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Perspectives on environmental ethics in sustainability of membrane based technologies for water and energy production

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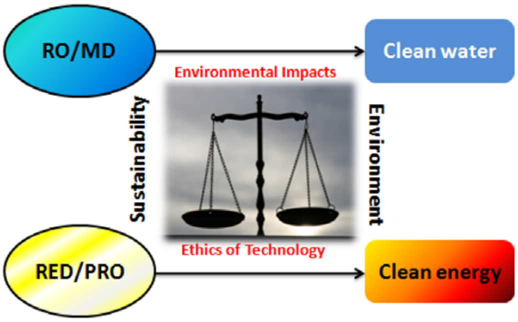
HIGHLIGHTS

- Assessed environmental impact from the emerging desalination technologies.
- Sustainability of desalination technologies evaluated.
- Methodology in consideration of environmental ethics for justification of sustainability.
- Process intensification and new developments as mitigation strategies.
- Future research directions in sustaining water and energy production technologies indicated.

GRAPHICAL ABSTRACT



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ABSTRACT

Securing a sustainable supply of water and energy is nowadays a key global issue. In the current practice of water and energy supply, there is still some gap in meeting the value criteria for sustainable development mainly related to environmental pollution as well as ecosystem disturbances. In this work, the sustainability of integrated membrane based processes for water and energy production is assessed with a special focus on environmental and ecosystem impacts. Feasibility of bridging the available gaps through process performance improvements is presented. Major environmental impacts from hybrid membrane based technologies for water and energy production are identified and considered for upstream balance of social benefits and burdens to the present and future generations. Ethical considerations were pointed mainly in the aspect of intergenerational justice (IRG-J) and ecological justice (EC-J) while setting value criteria for sustainability.

Abbreviations: DCMD, Direct contact membrane distillation; DT, Desalination Technology; EC-J, Ecological Justice; GHG, Green House Gas Emissions; IEA, International Energy Agency; IEM, Ion exchange membranes; IPCC, Salinity Gradient Power; IRAG-J, Intragenerational Justice; IRG-J, Intergenerational Justice; MD, Membrane distillation; PRO, Pressure Retarded Osmosis; RED, Reverse Electrodialysis; RO, Reverse Osmosis; SGP, Salinity Gradient Power; TDS, Total Dissolved Solid.

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The ethical significance of the identified impacts was predicted based on the associated difficulties to meet these criteria. The overall outcome will be beneficial in designing strategies for development and implementation of sustainable hybrid processes for clean water and energy production.

Contents

1. Introduction

The need to meet basic human needs in a sustainable manner is a major challenge nowadays for developing and developed countries. Key issues involve depletion of fossil fuels, global warming, water scarcity, rise in energy demand, loss of biodiversity and the human health impact which are exaggerated with the global expansion. The global demand for the two essential resources (water and energy) is drastically increasing due to economic expansion, population growth and increasing living standard in emerging countries. In 30 years, it is expected that energy demand will be projected by 50% while water withdrawal could go beyond 50% in developing countries and 18% in developed countries over the same period (EIA, 2013). Thus, technological innovations for sustainable water and energy production are highly demanding for societal and ecological benefits in terms of economic advantages, environmental safety, public welfare and national security.

This study presents a methodology for an integrated analysis in planning and technological implementations for sustainability of membrane processes applied to water and energy production. Emphasis is mainly given to reverse osmosis (RO) for clean water production and reverse electrodialysis (RED) for clean energy generation. Trends in research progress and recent technological development are highlighted. Identification of potential environmental threats and ecological impacts is done for justification of related ethical issues. Integrated analysis of the various factors that should be considered in technological advance of desalination processes; possibly in reduction of energy demand, use of clean energy sources, advanced materials, innovative system designs and social acceptance, were performed and evaluated according to a value criteria set for sustainability. From ethical point of view concerning justice, the listed factors were evaluated in terms of intergenerational equity in sustaining the processes without any damage to humans, non-humans and the whole ecosystem. This will be helpful in paving a way for the technological advancement through upstream balance of social burdens and benefits.

2. Current state-of-the-art technologies

2.1. Reverse osmosis: water

Production of pure water is mainly done by desalination of seawater. The major Desalination Technologies (DT) currently in practice is based on RO and thermal distillation (multistage flash and effect distillation). Thermal desalination is energy intensive compared to the membrane based processes like RO seawater desalination which is expanding rapidly due to its lower cost and simplicity. Currently, RO is the most widely used technology and accounts for over 50% of the installed capacity. However, at the current state-of-art, desalination of 1 m^2 seawater by RO (50% recovery) results in about 0.5 m^3 of pure water and 0.5 m^3 of retentate (brine), which is usually discharged into sea. Fig. 1 presents major steps involved in a typical seawater RO process.

Recent advances in RO development involves new membrane materials, modules and process design (Shenvi et al., 2015). The search for optimal polymeric membrane materials started early in 1950s, and the RO industry is nowadays dominated by these type of materials. Promising progress is observed in membrane research mainly in performance optimization through