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Key words: Desalination; Brine mining; trace metals; Radiation grafted sorbents;

Extended Abstract:

Introduction

Thermal and membrane based desalination plants are being operated all over the world to address the demand of fresh water required by industries and large cities in water scarce coastal areas. The desalination and energy are very much interlinked, as plants are energy intensive. The energy consumption of desalination plants varies from 5 to 15 kWh m^{-3} of product water depending on the technology. In addition, the percentage of reject seawater/brine exiting the plants varies from 60% to 80% depending on the desalination technique. The concentrated reject brine is a source of valuable trace elements/metals, which is an untapped source that is wasted. With advances in Desalination technologies, it has been established that recovery of critical metals and elements and their selective recovery from reject brine of desalination plants gives an added advantage of energy credits to desalination plants as well as reduce cost of desalinated water [1, 2]. Research and technological developments are required for brine mining from desalination plants, i.e., by the recovery of nuclear fuel and other valuable materials (e.g. U, Li, Rb), from reject brine streams. This is being achieved by adsorption of these elements/ions onto a selective sorbent that is dipped either in reject brine/inlet seawater or in the open sea [1]. The major factor determining the practical utilization of the technology and lifetime of the adsorbent is fouling of the adsorbent by suspended particles or due to biological growth.

The paper presents the status review on a recovery of important trace metals and other alkali metals from seawater and highlights the potential of Indian desalination plants for the recovery of trace metals. The adsorption studies carried out using radiation grafted polymeric adsorbents along with fouling studies are discussed in this paper. The studies involve determination fouling tendency of the adsorbents in a different environment, and recovery of uranium and vanadium from the reject brine. The paper also gives the schematic diagram and major unit operations involved in process flow scheme.

Materials and methods:

Manufacture of adsorbent:

Initial radiation grafting experiments were carried out using different types of fibers with varying cross-sections, geometry and with polymeric materials, e.g., polyester (PES) and polypropylene (PP). Based on preliminary studies, experiments were carried out using polypropylene fiber of 1.5 denier cross section as stem material in non-woven felt form. The optimization of the grafting of acrylonitrile on PP fiber was carried out using Electron Beam Radiation (EBR) to maximize the percentage grafting. The grafting level achieved was 110%. Subsequently, the conversion of grafted acrylonitrile into amidoxime was carried out as shown in Fig. 1.

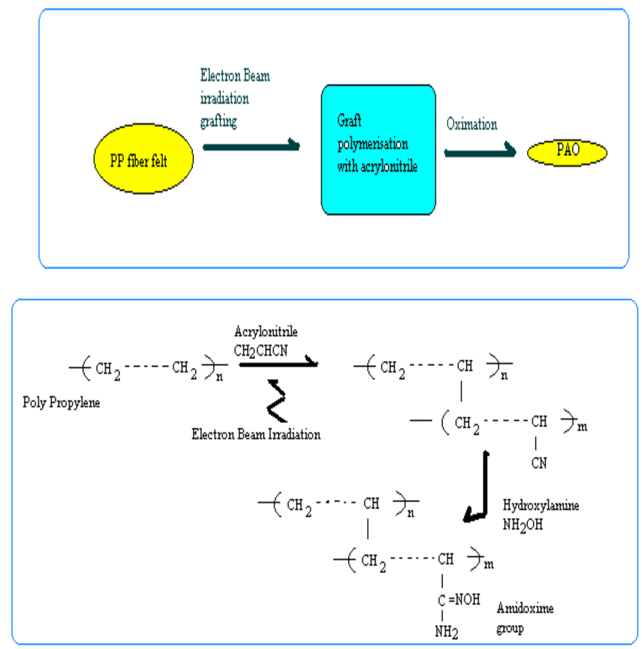

Fig. 1: Electron Beam Radiation induced grafting of acrylonitrile and conversion into amidoxime group

Fouling and Adsorption studies:

Fouling studies were carried out by immersion of adsorbent in different locations such as seawater in the lab and in actual location as well as inlet and outlet of desalination plants. The uranium and vanadium recovery from seawater reverse osmosis (SWRO) plant is estimated and the results are presented.

