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Technologies for Circular Economy in Desalination Industry

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Abstract

Seawater desalination is an alternative that can extend water supplies beyond what is available in the hydrological cycle, with a constant and climate-independent supply. Radical transformation in the way we use natural resources is central to meeting the needs of future generations. The growing desalination market across the world has thrown up the challenges of management of Brine and EoL (End-of-Life) membranes. For achieving sustainable desalination strategy, the current economy based on linear model has to be replaced with circular economy model through suitable technologies. Here in our study, we have carried out various process studies for brine management and membrane management for facilitating the value addition to desalination plants and facilitating the reuse and recycle for lower end applications. The process technologies based on these studies are presented in this engineering article. The coupling of recovery of technology trace metals from brine using Radiation Induced Grafted sorbents is highlighted. These process studies and technologies will help to incorporate principles of the circular economy for the sustainable development of desalination.

Keywords: Desalination; Brine management; Membrane management; Circular economy

Introduction

Water security is an urgent global issue, especially because many regions in the world are experiencing water shortage conditions. Globally one in six people are water stressed. Also the current trends in global resource extraction are incompatible with internationally agreed targets to limit the rise in global average temperature to below 1.5°C above pre-industrial levels. Water is a valuable resource for basic needs such as drinking and sanitation, or for irrigation. Diverting to a sustainable growth pathway will require both substantial improvements in the efficient use of primary resources and a significant degree of displacement of primary resources with secondary materials – those recovered from waste streams and repurposed or remanufactured for further use.

For achieving sustainable desalination strategy, the current economy based on linear model has to be replaced with circular economy model through suitable technologies [1, 2]. In our study, we have carried out various process studies for brine management and membrane management for facilitating the value addition to desalination plants and facilitating the reuse and recycle for lower end applications. The process technologies based on these studies are presented in this engineering article. The Coupling of Recovery of Uranium and other trace metals from Desalination Effluents (CRUDE) using Radiation Induced Grafted sorbents is highlighted. These process studies and technologies will help to incorporate principles of the circular economy for the sustainable development of desalination.

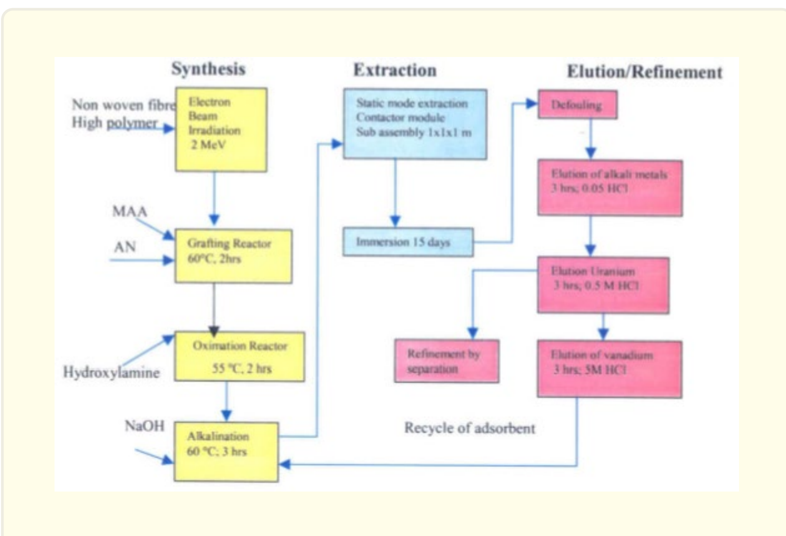
Results and Discussions

Brine/Desalination Effluent Management

The most commonly used methods of brine disposal are i) Discharge to the sea (surface and through multiport diffusers installed on the deep sea floor) ii) Disposal in sewers (wastewater collection system, low cost and energy) iii) Injections into deep wells (injected into porous subsurface rock formations) (iv) sewage disposal (wastewater collection system, low cost and energy) v) Deep well injections (injected into porous subsoil rock formations) (vi) Land applications (irrigation of salt-tolerant crops and grasses) (vii) Evaporation ponds (evaporation of brine in ponds, salts accumulate at the base of the pond). In addition, when selecting the disposal technology, it is important to consider the location, quality, and volume of the brines. Therefore, given the large amount of brine produced today, reutilization is a matter of principle that is strongly linked to the circular economy. For better utilisation of waste resources, the following technologies are being worked upon at our end.

