MEMBRANE PROCESSES IN NUCLEAR TECHNOLOGIES: THE TREATMENT OF RADIOACTIVE WASTE BY USING MICELLAR - ENHANCED ULTRAFILTRATION

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LIQUID RADIOACTIVE WASTE

1. From the nuclear power (decontamination, laboratories, the washing of the contaminated clothing, water storage facilities)

    - containing products of the activation, fission and the corrosion, such as: ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{51}Cr, ^{55}Fe, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{90}Y, ^{95}Zr, ^{95}Nb, ^{99}Mo, ^{99m}Tc, ^{106}Ru, ^{121}Te, ^{125}I, ^{131}I, ^{133}Ba, ^{134}Cs, ^{137}Cs, ^{140}La, ^{141}Ce, ^{144}Ce, ^{152}Eu i ^{154}Eu

    - containing transuranic elements

    - containing tritium

2. Institutional waste (from research reactors, medical and other applications, the production of radioisotopes)

3. Water in the spent fuel storage facilities; the wastes from water cleaning systems

MEMBRANE PROCESSES IN NUCLEAR TECHNOLOGIES

- Management of radioactive waste generated during the operation of nuclear reactors, in medicine and other fields of application of radioisotopes, is an important prerequisite for further development of nuclear techniques and nuclear energy in the world. Due to its harmfulness, the radioactive waste can not be directly discharged into the environment. Must be pre-segregated, and then processed to obtain a minimum volume for long storage or disposal.

- The conventional technologies have many drawbacks, such as high energy consumption or formation of secondary wastes;

- The newest achievement of the process engineering are membrane processes which can successfully replace many non-effective and out-of-date methods.

- The pressure-driven membrane methods (RO, UF, MF) have been already applied for liquid radioactive waste treatment

MEMBRANE PROCESSES IN NUCLEAR TECHNOLOGIES

MEMBRANE SEPARATION PROCESS				
Pressure Processes	Electrical Processes	Diffusion Processes	Thermal Processes	Chemical Processes
Microfiltration	Electro-dialysis	Dialysis	Membrane Distillation	Liquid Membranes
Ultrafiltration	Electro-osmosis	Pervaporation	-	Hemodialysis
Nanofiltration	-	Membrane Extraction	-	-
Reverse Osmosis	-	Membrane Absorption	-	-
Gas Separation	-	-	-	-

Membrane processes in Nuclear Technologies Institute of Nuclear Chemistry and Technology, G. Zakrzewska – Trznadel, Warsaw 2006, p.31

3-stage RO unit for the treatment of liquid low and intermediate level waste, implemented by INCT in Radioactive Waste Management Plant (ZUOP) – the only entity responsible for RW management in Poland

MICELLAR - ENHACED ULTRAFILTRATION (1/2)

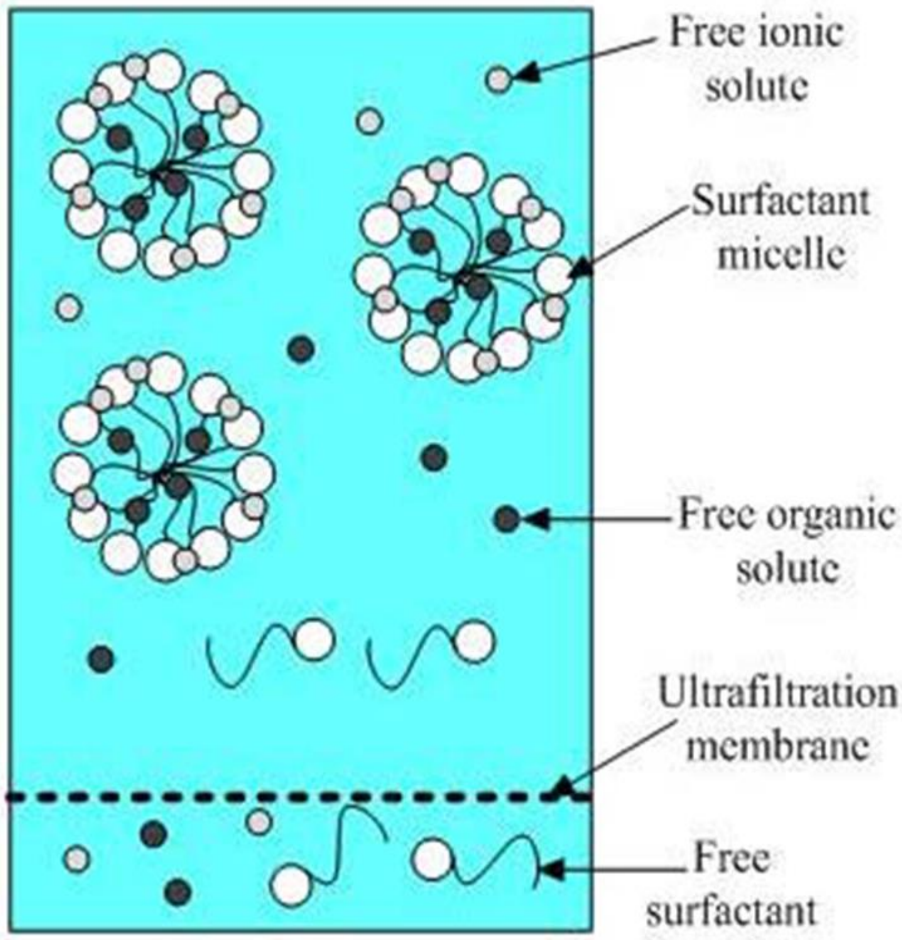
MEUF (Micellar Enhanced Ultrafiltration) is a new hybrid process, which combines the classic ultrafiltration with the ability of surfactants to solubilize the selected components in the aqueous solution.

