Waste to energy for seawater desalination plant

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Abstract

The solid waste management is, in different contexts, a very critical issue. The use of landfills can no longer be considered a satisfactory environmental solution, therefore new methods have to be chosen and waste to energy plants would provide an answer. As we know, is possible to recover thermal energy by combustion municipal solid waste (MSW) for electricity generation. However, with ever-increasing population and lasting droughts, there is a great demand for fresh water. So, many communities in arid regions could use thermal energy inherent in MSW to desalinate seawater. Methods of desalination are presented shortly. In this paper a small size RO desalination plant is coupled with multi-effect desalination system (MED). In the examined case, cogeneration coupled with hybrid desalination systems reveals economically convenient with respect to the production of the same fresh water flow rate by very efficient RO systems.

Keywords: *MSW, Desalination, Hybrid MED/RO.*

1. Introduction

Because of urbanization and, population increase and new regulatory measures, many countries are faced with a waste disposal problem. Hot Mediterranean countries also have a water resource problem. Indeed, fresh water is becoming an ever-more precious commodity, again because the arid regions of the world appear to be expanding. The desalination process consumes energy while municipal solid waste (MSW) may be transformed to produce electricity and thermal energy. It is suggested that there must be locations where it would be sensible to link the two processes, for example overcrowded tourist areas, or island in Albania. The communities in these areas have, combined waste disposal and fresh water availability problems.

The utilization of seawater desalination technologies could help to resolve local problems of water supply, which, especially in arid areas, can risk the development and the life of people. Since desalination involves high specific consumption of energy per m^3 of distilled water, the adoption of economic and efficient desalination technologies is desirable.

One of the problem solutions might be coupling of waste to energy system and desalination process. For small scale desalination plants hybrid coupling RO/MED (reverse osmosis/multi-effect distillation) might be the appropriate technology.

2. Energy from MSW

Waste treatment is an extraneous term in Albanian cities. The typical present-day per capita content of MSW is calculated to be 450-550 kg [2]. The energy content of MSW is significant. Its high calorific value is calculated 8.5-15.8 MJ/kg. This is a large amount of energy, which is not used, but wasted.

Using of MSW to produce energy (waste to energy system – WTE) is not only an important waste treatment option but it also cuts down the use of fossil fuels and hence can help to meet renewable energy targets [1]. To guarantee safe and continuous operation a most suitable type of technology for the burning process and emission control system must be adopted the choice must be based on an accurate analysis of the plant and consider environmental impacts, investment and operation costs, flexibility, material and energy recovery, plant surface area

and maintenance requirements. In modern WTE plants often both electric and thermal energy are produced, the benefits are high efficiency and costs are decreased.
Thermal treatment of waste has some advantages to other waste treatment methods.

- Achieves maximum volume reduction (70-90 %)
- incineration is a standard hygienic operation compared to open burning
- heat generated can be utilized for hot water/steam/electricity production
- less land required & minimal burden on landfilling facilities
- minimization of transport costs

The only disadvantage could be the higher costs towards capital, operation & maintenance, air pollution control equipment [2].

3. Seawater desalination processes

The process of generating fresh water from seawater, or desalination, has been in operation for over 50 years. The driving force for the development of this technology is clear as only 2.5 % of the total amount of water on the planet is freshwater, of which 74 % is frozen in ice caps and glaciers, 25.7 % is underground or in soils, and only 0.3 % is available as surface freshwater [3]. As a result, 40 % of the world population is struggling with serious water shortages, with the majority of this burden falling on people who live in remote rural areas and rapidly expanding urban areas. The main technologies utilized to remove the salts from seawater are: *thermal distillation* (multi-stage flash distillation, multiple-effect distillation, MVC) and *membrane separation* (reverse osmosis and electro-dialysis).

- Multiple effect distillation (MED)

Today this technology has become the most widespread distillation method for small to medium size power plants (2000-15 000) m3/d) and it is now starting to penetrate the field of large capacity municipal plants [4]. Efforts are now oriented to reduce fresh water costs by increasing heat transfer coefficients, using cheaper materials and waste heat in thermal processes, reducing chemical pre-treatment, increasing product recovery, adopting high temperature operation and enhancing energy recovery in the membrane processes. The main feature of the MED process is that it operates at low top brine temperature 60-70^{o}C. A MED system is composed of series of chambers in which the latent heat is used in order to evaporate the liquid part. In such a system the vapor generated in the first stage goes to the second one and is used in order to evaporate part of feed water, also coming from the first stage. In order to permit the thermal exchange between vapor and feed water, the second stage is at lower pressure than first one. Thus in MED plants the vapor produced is sent to the third stage, at a pressure even lower than the previous up to the last stage, where the vapor is sent to the condenser [5].