Recovery of technology metals from Seawater/Brine

Based on initial success of extracting micro grams and milligrams of uranium at lab scale by harnessing the tidal wave using PAO adsorbent, a process flow sheet for a facility to extract 100gU/year has been developed. Compare to lab scale a surface area scale up factor of 1200 has been maintained in pilot scale facility. The process flow sheet RUSWapp~100g facility was evolved, designed, installed and commissioned at Trombay for demonstration trials. The process block diagram is as shown in Fig.1 below. The holdup volumes of process reactors are 2000 litres and 2 bar steam is used as heating medium. The required mixing and turbulence is maintained in the process using continuous recirculation of the solution mixture. The adsorbent is used in the form of leaflets of size 1mx1mx1m with 27 of sheets per contactor assembly and a gap of 30 mm is maintained between the sheets for achieving optimal hydrodynamics. The material of construction for contactor assembly is polypropylene, which is compatible for both hot alkali and acid solutions. The scaled up facility has given pick up rate of 0.6 g of Uranium per kg of adsorbent material. The preferential elution for technology metals of interest is demonstrated with this facility.



Bio desalination for brine management

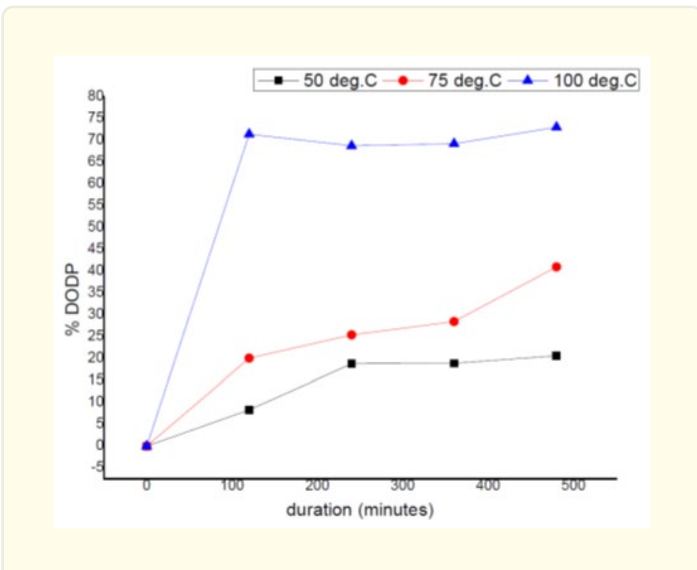
Current desalination technologies based on thermal and membrane methods are expensive and energy inefficient. The effluents from these desalination plants cause environmental impacts in coastal areas. The current demands of sustainable green technologies have increased the use of bio based systems for industrial processes. As an alternative, Bio desalination processes using only resources of biodegradable organic matter and bacteria for desalination are attempted in this work. There are multiple mechanisms in this domain. We have tried with (i) Saline tolerant bacteria (M1) (ii) Bacteria isolated from cow dung (C1) (iii) Algae (A1). This work emphasizes on conversion of brines for reuse as agricultural grade water using new concept techniques [4].

EoL membrane management

Reverse Osmosis's (RO) share of total installed capacity, continues to grow up at a rate of 10-20% and cumulative global contracted capacity as of 2016 reached 95.6 million m^3/day. It is observed that the adoption of membrane technologies over thermal technologies globally, due to reduced capital costs and versatility of RO. It is estimated that Reverse Osmosis (RO) desalination will produce, by 2025, more than 2,000,000 end-of-life membranes annually worldwide. Widely used TFC membranes consist of ultra thin layer of polyamide which is interfacial polymerized onto asymmetric porous polysulfone cast on a polyester support. The life and efficiency of membrane processes can be increased by periodic flushing and cleaning. But membrane recovery ratio reduces during operation due to progressive bio fouling; scaling; colloidal fouling etc. Membranes need to be managed after its life cycle of the order of 3 to 5 years. The following process studies being carried out for developing the process technologies for management of spent membranes.

