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Brine management methods: Recent innovations and current status

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HIGHLIGHTS

- Reject brine or concentrate is the product from desalination processes.
- Reject brine has potential damages to the environment, marine and habitats.
- Brine management involves strategies such as minimization, disposal and reuse.
- A critical review of different brine management methods has been developed.

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ABSTRACT

Reject brine is the product from desalination processes containing high salinity, high temperature, and at many times, dissolved chemicals. With the growing demand of water, increasing amounts of brine are being produced from the desalination plants leading to significant adverse impacts on the environment. It is necessary therefore to effectively manage desalination reject brine in order to ensure more efficient disposal and reuse. This review gives a general idea on the recent and currently devised brine management processes, which have been employed to reduce the environmental issues related to concentrate dumping. Those management approaches consist of minimization techniques that can be divided into membrane-based, thermal-based and emerging technologies. Moreover, this critical review gives an overview of the various applications of brine and some sustainability aspects of the reject brine disposal and reuse. The most obvious sustainable improvements in reject brine management are based on minimization techniques or reuse that can be achieved through the recovery of valuable materials such as salts, metals, and chemicals. Many new research works in this field have been introduced and scientists have continued to devise reject brine reuse strategies and minimization technologies leading to very low quantities of residual brine.

Contents

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1. Introduction

Increase in water stress arising from population growth and scarcity of fresh water resources have resulted to a rise in water desalination. Desalination technology is widely used in areas where fresh water resources are limited. More desalination plants are being constructed everyday worldwide [1]. A large number of desalination plants have been constructed in the Middle East, mostly especially in the Gulf Cooperation Council (GCC) region. In the United Arab Emirates (UAE), for example, desalination is a highly important source of potable water and Multi Stage Flash (MSF) is the most dominant technology followed by Reverse Osmosis (RO). Regardless of the desalination plant type, many plants in the UAE dispose their reject brine (concentrate or retentate) in the sea while some of them dispose the brine in closed water courses that are connected to the sea. Although desalination potentially provides clean water, the reject brine from desalination is a critical environmental issue [2,3]. This is due to the residual pretreatment chemicals in the brine, and high salinity and temperature of the disposed brine. Also, the heavy metals in the reject brine due to pipe corrosion (copper, nickel, iron, chromium, zinc etc.) constitute serious environmental risks. Generally, the characteristics of reject brine depends on the quality of the supplied and generated water, the techniques used for pretreatment, and the desalination process employed [4].

The potential damages of reject brine to the environment include eutrophication, pH fluctuations, proliferation of heavy metals in marine environments, and sterilizing characteristics of disinfectants which can cause a series of problems to marine and underground habitat. In order to select a suitable brine management method that is environmentally friendly, several factors such as reject brine volume; chemical components of concentrate; geographical position and availability of the disposal spot; feasibility of the management method in terms of public allowance, capital and operational costs; and capacity of facility to be developed for storage and transportation of reject brine to location of treatment should be taken into consideration [5–7].

There are different reject brine management strategies, including brine minimization, direct disposal, or direct reuse. The minimization strategy can be implemented through membrane-based, thermal-based, and emerging technologies. Direct disposal strategies involve inland and offshore disposal methods. Other strategies for reject brine management involve the extraction of minerals and salts from the brine for different applications. This review paper aims to investigate the most recent advancements in the management of reject brine from desalination plants. It provides updated information on technologies that produce low amounts of reject brine through minimization techniques. Moreover, this paper also reviews the direct disposal methods which have recorded some improvements over time. In addition, the reuse of reject brine through recovery of valuable products and carbon dioxide sequestration has been discussed. Sustainability is a critical factor which must be taken into consideration to ensure the continuous operation of the reject brine management systems in order to ensure minimal environmental and economic consequences. Therefore, the sustainability aspects of reject brine management approaches have also been discussed in this paper.

2. Brine volume minimization strategies

Most desalination technologies do not usually achieve 100% water recovery. As a result, desalination plants produce vast volumes of brine wastes with many retained substances [8]. Different practices need to be followed to overcome the environmental issues linked to brine disposal by achieving higher water recovery from desalination processes. Recently, some processes and technologies have been proposed and studied to accomplish higher water recovery through brine treatment. These processes include the use of pressure-driven and electrical potential-driven membranes, thermal-based technologies and other technologies. Zero-liquid discharge (ZLD) or close-to-ZLD schemes are undergoing investigations in order to minimize reject brine volume and recover water as well. High-purity distillate reaching 95–99% recovery can be obtained from the waste brine streams. The residual waste generated from these processes can then be disposed to landfills, but this is not the ultimate solution for the brine problem. Designing a system that is able to recover a high-purity water as well as profitable products from brine with reasonable operating costs and energy consumption will result in a revolution in the desalination industry [9,10].

2.1. Minimization strategies for reject brine from low-salinity sources

2.1.1. Pretreatment of reject brine from low-salinity sources

Brackish water, reclaimed water from wastewater treatment, and moderately saline inland desalination feed water can be classified as the low-salinity sources. In order to increase recovery of fresh water through a secondary process and minimize the volume of reject brine obtained from these sources, sufficient scale removal from the brine needs to be carried out through pretreatment. Scale removal is particularly required if the brine would be treated using membrane technologies. Scale-forming salts including calcium sulfate and carbonate, barium sulfate, and strontium sulfate are present in primary RO concentrate produced from brackish and moderately saline inland water sources. Infiltration of geological sediments and discharge of wastes from domestic, industrial, and commercial activities are mainly responsible for the presence of scale-forming salts in water. These soluble salts would precipitate on the surface of membranes during secondary treatment and cause flux reduction known as membrane fouling [11,12]. Several pretreatment technologies are used prior to membrane-based brine treatment. Examples of these technologies are chemical softening via the coagulation/precipitation of foulants, fluidized bed reactors, electrokinetic separation, biodegradation, ion exchange and electrodialysis (ED). In addition, many new two-step high efficiency systems exist. These systems can be used to improve the overall treatment efficiency [13].