- Reverse Osmosis (RO)

Energy consumption of reverse osmosis is the lowest among all options for seawater desalination, making it most cost efficient in regions with high-energy cost. RO is highly efficient due to developments made in membrane materials. Initially membranes were based on cellulose acetate. There is now a wide range of polyamide materials and the properties of the material might be optimized for particular applications. The energy recovery system is responsible for the transfer of potential energy from the concentrate to the feed. Current energy recovery systems such as work exchangers operate with efficiencies of up to 96 % [7].
The water produced by reverse osmosis is usually acidic with no alkalinity and is very corrosive. In post-treatment permeate is re-mineralized, re-hardened, disinfected by chlorination and pH adjusted to drinking water standards.

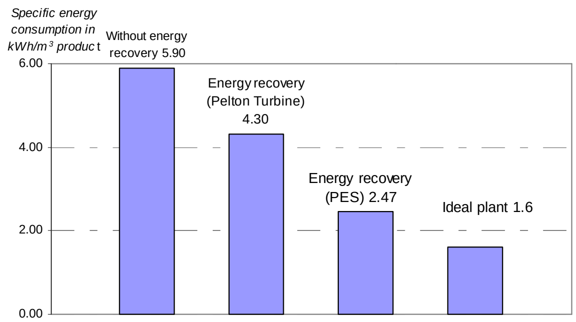

Fig. 1. *RO specific energy consumption*

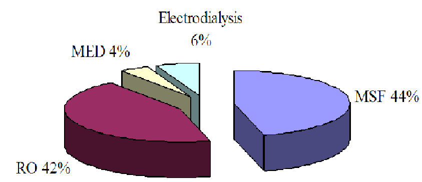

Fig.2. *Global share of desalination technologies*

4. Hybrid RO/MED system powered by a WTE plant

Hybrid systems, in recent years, have become widely spread. These plants have thermal and mechanical units, so they simultaneously need thermal and electric energy, thus cogeneration is a suitable technology for their operation. Hybrid (membrane/thermal/power) configuration are characterized by flexibility in operation, less specific energy consumption, low construction cost high plant availability and better power and water matching [8]. Hybrid systems for desalination have a typical small electricity/heat ratio (0.15-0.35) that depends on the inlet water flow in a RO section. Thus the choice of cogeneration unit depends on the value of thermal energy needed. So, WTE process is suitable to produce thermal energy for these plants. The proposed system will be composed of :

- a WTE plant fed by residues, resulting from MSW selection, with a capacity of 7.5 t/h;
- a heat recovery system at 120^{o}C after turbine;
- a three-phase synchronous alternator for electricity production;
- a MED thermal section fed by thermal reject and electric energy from the WTE plant;
- An RO section fed by electric energy from WTE plant.

In the supposed plant the RO section is practically independent of the MED section as shown in **Fig.3**. Composition and heating value of the residue of material recovery obviously depends on the gross MSW production and on the selected system efficiency.
Considering that feeding MSW around 7.5 t/h, than nominal thermal power of the steam boiler is P_{sb}= 31.25 MWth; where thermal efficiency for steam production is η_{th} =0.88 and the electric efficiency η_e=0.26. Gross electric power P_{el}= 8.1 MWel. Thermal reject of steam turbine will be recovered by a condenser with a water heat exchanger, which η_{he}=0.85; therefore thermal power for the MED section P_{MED}=23.4 MWth.
An MED plant with 12 effects operating between 40-120^{o}C needs the thermal and electric energy around 193kJ/kg and 2.2kWh/m, respectively [6].

$$M = 23.4\ MW_{th} / 193\ MJ/m^3 = 10\ 475\ m^3/d \quad (1)$$

whereas the electric power needed for MED plant is: $P_{el(MED)}$= 0.96 MW_{el}

The water produced by the MED plant has a very small total dissolved solids TDS value (15-20 ppm) [9], so is possible for the RO plant to use a low selectivity membrane that is low cost and produces low quality permeate.

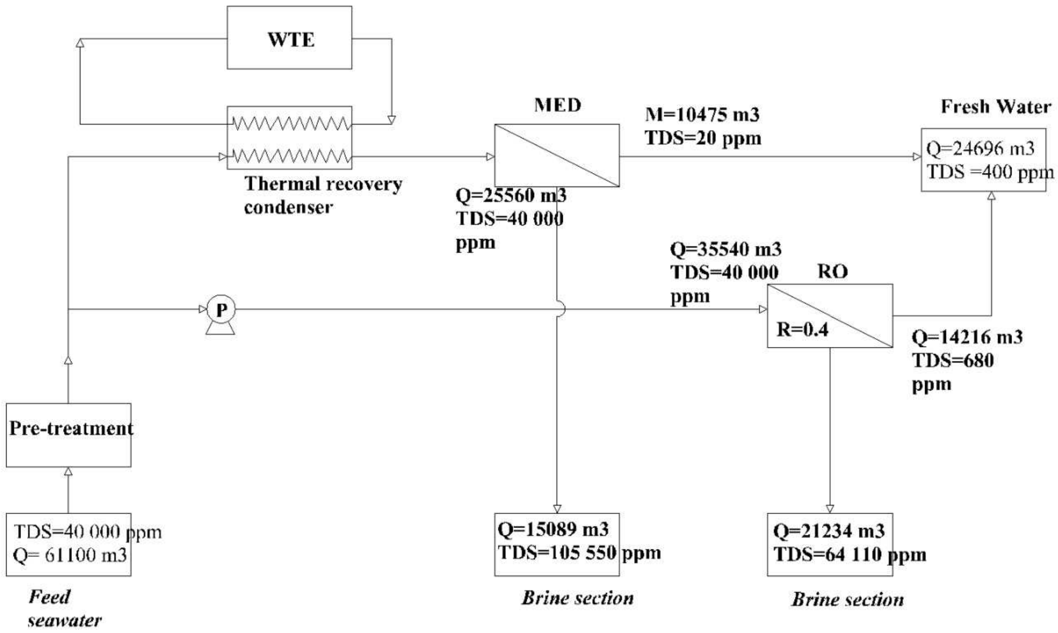

Fig.3. *Layout of the hybrid schneme RO/MED*

In this paper I have supposed for fresh water a TDS of 400 ppm, a TDS_{MED} of 20 ppm, and a TDS_{RO} of 680 ppm. This figure contents the instructions of WHO for potable water. So water mass flow from the RO section is:

$$Q_{RO} = Q_{MED} * \frac{TDS_F - TDS_{MED}}{TDS_{RO} - TDS_F} = 14216 \ {m^3}/{d} \qquad (2)$$

Specific energy consumption for an RO is 3.6kWh/m3, therefore electric power and electric energy neccessary are:
P_{el}= 2.13 MW_{el} and E_{el}= 15 353 MWh.

Below are presented the main parameters for the three sections, WTE, MED, and RO.

Table1. *Main characteristics for the supposed WTE plant*

MSW capacity, t/h	7,5
Annual waste capacity, t/y	54000
LHV, kJ/kg	13000
Thermal efficiency of steam production, %	88
Nominal thermal power of steam boiler, MWth	31,25
Electric efficiency, %	26
Gross electric power, MWel	8,1

Table2. *Characteristics of MED section*

Number of effects	12
Feed water capacity, m3/d	25 560
Feed water TDS, ppm	40 000
Permeate capacity	10475
Distillate TDS, ppm	20
Brine outlet capacity,m3/d	15 089
Brine TDS, ppm	105 050
Thermal power, MW	23,40
Necessary electric energy MW_{el}	0,96

Table3. *Main characteristics of RO section*

Feed water capacity, m3/d	35 540
Feed water TDS, ppm	40 000
Permeate capacity, m3/d	14 216
Permeate TDS, ppm	680
Brine capacity, m3/d	21 234
Brine TDS, ppm	64 110
Electric power necessary MW	2,13

5. Conclusions

A dual purpose hybrid desalination plant was presented, consisting of a WTE system with heat recovery which supplies heat and power for a MED and RO plant. Recovery of thermal energy from MSW makes good environmental-energetic sense. Waste combustion reduces the loss of space to landfill sites, reduces the environmental impacts caused by gas and leachate formation from landfill organic waste and it contributes to reducing the use of fossil fuels. In this paper is shown that thermal energy can be used to generate considerable quantities of fresh water, simply by coupling the WTE plant and desalination techniques with many technical and economical advantages. In this attempt I have just shown the principle of this coupling scheme, and a part of energetic use of waste. It is obvious that energetically this method could be efficient and remains to see if the cost are comparable to other methods.
Economical advantages and cost behavior of this coupling scheme will be object of further studies.

Symbols

MSW - Municipal Solid Waste
RO - Reverse Osmosis
MED - Multi-effect distillation
WTE - Waste-to-energy
P_{sb} - thermal power of steam boiler
P_{el} - electric power
TDS - total dissolved solids
Q - Flux rate
WHO - World Health Organization
M - Permeate mass flow

ppm - part per million
E - Electric energy

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