Low temperature AOP studies

The effectiveness of various AOP based on hydrothermal process techniques to depolymerise the various components of the TFC membranes has been carried out in this work. This helps in conversion of bulky molecules into smaller ones and facilitates towards meeting environmental regulations. The hydrothermal process studies are carried out in one litre scale batch reactor with respect to desalination membrane substrates. The samples are collected periodically and analysed for COD/TOC analysis. The solid substrate tokens are analysed for molecular changes by FTIR analysis. The effect of factors such as temperature, duration and concentration of reaction media on depolymerisation of desalination membrane substrate has been established in this work. The effects of HTP-2 process on depolymerisation of PA-TFC token at different temperatures are as shown in Fig. 2 below.

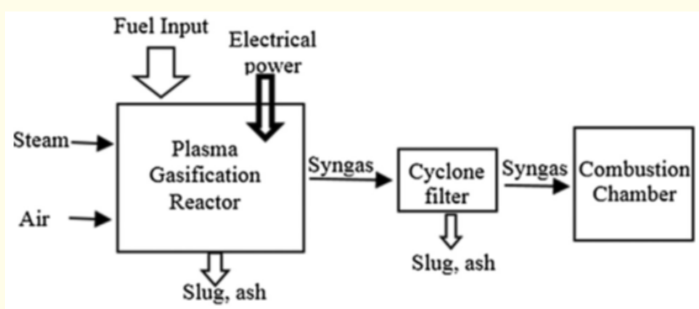


Quaternary recycling through High temperature thermal oxidation processes

Quaternary recycling refers to the recovery of polymeric membrane energy content. Incineration aiming at the recovery of energy is currently the most effective way to reduce the volume of organic materials. Although polymers are actually high-yielding energy sources, this method has been widely accused as ecologically unacceptable owing to the health risk from air born toxic substances e.g., dioxins (in the case of chlorine containing polymers). To achieve improved and efficient combustion, exploratory studies were carried out using air plasma.The comparative studies of conventional resistance heating and thermal plasma are established in this work. The observed mass reduction factors and gasification efficiencies are determined. This work highlights the feasibility studies of the treatment of spent RO module components using air plasma gasification technology developed by BARC. The air plasma studies carried out for RO membranes are as shown in Table-1 below.

Operating conditions		
Voltage (volts)	160	
Current (A)	199	
Power (kW)	31.84	
Plasma gas flow (lpm)	30	
Additional air flow (lpm)	50	
Duration(min)	15	
Average temperature (K)	3000	
For RO-TFC membranes		
Initial mass(gm)	97	
Final residue mass(gm)	10.31	
Mass reduction factor	89.38	
Elemental composition		
Element	**Reverse Osmosis Thin Film Composite (RO TFC)**	**Plasma residue of RO TFC (RES1)**
Aluminium	NA	0.64%
Iron	NA	1.20%
Copper	NA	0.61%
Silver **(Detection Limit < 25 ppm)**	ND	ND
Hafnium **(Detection Limit < 25 ppm)**	ND	ND
Silica	NA	1.80%
Carbon	64 %	7.00%
Hydrogen	6%	NA
Nitrogen	< 0.05ppm	NA
Oxygen	NA	NA
Sulphur	2ppm	3ppm

The conceptual process flow scheme to address the requirements of 6.3 MLD desalination plant NDDP Kalpakkam are shown in Fig. 3 below. Air plasma gasification was tried as a new technology for the new stream of waste consisting of desalination membranes and stability of plasma was observed with efficient conversion.



Conclusions

One of the main problems in the installation of desalination plants is the cost of brine disposal, which is usually very high, ranging from 5 to 33% of the total cost of the desalination plant. Innovation strategies will be required to encourage R&D in CE solutions beyond recycling and waste management. Where CE approaches are untested or involve coordination across multiple actors in a supply chain, novel financing mechanisms are likely to be needed to lower the investment risk. Finally, this study opens some potential opportunities for future research, such as the implementation of this type of projects in desalination industry, considering the use of reject steams as a source of water for agriculture, maintaining the circularity of desalination plants.

Acknowledgements

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