Results and discussions:

Fouling factors assessment of various submergence conditions:

The seawater/brine is bio aggressive multi component feed. The feed solution conditions and fouling conditions have an effect on the adsorptive properties of radiation grafted adsorbents [3]. In case of uranium recovery from seawater/brine, the functional groups existing on the surface layer are occupied by various kinds of metal ions and are quickly covered with dirt and bio growth. The fouling factor assessment was carried out at various locations and is shown in Fig 2. The recovery of trace metals depends on diffusion in bulk, in film, intra-particle type of diffusion as well as chemical reaction steps. The fouling factors observed for nuclear power plants and desalination plant conditions are lower than the seawater conditions at high seas. The submergence period of beyond 12 to 13 days is possible for brine conditions due to less biofouling and dirt fouling. The fouling factors observed for nuclear desalination plats were negligible, even with extended submerged periods.

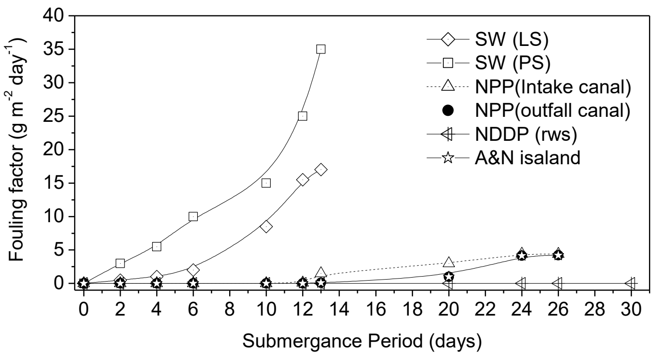

Fig. 2: Variation of fouling factor as a function of submergance period at various locations (NPP: Nuclear Power Plant; NDDP: Nuclear Desalination and Demonstration Plant; SW (LS) Seawater Lab Scale; SW (PS) Seawater Plant Scale; A&N: Andaman and Nicobar)

Brine Mining studies at NDDP site:

Bench-scale brine mining experiments were carried out by using Poly(Amidoxime) (PAO) adsorbent coupons of various sizes and are submerged in Reverse Osmosis (RO) reject water sump (RWS) and clarified water tanks (CWT) at NDDP Kalpakkam for a period of around 15 days to assess the feasibility of recovery of valuables from reject brine stream and the results are presented in table 1.

Conclusions:

The brine mining studies have given promising results for recovery of uranium from brine/seawater. The fouling factor, which decides the lifetime of the adsorbent in the actual condition, is the deciding factor for the implementation of the technology at a specific location. The study shows that the coupling of uranium recovery unit with desalination plants gives the added advantage of faster adsorption kinetics with bare minimum fouling factors for the mass transfer coefficient. The economics of desalination process will become still more attractive as more and more rare and strategic elements like lithium, rubidium is extracted in addition to uranium and vanadium.

Table 1: Uranium and Vanadium pick up assessment at Sea Water Reverse Osmosis (SWRO) brine stream NDDP Kalpakkam

Sl. No.	**Parameters**	**Poly(Amidoxime) (PAO) token 2**	**Poly(Amidoxime) (PAO) token 6**
1	Substrate a.Size (mm) b.Weight (g)	a.110x70 b.6.7	a.120x75 b.9
2	% grafting	110	110
3	In situ Alkalination a.Concentration b.Duration	a.5% NaOH b.2 hrs	a.5% NaOH b.2 hrs
4	Submergence a.Location b.Duration	a.RO-Reject Water Sump (SW direction.) b.360 hrs	a.RO-Clarifier Water Tank (NE direction) b.360 hrs
5	Elution for Uranium/Vanadium a.Temperature (°C) b.Time (hr) c. Eluent	a. 60 b. 4 c.0.5M HCl	a. 60 b. 4 c. 0.5M HCl
6	Analysis of elute* a.Uranium b.Vanadium	a.339 ppb b.37.8 ppb	a.393 ppb b.41.6 ppb

* As reported by AChD, BARC

References: