EVALUATION OF DESALINATION AND WATER TRANSPORT COSTS (CASE STUDY: ABU SOMA BAY, EGYPT)

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ABSTRACT

Egypt is facing water scarcity although there is the Nile River. The per capita of Nile water drops sharply under the measures of water poverty. The main response to water scarcity has been to increase the supply by using sea and brackish water desalination. In some regions, the chance for transporting water from near places exists. The comparison between the water price from desalination and water transport is studied. The Abu Soma Bay on the Red Sea is taken as a case study. This region has its desalination facilities of vapour compression. The unit cost of desalinated water using the vapour compression process is shown to be 6.06 L.E./m^3 for brackish water. Transport costs is about 4.753 L.E. per cubic meter. This is very low compared to the current marginal cost of water produced by the existing desalination plant.

Keywords: Water Cost, Desalination, Water Transport, Vapour Compression.

INTRODUCTION

The fast growing development in Egypt has required big movements of investments and people from the Nile Valley towards the East, i.e. the Red Sea and Sinai coastal zones, and also towards the Western Desert. In both cases, fresh water supply is essential and desalination is a feasible option that can cover the wide gap between the available capacities and the accelerating demands.

Desalination of seawater in Egypt has been given low priority as a source of water. That is because the cost of treating seawater is high compared with other sources, even the unconventional sources such as drainage reuse. The average cost of desalination of one cubic meter of seawater ranges between 3 to 7 L.E. (Egyptian pound). Desalination is actually practiced in remote areas where the cost of constructing pipelines to transfer Nile water is relatively high.

Large sectors of the Egyptian coasts of the Red Sea, the Gulf of Aqaba and the Gulf of Suez have been developed into beach resorts. Most of the Egyptian Red Sea coast tourism areas meet their fresh water requirements through desalination of seawater or of brackish groundwater, many of the coastal towns have their own desalination facilities. These facilities usually discharge their highly saline brine effluent into the sea, which has been shown to cause considerable damage to marine life.

The Egyptian Government established a water pipeline from the Nile River to supply all the cities that lie on the Red Sea Coast. Some regions are not connected to this pipeline. If we would know the costs of water supply from the pipeline for a region, we could then evaluate the potential of desalination. The scope of the study is to evaluate the water price from desalination and water transport. The Abu Soma Bay on the Red Sea is taken as a case study. This region has its desalination facilities of vapour compression.

ABU SOMA REGION

The Red Sea Governorate has an area of 130,000 km^2 (Fig. 1). The total population is 122,000 inhabitants consisting of some Bedouins and city inhabitants located in small cities as Hurghada and Ras Ghareb. The investigated region is Abu Soma Bay that lies between Hurghada and Safaga cities on the Red Sea, Fig. 1. The area represents an important part of Egypt for development. Abu Soma is a prosperous Egyptian Red Sea tourist resort area remote from the Nile comprising isolated and developing communities. It has an attractive beach and very beautiful coast for marine tourist activities, Fig. 2. It accommodates more than 3 (5 star hotels) with a total number of rooms of 700. There is an on-going need for expanding and updating the infrastructure for supplying potable water. There are three sources of potable water: long distance tanker trucks, water pipeline and desalination plants.

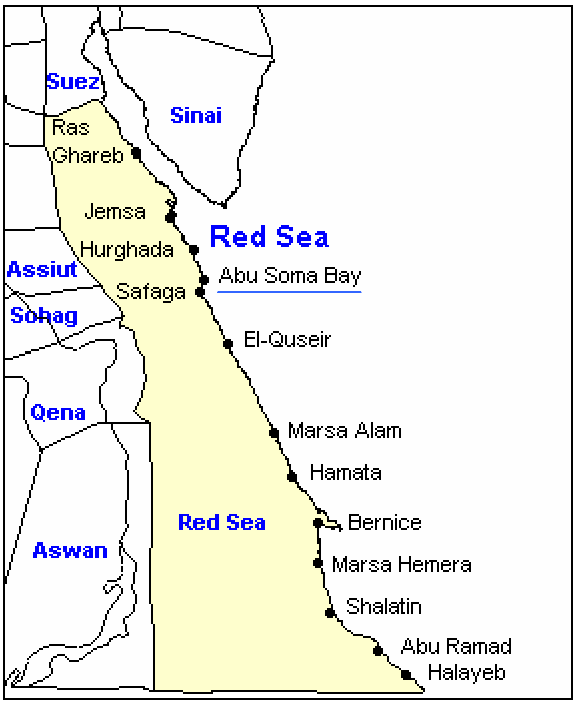

Fig. 1. Red Sea Governorate

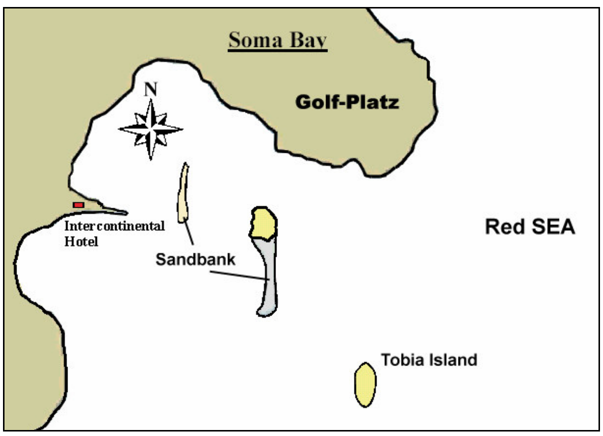

Fig. 2. Abu Soma Bay

DESALINATION

In arid areas, desalination is becoming a serious option for water production as alternative for traditional surface water treatment and long distance conveyance. A large number of desalination plants have become operational in tourism sector, mainly along the Red Sea Coast, South Sinai and the Northern Coast. In Soma Bay, there are three mechanical vapour compression units, which produce 4500 m^3/day. These units have been installed in the years 1997 and 1998.

General Description for Vapour Compression Unit

The vapour compression unit is an ambient temperature double-effect vapour compression distillation unit, the principal components of the unit are, Fig. 3:

1. The Evaporator-Condenser [consisting of two effects]
2. NCG Removal System
3. The Centrifugal Vapour Compressor
4. The Pumps and Piping
5. The Feed Heat Exchangers
6. Control and Instrumentation