This process utilizes the ability of transferring to the solution the hydrophobic substances, which are hardly soluble or insoluble in water, by introducing a surfactant at concentration exceeding the critical micelle concentration - CMC.

Advantages:

- selectivity
- efficiency (the relatively short time of the process)
- no use of harmful solvents
- low energy requirements

MICELLAR - ENHACED ULTRAFILTRATION (2/2)



1. Micellar aggregates – after exceeding the critical micelle concentration; below the CMC amphiphilic molecules form a true solution

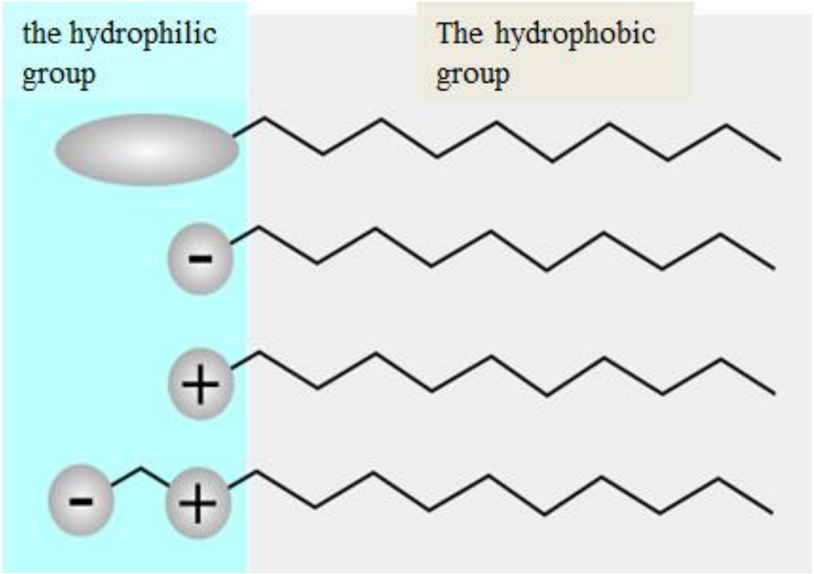
2. CMC value depends on:
   - type of surfactant
   - dispersion phase
   - ions and molecules present in the solution

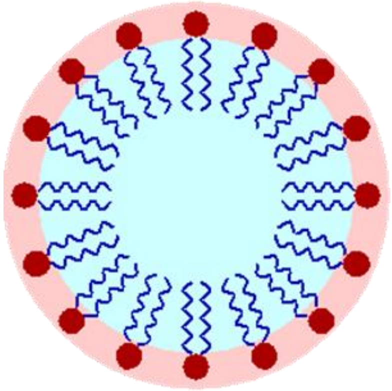
3. The use of micellar systems allows to increase the effectiveness and efficiency of separation (increasing gradient of the concentration of the component separated in the membrane pores)

SURFACTANTS USED IN ULTRAFILTRATION

Hydrophilic group is a ionic or strongly polar group. Depending on its nature, surfactants are divided into four types:

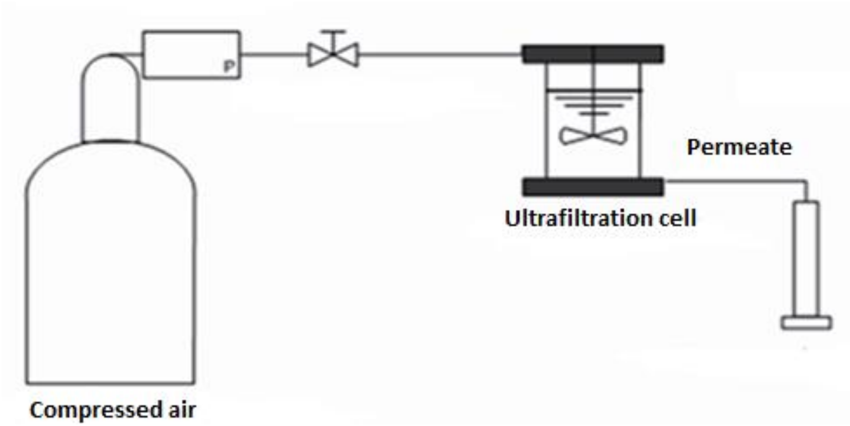
- **Anionic** - active surface part of the molecule carries a negative charge, such as $RCOO^{-} Na^{+}$ (soaps), $RC_6H_4SO_3^{-}$ Na^{+} (alkylbenzene sulfonate)
- **Cationic** - active surface part of the molecule carries a positive charge, such as RNH_3^{+} Cl^{-} (long-chain amine salt), $RN(CH_3)_3^{+}$ Cl^{-} (quaternary ammonium chloride)
- **Amphoteric (zwitterionic)** - positive and negative charges may be present in the active part of the surface, for example, $RN^{+}H_2CH_2COO^{-}$ (long-chain amino acid), $RN^{+}(CH_3)_2CH_2CH_2SO_3^{-}$(sulfobetaine)
- **Nonionic** - the active part of the surface has no visible ionic charge, e.g., $RCOOCH_2CHOHCH_2OH$ (fatty acid monoglyceride), $RC_6H_4(OC_2H_4)XOH$ (alkylphenol polyoxyethylene)





MEUF IN THE PRACTICE - OWN RESEARCH

Set-up used for Micellar-Enhanced Ultrafiltration experiments



Characteristics of ultrafiltration membrane

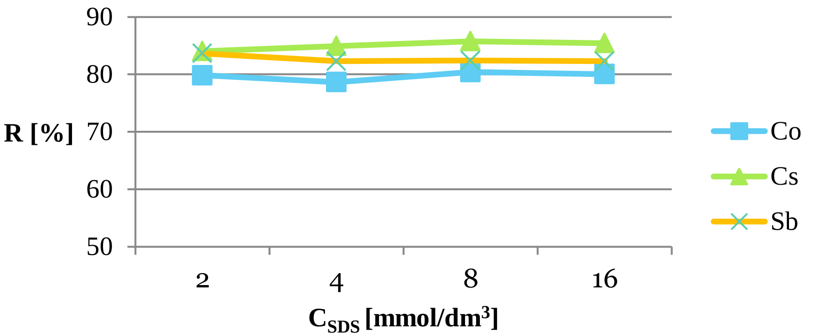
Membrane material	RC
Nominal MWCO [kDa]	5
Rejection [%]	92-96
pH range during filtration	1-11
Processing temperature [°C]	5-55
Membrane surface area [cm^2]	4.712

The content of surfactant - a method of TOC

The content of radionuclides - a method of ICP-MS (ELAN DRC II, Perkin Elmer SCIEX)

OWN RESEARCH – SEPARATION OF Co^{2+}, Cs^{+} and Sb^{3+} (analogues of radionuclides: ^{60}Co, ^{137}Cs and ^{125}Sb)

