**3.41**	18.15 / 37.24
250006-47-N	**PA**	hydrophilic	**1.21**	55.49 / 67.97	**3.23**	18.33 / 35.60

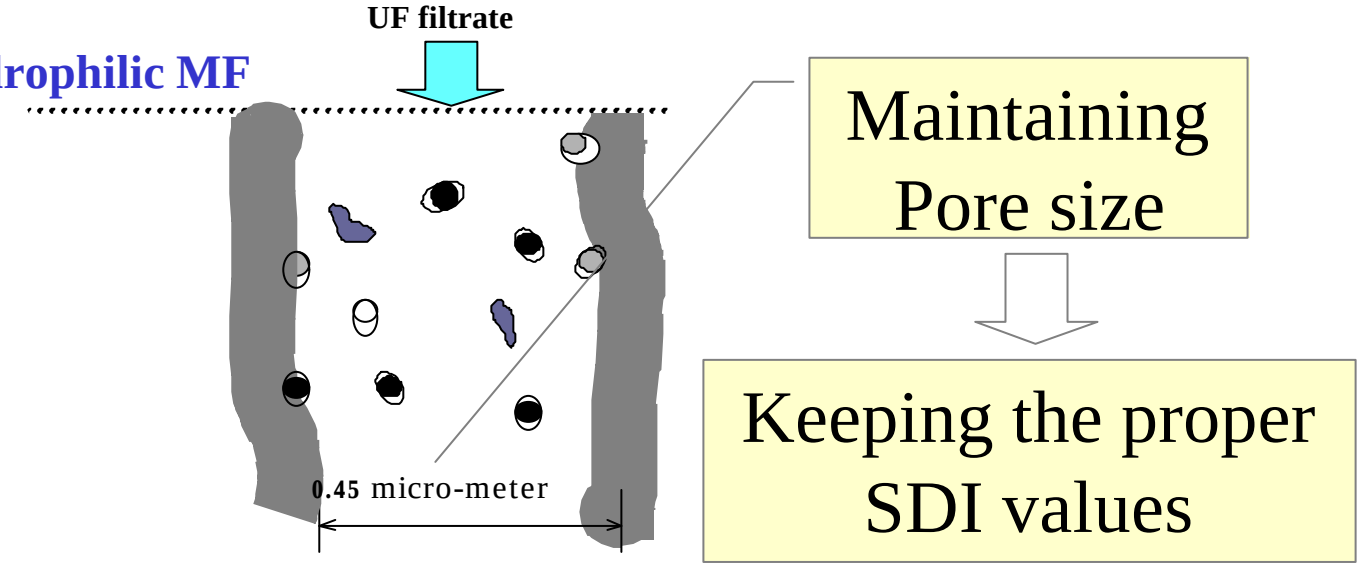
The standard Test method of SDI is not specifying filter material, but only pore size of 0.45µm.

However, the Table shows the wettability is very important factor to determine the SDI value. Hydrophilic nature of MF gives better SDI-values than hydrophobic one.

(Scheme 1) Model Structure and Mechanism of SDI-increasing



(Scheme 2) Model Structure and Mechanism of SDI-retaining



Conclusion

- SDI method should not be applied to UF/MF membrane pretreated RO feedwater.

Because the SDI values themselves will not give us any significant information on detecting potential risks of particulate fouling for RO membranes.

- For monitoring purpose of RO feed with UF/MF membrane (of which pore size is less than 0.1μm) pretreated seawater, a high sensitive turbid meter is available recording down to 0.001NTU .
- The maximum turbidity should be 0.1NTU as a guideline for RO feed, no more SDI.

Recommendations

- In case of measuring SDI of RO feed, micro-air-bubbles in water shall be eliminated by pressurizing at about 60 bar for several seconds to measure the proper SDI-value of RO feed water at outlet portion of high pressure pump.
- As an alternative method to get a proper SDI-value, we suggest to use degasifying membrane module to eliminate micro-air bubbles in RO feed water sample prior to testing SDI measurement.
- In order to eliminate adsorption phenomena onto standard Millipore filter during SDI measurement, we recommend using a real hydrophilic membrane filter of HVLP or equal one.