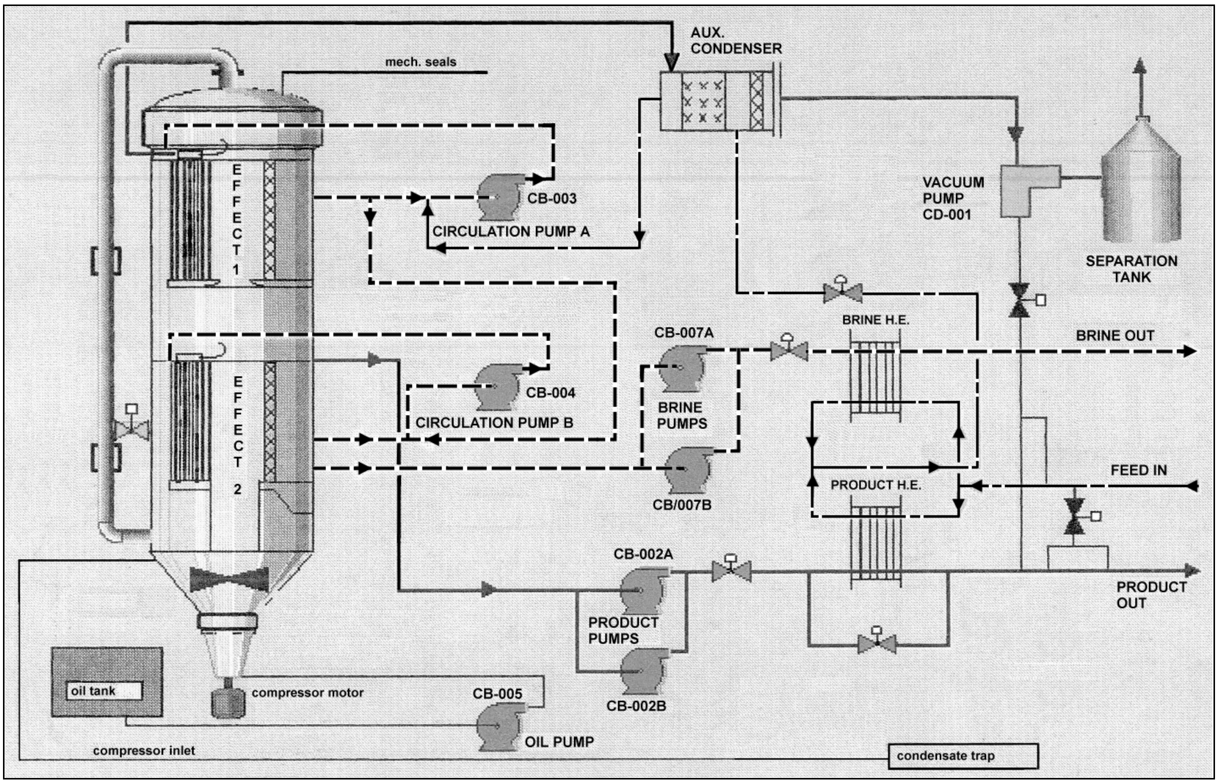

Fig. 3. Vapour compression unit of Abu Somna

The incoming seawater first enters two parallel heat exchangers. In one, the feed water is heated by the product water and in the second by the brine stream, thus recovering process heat. On the way to the evaporator the feed water is further heated as well as deaerated in an auxiliary condenser, which is part of the air removal system.

The heated and deaerated feed water is then mixed with the brine from the evaporator [at Effect No.1] at the suction of the recirculation pump No P-3 [CB-003], and is discharged back to the evaporator through spray nozzles to form continuous thin water films over the evaporator tubes.

Since the vapour compressor, through its suction, provides a pressure lower than the equilibrium pressure of the brine film on the tubes, part of the brine flashes into vapour. The vapour generated passes through a demister to remove droplet carryover and is compressed by the compressor and discharged into the tubes of Effect No.1 at a pressure which is now slightly higher than the liquid-vapour equilibrium pressure. The vapour condenses, therefore, gives up its latent heat of condensation across the walls of the tubes to the brine flowing on the outside, thus providing the latent heat required to evaporate an additional equal amount of brine.

As the pressure in Effect No. 2 is lower than that of Effect No. 1, due to the difference in temperature, the vapour evaporated in Effect No. 1 is drawn through a horizontal demister into the tubes of Effect No. 2 where it condenses. Latent heat of condensation is transferred through the walls of the tubes and supplies the latent heat for evaporation of the vapour drawn by the compressor and discharged again into the tubes of Effect No. 1.

Excess brine from Effect No. 1, that is the feed less the evaporated vapour, overflows into the suction pipe of the recirculation pump P-4 [CB-004], and is mixed with the brine recirculation and sprayed over the evaporated tubes of Effect No. 2.

The excess brine [from Effect No.2], and the condensate which is the salt-free product, are both pumped out of the evaporator-condenser by separate pumps. On their way out, the brine and product exchange heat with incoming feed.

Air and other non-condensable gases must be continuously removed from the process. They are bled from the main condenser as an air-vapour mixture, which is first concentrated in an auxiliary condenser, by condensing part of water vapour and then are exhausted by means of the vacuum pump. This vacuum pump also produces the initial vacuum.

A small dosage of scale inhibitor is added to the feed water and to the circulation pump P-4 [CB-004] suction line, to retard scale deposition in the evaporator.

To neutralize the slight natural acidity of the product water, a chemical treatment is applied to the product discharged stream.

Product Post Treatment System

The product discharging from the plant is slightly acidic with a pH of about 5.5-6.0, with slight corrosive tendencies. In order to raise the pH level of water and conform the water properties to the health standers for potable water, a system of product treatment was designed and assembled. It consists of adding three types of chemicals, to raise the pH and create a buffer solution or a solution with a stable pH. The chemicals are sodium carbonate (soda ash), sodium bicarbonate and calcium chloride. They are added with suitable dosing rates.

In addition of the above-mentioned chemicals, the product water is treated by sodium hypochlorite to treat any organic or biological specimens which might enter the water in the client's storage tank.

Feed Treatment System

As a result of the evaporation process a scale is formed and builds up on the heat transfer tubes.

The scale is composed of a mixture of calcium salts namely calcium carbonate and calcium sulphate. Calcium carbonate is formed when bicarbonate existing naturally in seawater is partially decomposed during evaporation to carbonate and together with calcium ion precipitates on the surface of the tubes. Calcium sulphate rate of precipitation depends on seawater temperature and salinity.

The rate of precipitation can be controlled and greatly reduced by limiting the plant process conditions to temperature of 70 - 74°C and salinity of 7% and by introduction of a polyelectrolytes and dispersant inhibitor into the feed stream. The inhibitor is composed of a mixture of polyacrylates and poly phosphonates.

A feed treatment system is provided for the ployelectrolyte scale inhibitor [ID-204] solution and for dosing the feed stream at the pipe entering the unit.

Desalination Cost by Vapour Compression

The costs of desalination vary significantly depending on the size and type of the desalination plant, the source and quality of incoming feed water, the plant location, site conditions, qualified labor, energy costs and plant lifetime. Lower feed water salinity requires less power consumption and dosing of antiscale chemicals. Larger plant capacity reduces the unit cost of water due to economies of scale. Lower energy costs and longer plant period reduces unit product water cost.

The primary elements of desalination costs are capital cost and annual running cost. The capital cost includes the purchase cost of major equipment, auxiliary equipment, land, construction, management overheads, contingency costs etc. Annual running costs consist of costs for energy, labor, chemicals, consumables and spare parts. The energy costs play a dominant role for vapour compression processes.

The cost of vapour compression process has decreased considerably over time, from 5.0 $/m^3 in 1970 to about 1.0 $/m^3 at present, [1]. The detailed cost studies in Abu Soma indicated the total cost of the desalination of one cubic meter is about 6.06 L.E., Table 1.

Table 1. Total costs of the desalination in Abu Soma units

Item	**Cost (L.E./m^3)**
Power cost	3.320
Well cost	0.131
Raw water cost	0.163
Chemical cost	0.343
Depreciation cost	1.550
Salaries cost	0.550
Total	**6.057**

WATER TRANSPORT

The scientific literature search little has been published on the costs of transporting water by canals, pipes and tunnels and that most of them refer back to Kally [2]. His cost estimates make clear that horizontal distance is not the main driver of water transport costs, but the vertical distance is. Unfortunately, cost estimates for alternative lift heights are not presented. Kally reports that investment and operation and maintenance have an equal share in the costs of transporting water.

Gruen [3] provides estimates of water transport costs from Turkey to Turkish Cyprus by a 78 km pipeline with a capacity of 75 Mm^3/year to be at 25-34 ¢/m^3.

Nile Water Transported by Pipeline to the Red Sea Governorate

The Egyptian Government did a plan for establishing a water pipeline from the Nile River to supply all the cities that lie on the Red Sea Coast, and now the pipeline supply the area until Hurghada and still working to feed the other areas to the south until

Halayeb area. There are two main lines (Fig. 4), [4], the first is Qena-Safaga pipeline with total length of 180 km. There are three parallel lines with different diameters: 200 mm, 300 mm and 400 mm. They are supported by 13 pumping stations distributed on the distance from Qena to Safaga. The total capacities of the lines are 17,000 m^3/d distributed on three cities: Hurghada, Safaga and El-Quseir.

The second line is the Koraimat pipeline with diameter 1000 mm until Ras Ghareb and 600 mm to Hurghada. The total capacity of the pipeline is 28,000 m^3/d distributed on three cities: Zafarana, Ras Ghareb and Hurghada. There are seven pumping stations on the pipeline. The total cost of this pipeline is 660 millions L.E. which was equivalent to $US 194 millions. The installation cost per m^3 depreciated on 15 years is 2.15 L.E./m^3. The running cost including maintenance cost is 1.5 L.E./m^3. The total cost including installation cost is 3.65 L.E./m^3