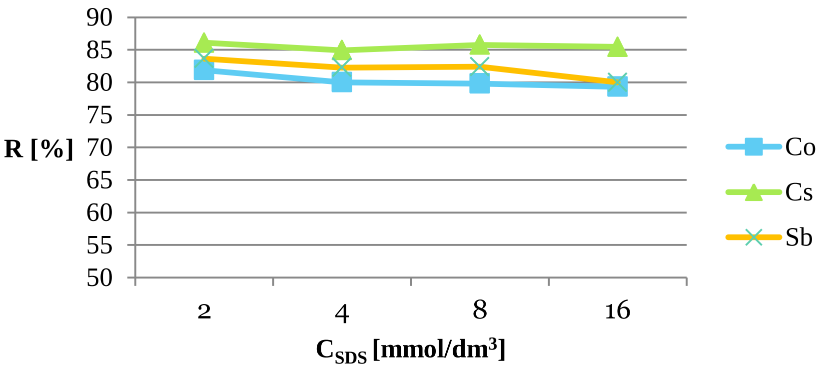
pH = 3.5



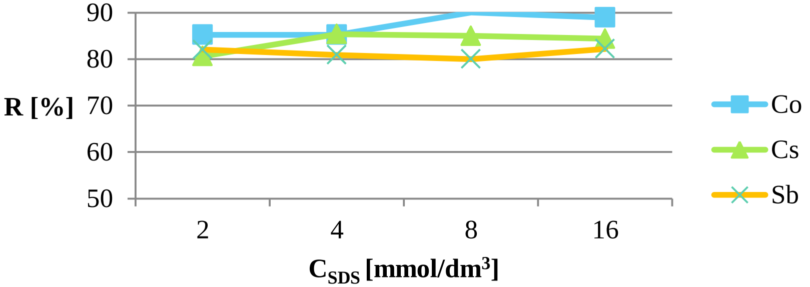
Conditions:

pH = 3.5-10.5
RC = 5 kDa
rpm = 60
p = 1bar

pH = 6.5

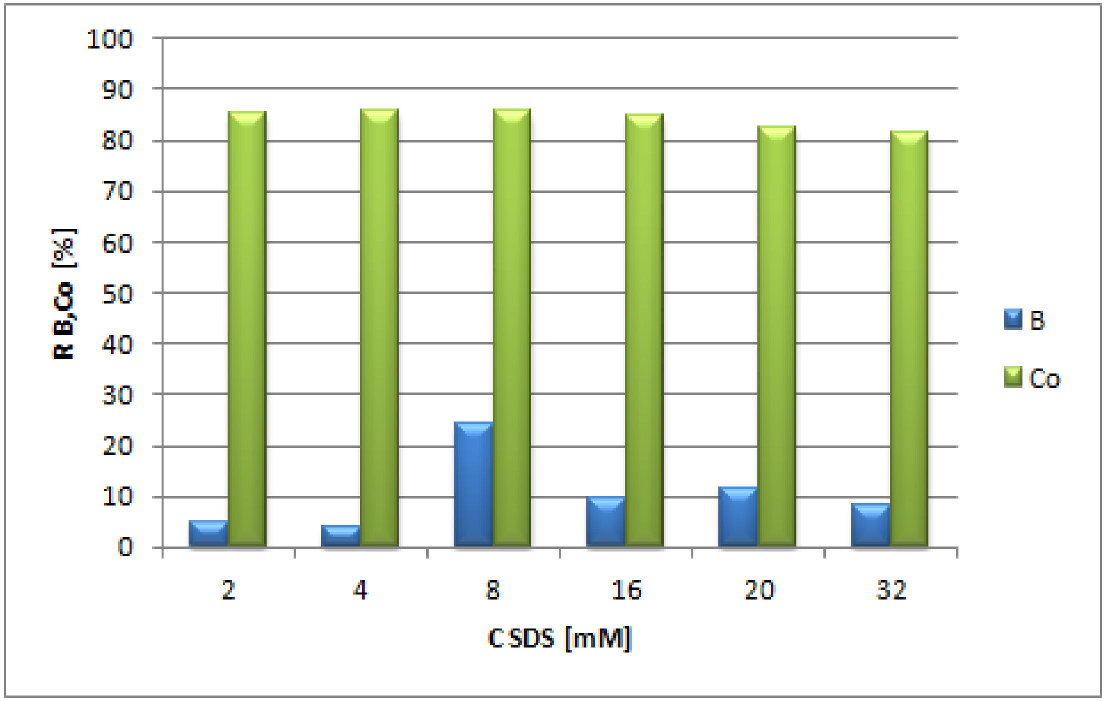


pH = 10.5



MEUF– RECOVERY OF BORIC ACID

Warunki:
pH= 10,5-11
H_3BO_3 = 7 mM
SDS = 2-32 mM
RC = 5 kDa
rpm = 60



CONCLUSIONS

- This presentation shows a review of the membrane methods recently introduced into nuclear technology with particular attention to the micellar-enhanced ultrafiltration;

- Micellar-enhanced ultrafiltration can be an efficient process for radioactive waste processing, enabling complete purification of the effluent and high volume reduction;

- The high effectiveness of removal of the main components of liquid radioactive waste like ^{137}Cs, ^{60}Co and ^{125}Sb with a hybrid ultrafiltration is possible;

- The method can be used for purification of reactor water with boric acid recovery or liquid radioactive waste treatment.

Thank You
for Your kind attention