Desalination 351 (2014) 184–201

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Design and operation of water desalination supply chain using mathematical modelling approach

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HIGHLIGHTS

- Water supply chain is formulated as a multi-period mixed integer linear problem.
- The objective function minimizes the net present value of the water supply chain.
- Strategic decisions optimize capacity expansion for the water supply chain assets.
- Operational decisions optimize water production and transportation for various sites.
- A case study shows economic and environmental benefits of the proposed model.

ARTICLE INFO

Article history:
Received 20 May 2014
Received in revised form 25 July 2014
Accepted 26 July 2014
Available online xxxx

Keywords:
Water desalination
Supply chain network
Capacity expansion
Integer linear programming

ABSTRACT

This study presents the retrofit of water supply chain problem through multi period mixed integer linear program (MILP) model. The major strategic decisions include the determination of optimal new facility locations and capacity expansions of water desalination supply chain infrastructure assets which consists of water desalination plants, pipelines, and storage tanks, over a long time planning horizon. Other strategic decisions deal with the optimal selection of desalination technologies for existing and new desalination plants. In addition, the model provides decisions to define the pipeline network configuration for water transportation among several sites. The operation decisions are modelled to optimize the water production from desalination plants, energy consumption, brine disposal, as well as CO_2 emissions. In addition, water transportation through the pipeline network and water storage at every site are optimized to satisfy water demand at every time period, and to minimize the net present value of the supply chain network. Finally, the proposed approach is solved for a case study to illustrate the application of the proposed mathematical programming model. The results show economic and environmental benefits if one considers full site integration and water production coordination in the supply chain network through the planning time horizon.

1. Introduction

Water scarcity, population growth, and stringent environmental constraints are the main drivers for desalination industry to put long term plans in order to deal with the previously mentioned concerns [1]. For many countries in the Middle East and North Africa (MENA), seawater desalination is practically the only source of water supply. There are many desalination technologies (e.g., reverse osmosis (RO), multistage flash distillation (MSF), etc.) which can be considered effective to satisfy water demand from seawater. However, these technologies differ in terms of investment cost, energy consumption, water recovery, and environmental impact [2]. Therefore, there is a legitimate question to raise about the best choice of desalination technology selection in a specific project in order to gain economic and environmental benefits.

Seawater desalination plants are normally distributed over large geographical area to supply water demand in different locations [3]. These desalination plants are normally located on coastal area in order to have easy access of seawater intake. Furthermore, these plants may have different desalination technologies in hybrid designs with different production capacities. Water supply by these desalination plants may satisfy local water demand and other needs for other area (e.g., noncoastal area). Other water supply chain infrastructure assets (e.g., pipelines, storage tanks) normally exist over large area to allow the transportation and storage of water through nationwide network. Such a system defines the water desalination supply chain network.

There are large numbers of optimization studies related to desalination with diverse subjects. Plant design problems have attracted many researchers to find optimal process unit arrangement and operation conditions [4–9]. Hybrid desalination plants seek synergies between different desalination technologies in order to minimize capital and operation cost [10–13]. Other studies looked for operational problems and

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http://dx.doi.org/10.1016/j.desal.2014.07.037
0011-9164/

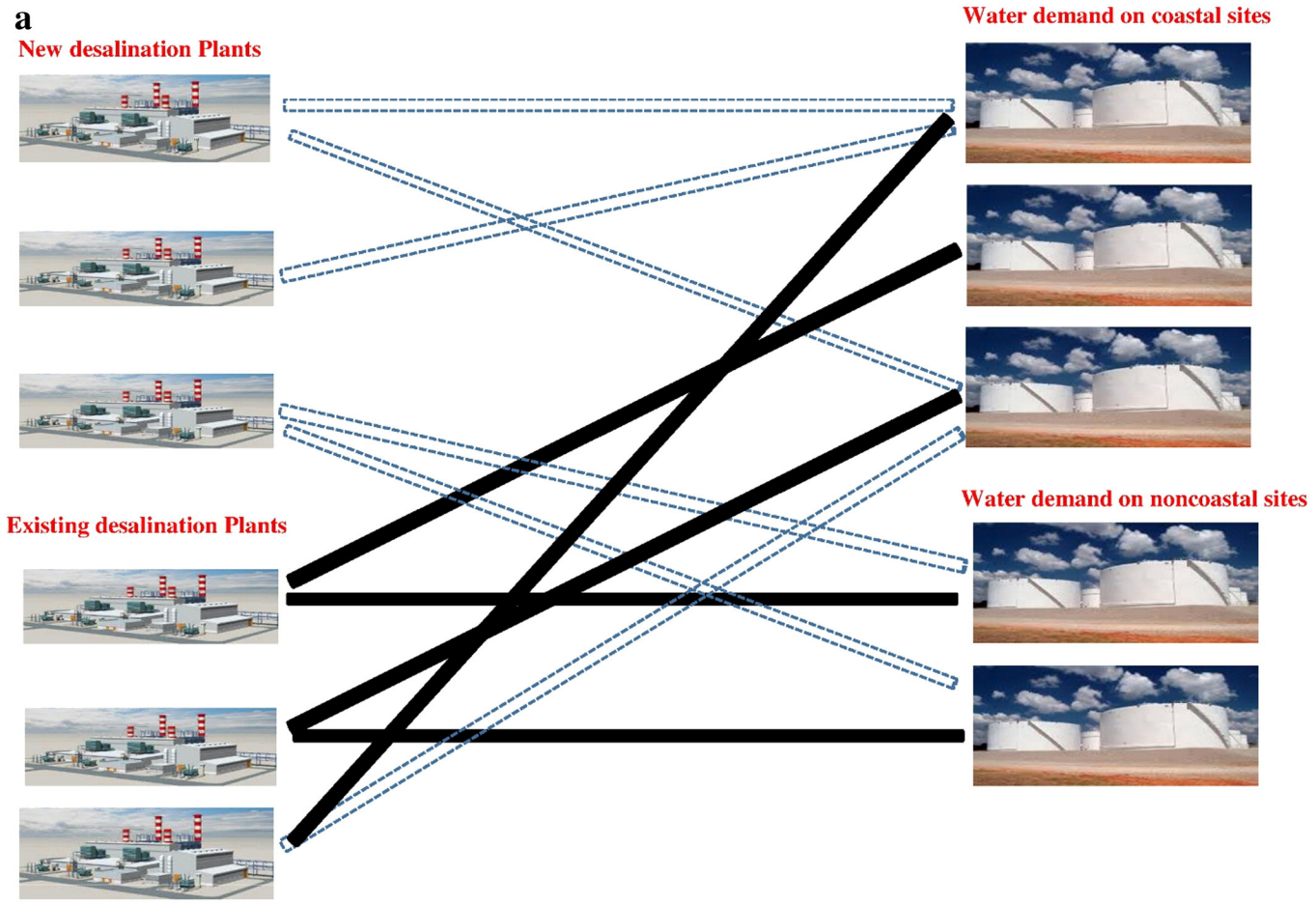

Fig. 1. a. Representation of water desalination supply chain network. b. Seawater desalination supply chain representation.