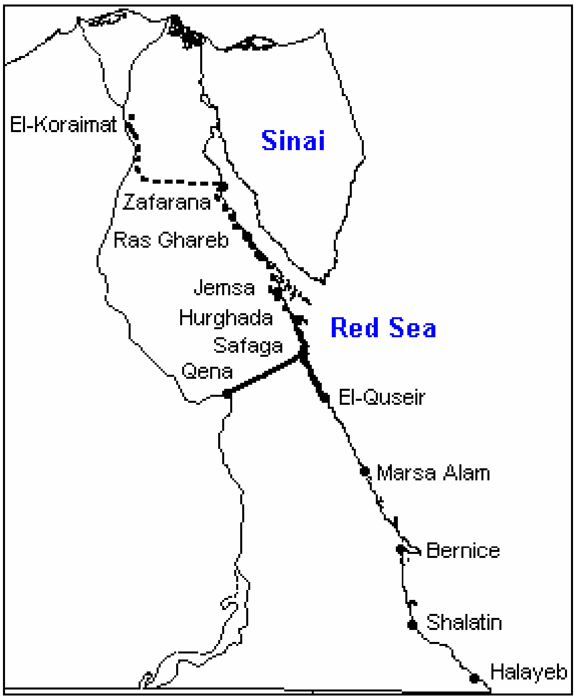

Fig. 4. Water transportation to the Red Sea Governorate by pipelines

Extension of the Qena-Safaga Pipeline to Abu Soma

The subject of this study is the development of a pipeline to supply the Abu Soma region with potable water. The transported water can be provided from other regions, that not far from Abu Soma such as the pipeline connecting Safaga to Hurghada City, Fig. 4. The cost of providing water is directly related to the quantity provided which must balance the demand for the water at the region. The current forecast of extra water demand remains at near 6,000 m^3 per day by 2015. The three desalination units provide 4,500 m^3/day, therefore the required additional demand is 1,500 m^3/day. The costs relating to the development and operation of a pipeline to deliver 1,500 m^3/day from the Safaga-Hurghada pipeline to Abu Soma (10 km) are likely to be insignificant. The estimations presented here provide a general trend of costs under rough assumptions.

Infrastructure Costs

The estimated cost of the project infrastructure is likely to be 1.13 million L.E. This is proposed according to the construction of the existing pipeline (in year 1998) from Safaga-Hurghada to Abu Soma (5 km) which was in the figure of 0.331 million L.E. The new pipeline construction takes the increment in pipeline materials costs.

Operating Costs

The annual operating cost of the pipeline is estimated at 0.63 million L.E. per year. The major component of the operating cost is the power delivered to the pumps.

Cost of Water

The Government has estimated the costs to consumers of buying water from the proposed pipeline at 3.5 L.E./m^3.

Other Economic Issues

The costing for this concept is based on a direct pipeline route from Safaga-Hurghada pipeline to Abu Soma. No tourism or other developments on route requiring water is designed. Such developments would require more water and therefore higher costs.

COMPARISON OF WATER TRANSPORT WITH DESALINATION

The installation cost per m^3 depreciated on 20 years is 0.103 L.E./m^3. The running cost including maintenance cost is 1.15 L.E./m^3. The total cost (including installation cost, running cost and water cost) is 4.753 L.E./m^3. This is very low compared to the current marginal cost of water produced by the existing desalination plant (6.06 L.E.).

CONCLUSIONS

Desalinated water may be a solution for some water-stress regions, but not for places that are poor, deep in the interior of a continent, or at high elevation. The costs of desalination still remain higher than other alternatives for most regions of the world. Desalination processes are accompanied by some negative impacts on the environment such as production of concentrated brine and carbon dioxide emissions.

In this study, the case of Abu Soma Bay has been taken. The investigated area lies along the Red Sea Coast and the desalinated water is used tourist buildings and for the human settlement. Three desalination plants are established producing 4500 m^3/day.

The analysis presented here provides a general trend of costs under rough assumptions. Transporting water horizontally is relatively cheap whilst the main cost is lifting it up. While the new pipeline concept to supply water to Abu Soma is technically feasible, and should remain the future water source option, it may become less competitive with desalination because of cost reductions in desalination technology.

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